Appendix A



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Appointments

- Associate Professor with Tenure, Electrical and Computer Engineering, Wayne State University, Detroit, August 2009 - Present.
- Director, Wayne State Computer Systems and Deep Learning Research Laboratory, Dept. of Electrical and Computer Engineering, Wayne State University, Detroit, August 2018 - Present.
- Director, Interdisciplinary M.S. in AI Program (Systems and Hardware), College of Engineering, Wayne State University, Detroit, August 2022 – Now.
- Overall Coordinator, Interdisciplinary M.S. in AI Program, College of Engineering Wayne State University, Detroit, August 2022 – Now.
- Director, Wayne State Multimedia Computing and Networking Research Laboratory, Dept. of Electrical and Computer Engineering, Wayne State University, Detroit, August 2003 – July 2018.
- Graduate Program Director, Electrical and Computer Engineering, Wayne State University, Detroit, August 2011 - January 2013.
- Assistant Professor, Dept. of Electrical and Computer Engineering, Wayne State University, Detroit, August 2003 - August 2009.

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- Graduate Lecturer/Teaching Assistant/Research Assistant, Dept. of Computer Science and Engineering, Pennsylvania State University, University Park, June 1999 - August 2003.

- Intern, Unisys, Malvern, Pennsylvania, May 2002 - September 2002: I participated in discussions of new multiprocessor systems, made proposals for new architectures, developed SES models, and developed an automatic statistic extraction and post-analysis tool.

- Teaching Assistant, Electrical Engineering Department, Jordan University of Science and Technology, 1996 - 1997.

- Engineer, Voice Processing Dept., Jordan Computer Center, Amman, Jordan, November 1995 - February 1996: I was responsible for developing phone bank and voice-mail computer systems.

Expert Witness Experience in Patent Infringement and Patent Validity Cases

Cases with Deposition and Testifying at Trial:

- Expert Witness and Consulting Expert, *patent infringement* and *validity* cases, ACQIS v. ASUSTeK and ASUS Global, United States District Court for the Western District of Texas, on the plaintiff's side, January 2022 – March 2024.

- Expert Witness and Consulting Expert, *patent infringement* case VideoShare v. Google (for YouTube Service), United States District Court for the Western District of Texas, on the plaintiff's side, July 2020 - November 2021.

Ongoing Cases:

- Expert Witness and Consulting Expert, patent infringement case, ACQIS v. Sony, on the plaintiff's side, April 2023 – Now.

- Expert Witness and Consulting Expert, patent infringement case, ACQIS v. Hon Hai, on the plaintiff's side, October 2023 – Now.

- Expert Witness and Consulting Expert, patent infringement case, ACQIS v. Quanta, on the plaintiff's side, October 2023 – Now.

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Other Cases:

- Expert Witness and Consulting Expert, *patent infringement* case, ACQIS v. Microsoft, on the plaintiff's side, April 2023 – June 2023. The case was settled.

- Expert Witness and Consulting Expert, patent infringement case, ACQIS v. Wiwynn, on the plaintiff's side, January 2022 – May 2023. The case was settled.

- Expert Witness and Consulting Expert, patent infringement and validity cases, ACQIS v. Lenovo, on the plaintiff's side, January 2022 – November 2022. The case was settled.

- Expert Witness and Consulting Expert, patent infringement case VideoShare v. Meta (Facebook), on the plaintiff's side, patent: "Systems and Methods for Sharing Video with Advertisements over a Network", November 2021 – March 2023.

Major Source Code Review Experience

- Review of Facebook and Instagram source code in patent infringement case VideoShare v. Meta (Facebook), March and April 2022.

- Review of YouTube source code in patent infringement case VideoShare v. Google, February 2021.

Consulting Expert Experience in Patent Infringement and Other Corporate Litigation Cases

- Consulting Expert, a patent infringement case on video sharing and streaming systems, February 2020 - October 2020.

- Consulting Expert, a patent infringement case on video streaming and multimedia systems: Visual Interactive Phone Concepts (VIPC) v. US Cellular, 2014 - 2015.

- Consulting Expert, a patent infringement case related to video streaming: Visual Interactive Phone Concepts (VIPC) v. Verizon, on the Plaintiff's side, 2012 – 2014.

- Consulting Expert, a patent infringement case related to video streaming: Visual Interactive Phone Concepts (VIPC) v. US Cellular, on the Plaintiff's side, 2012 - 2014.

- Consulting Expert, a patent infringement case related to video streaming: Visual Interactive Phone Concepts (VIPC) v. Google, on the Plaintiff's side, 2012 - 2014.

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- Consulting Expert, a patent infringement case related to video streaming: Visual Interactive Phone Concepts (VIPC) v. Samsung, on the Plaintiff's side, 2012 - 2014.

- Consulting Expert, an intellectual property corporate litigation case involving secure multimedia products for medical applications: MIANTS, LLC, a Michigan limited liability company, MATTHEW VISCONTI, M.D., an individual, SANDY VISCONTI, an individual, APG, LTD, a Canadian corporation, FELICE IAFRATE, ESQ, an individual, LARRY DAVIDSON, an individual, and CRYSTAL DAVIDSON, an individual, directly and derivatively on behalf of BRIGHT PURPLE ENCRYPTION, LLC, a Michigan limited liability company, and ENCRYPTION SECURITY SOLUTIONS, LLC, a Michigan limited liability company v. KEVIN LASSER, an individual, RAMIE PHILLIPS III, an individual, MEDTEDCO, LLC, a Michigan limited liability company, PHILLIPS CONSULTING, INC., a Michigan corporation, JEMS TECHNOLOGY, LLC, a Michigan limited liability company, DAVID UNDERDALE, an individual, TIMOTHY FOLEY, M.D., an individual, TRUDY HABLE, an individual, and ROBERT HUTH, an individual, on the plaintiff's side, 2014.

- Consulting Expert, a corporate litigation case involving IP addresses and anonymous e-mails: Integrated Health Group v. Integrated Healthcare Systems, on the Plaintiff's side, 2014.

Consulting Experience in Accreditation, Review, and Educational Reform

- Program Evaluator, Accreditation Board for Engineering and Technology (ABET), 2023 – Now.

- External Reviewer, Master of Science Program in Computer Engineering, University of Michigan – Dearborn, February 2024.

- Chair, numerous Program Accreditation Panels, Education & Training Evaluation Commission, National Center for Academic Accreditation & Evaluation (ETEC-NCAAA), Saudi Arabia: reviewing the following programs:
    - B.S. in Computer Engineering and B.S. in Information Technology at Tabuk University, Saudi Arabia, June 2024.
    - M.S. in Energy Engineering, Effat University, Jeddah, Saudi Arabia, May 2024.
    - B.S. Program in Electrical Engineering, B.S. in Mechanical Engineering, and BS. In Civil Engineering programs, Taif University, Taif, Saudi Arabia, January 2024:
    - M.S. in Information Technology and M.S. in Computer Science at King Khalid University, Abha, Saudi Arabia, December 2023.
    - B.S. Program in Computer Science at Prince Sattam bin Abdulaziz University, Saudi Arabia, May 2023.

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- Bachelor of Electrical Engineering program at Northern Borders University, Saudi Arabia, February 2023.
- Bachelor of Science in Information Technology program at Majmaah University, Saudi Arabia, January 2023.
- Bachelor of Computer Science Program at Shaqra University, Saudi Arabia, November 2022
- Bachelor of Science in Computer and Network Engineering program at Jazan University, Saudi Arabia, October 2021
- Master of Science Program of Electrical Engineering at King Saud University, Riyadh, Saudi Arabia, March 2021
- Bachelor of Science in Electrical Engineering Program at Najran University, Najran, Saudi Arabia, February 2021
- Bachelor program in Graphics Design and Digital Media Program at Princess Nourah Bint Abdulrahman University, Riyadh, Saudi Arabia, November 2020
- Bachelor of Science in Electrical Engineering Program at Majmaah University, Al Majma'ah, Saudi Arabia, November 2020
- Bachelor of Science in Electrical and Computer Engineering Program at Effat University, Jeddah, Saudi Arabia, September 2020
- Bachelor of Science in Software Engineering Program at King Saud University, Riyadh, Saudi Arabia, May 2017
- Bachelor of Science in Electrical Engineering Program at Taibah University, Medina, Saudi Arabia, March 2016

- Chair, Institutional Accreditation Panels, Education & Training Evaluation Commission, National Center for Academic Accreditation & Evaluation (ETEC-NCAAA), Saudi Arabia: reviewing the following universities:
  - Alfaisal University, Riyadh, Saudi Arabia, March 2024
  - University of Hafr Al Batin, Saudi Arabia, October-November 2021

- Reviewer, the Academic Accreditation Policy Book 2021, Education & Training Evaluation Commission, Saudi Arabia, 2021

- Educational Expert, Digital Design Courses and Labs Revision, Computer Engineering Department, Birzeit University, Palestine, August 2018 – December 2018

- External Educational Expert, Computer Engineering and Computer Science Reform, Birzeit University, Palestine, February 2018 – June 2018

- Member, Program Accreditation Panels, The National Commission for Academic Accreditation and Assessment (NCAAA):
  - Electrical Engineering Program at Prince Sattam University, Riyadh, Saudi Arabia, March 2016

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- Electrical Engineering Program at King Saud University, Riyadh, Saudi Arabia, April 2015

- Member, Institutional Accreditation Panels, Education Evaluation Commission-Higher Education Sector (EEC-HES):
  - King Abdulaziz University, Saudi Arabia, February 2022
  - Shaqra University, Shaqra, Saudi Arabia, October 2020
  - University of Business and Technology, Jeddah, Saudi Arabia, May 2017
  - Effat University, Jeddah, Saudi Arabia, December 2016

Other Consulting Experience

- Expert, Specialty Occupation evaluation of **numerous** H-1B visa cases for Software Developer, Software Engineer, Web Developer, Hadoop Developer, Database Administrator, Project Engineer, ServiceNow Developer, and PLM Engineer positions, 2018 - 2020.

Honors/Awards

- Was inducted into the *WSU Academy of Teachers* in 2022.
  - Induction statement: "Professor Nabil Sarhan is a master of developing project-based courses and new cutting-edge curricula for engineering students, such as a new M.S. degree in Artificial Intelligence. Students in his classes are immersed in a research-like environment with hands-on activities and training in technological problem-solving. This approach builds student interest and excitement as it prepares students for their future careers. Sarhan is an indefatigable innovator who has reformed multiple courses at the undergraduate and graduate levels based on design approaches and active learning. His courses are cutting-edge, covering topics from computer networks to artificial intelligence. Through industry grants and connections, he has also made 21st-century technology available to his students. As a member of the Academy of Teachers, Sarhan will be able to share his knowledge and experience of developing innovative and project-based STEM courses with instructors across Wayne State University".

- Served as a Reviewer of the Academic Accreditation Policy Book 2021 for Saudi Arabia, 2021.

- Received two **Certificate of Appreciation Awards** from the IEEE SEM Section for significant contributions to the Spring Section Conference, May 2, 2019.

- Served as **Chair** of the ACM SIGMM Workshop on Network and Operating Systems Support for Digital Audio and Video (NOSSDAV), 2018.

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- Received **Certificate of Appreciation Award** from the IEEE SEM Section for dedicated leadership and significant contribution to the IEEE SEM Humanitarian Technology Conference and to the success of IEEE SEM activities, July 9, 2016.

- Served as **General Chair** of the Fifth IEEE International Workshop on Quality of Experience for Multimedia Communications (QoEMC 2016), Washington, DC USA, December 8, 2016.

- Received **Certificate of Appreciation Award** from the IEEE SEM Section for being an invited speaker and for outstanding contribution to the success of the IEEE SEM Section Spring 2015 Conference, April 28, 2015.

- Served as the **Chair of the Interest Group on Media Streaming**, IEEE Multimedia Communication Technical Committee, 2012 - 2014.

- Served as **Associate Editor** of the IEEE Transactions on Circuits and Systems for Video Technology, 2012-2015.

- Served as the **Guest Editor** for Multimedia, IEEE COMSOC MMTC E-Letter, Special Issue on Cloud Computing, Vol. 8, No. 6, November 2013.

- Served as a **Guest Editor** for Multimedia Tools and Applications Journal, Special Issue on Real-time Multimedia Computing, 65(2), July 2013.

- Served as **Chair** of the Multimedia Computing and Communications (MCC) Symposium, 2015.

- Served as **Co-Chair** of the Technical Program Committee of the International Conference on Computing, Networking and Communication (ICNC 2014), 2014

- Served as **Chair** of the Green Computing, Networking, and Communications Symposium (GCNC), 2014.

- Has a published paper that was nominated for the Best Paper Award at the IEEE International Conference on Multimedia and Expo (ICME 2013). (ICME is a premier conference with an acceptance rate of 12.7% for regular papers.)

- Served as **Co-Director** of the IEEE Multimedia Communication Technical Committee Review Board, 2010 - 2012.

- Received the 2009 **President's Award for Excellence in Teaching**, Wayne State University, April 28, 2009.

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- Received The 2008 **Outstanding Professional Award** from the Institute of Electrical and Electronics Engineers (IEEE) Southeastern Michigan Section for many accomplishments in multimedia computing and networking research and university teaching profession, March 2008 (at Engineering Society of Detroit Banquet) and April 2008 (at IEEE-SEM Spring Conference).

- Received The 2007 College of Engineering **Excellence in Teaching Award**, College of Engineering, Wayne State University, April 2008.
- Received 2007-2008 Wayne State University **Research Award**, March 2008.

- Served as the Faculty Counselor of the Institute of Electrical and Electronics Engineers (IEEE) Wayne State University Student Branch, which

    - Won The 2011 Michael Darson Award for Most Outstanding Student Organization.
    - Won the 2010 Michael Darson Award for Most Outstanding Student Organization.
    - Won The 2009 IEEE Southeastern Michigan Outstanding Student Branch Award, April 2009.
    - Won The 2008 IEEE Southeastern Michigan Outstanding Student Branch Award, April 2008.
    - Received Special Recognition Certificate from IEEE-USA for outstanding service, leadership, and commitment to IEEE-USA and the Profession.
    - Received two Recognition Certificates from IEEE Southeastern Michigan Section (2008 and 2009).
    - Was nominated for the 2007 IEEE Southeastern Michigan Outstanding Student Branch Award.
    - Was selected as the host and organizer of the 2008 IEEE-USA Student Professional Awareness Workshop on October 18, 2008: Many national IEEE leaders and more than 70 students from 5 universities participated in this workshop.
    - Had an officer who received the 2007 IEEE Southeastern Michigan Outstanding Student Involvement Award.
    - Won third place in the IEEE Region 4 Ethics Contest, November 2007.

- Received a **Certificate of Appreciation Award** from the Institute of Electrical and Electronics Engineers Southeastern Michigan Section for outstanding contribution as an invited speaker at the Spring 2008 Section Conference, April 2008.

- Received the **Computer Science and Engineering Graduate Student Teaching Award**, Computer Science and Engineering Department, Pennsylvania State University, University Park, March 2001.

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- Served as the president of a Penn State student organization for two years.

- Was named to Marquis Who's Who Emerging Leaders, Who's Who in Science and Engineering, and Who's Who in America.

Educational Background

- Ph.D., Computer Science and Engineering, Pennsylvania State University, University Park, GPA = 4.0 / 4.0, August 2003.

- M.S., Computer Science and Engineering, Pennsylvania State University, University Park, GPA = 4.0 / 4.0, May 2003.

- B.S., Electrical Engineering with Computer Engineering specialization, Jordan University of Science and Technology, Jordan, September 1995.

Research Areas of Interest

Computer systems design, multimedia systems, video streaming, computer networking, data communication, deep learning, hardware accelerators for AI, computer vision systems, automated video surveillance, I/O

Research Grants/Awards

- National Science Foundation, EPCN-Energy-Power-Ctrl-Netwrks: “An Energy-Efficient, CMOS-based, and Scalable Mixed-Signal DNN System with Reconfigurable Crossbars”, As Co-PI with Mohammad Alhawari, September 2022 – August 2025, $418,907.

- Silicon Mechanics, Third Annual Research Cluster Grant: “Silicon Mechanics Research Cluster Grant”, as Co-PI with Loren Schwiebert et al., March 2014, Equipment Grant for a high-performance computing cluster, valued at about $190,000.

- National Science Foundation, Computer Systems Research (CSR) Program, “DMSS: Towards Resource-Efficient Automated Video Surveillance Systems”, As PI and Sole Investigator, September 2008 - August 2014, $290,000. (Only 10-15% of proposals were accepted.)

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- National Science Foundation, Networking Technology and Systems (NeTS) Program, "NBD: Efficient Delivery of Video-on-Demand Streams to Heterogeneous Receivers", as PI and Sole Investigator, September 2006 - August 2008, $180,887, (Only 10% out of 274 proposals were accepted).

- National Science Foundation, Computing Research Infrastructure (CRI), "CRI: Reconfigurable High Performance Cluster Computing and Medical Engineering Applications", as Co-PI with Cheng-Zhong Xu, September 2007 - August 2009, $200,445.

- Sun Microsystems, "Sun's Center of Excellence in Open Source Computing and Applications", Equipment Grant of cluster of 8 servers with a total of 40 cores, As Co-PI with Cheng-Zhong Xu and S. Jiang, January 2009 - December 2010, valued at $150,000.

- Sun Microsystems, "Integration of Sun Technologies in Wayne State Classes", Equipment Grant, March 2008, As Co-PI with Cheng-Zhong Xu, Approximate Value: $50,000.

- National Science Foundation, Networking Technology and Systems (NeTS) Program, REU Supplement, "NBD: Efficient Delivery of Video-on-Demand Streams to Heterogeneous Receivers", As PI and Sole Investigator, June 2008 - August 2008, $12,000.

- National Science Foundation, "REU Site Telematics and Automotive Information Technology", As Faculty Mentor, with Cheng-Zhong Xu, 2009-2010, $314,500. (As mentor)

- Wayne State University Research Award, "Towards Resource-Efficient Automated Video Surveillance", As PI and Sole Investigator, April 2008, $10,000.

Patents

- Nabil. J. Sarhan. US Patent 9,313,463: "Automated Video Surveillance Systems", April 12, 2016.

- Hamza Al-Maharmeh, Mohammad Alhawari, Nabil Sarhan, and Mohammed Ismail Elnaggar. Energy Efficient Digital to Time Converter (DTC) for Edge Computing, US Patent App. 18/227,613, 2024 (pending).

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Editorships

- NOSSDAV '18: Proceedings of the 28th ACM SIGMM Workshop on Network and Operating Systems Support for Digital Audio and Video, Association for Computing Machinery, Amsterdam, Netherlands, June 12-15, 2018, ISBN: 978-1-4503-5772-2. Link. (As Program Chair)

- Special Issue on Cloud Computing for Multimedia, *IEEE COMSOC MMTC E-Letter*, Vol. 8, No. 6, November 2013. (As Guest Editor)

- Special Issue on Real-time Multimedia Computing, *Multimedia Tools and Applications Journal*, 65(2), July 2013. (As Guest Editor with SooKyun Kim, Henry Duh, and Vladimir Hahanov). DOI: https://doi.org/10.1007/s11042-013-1428-6. Journal metrics: Impact factor: 2.577 (2021).

- Proceedings of the 15th International Conference on Internet and Multimedia Systems and Applications, May 16 – 18, 2011, Washington, DC, USA, ISBN 978-88986-871-7. (As the Editor).

- IEEE Computer Society Multimedia Communications Technical Committee R-Letter, Vol. 3, No 3, June 2012. (As Co-Director of the Editorial Board)

- IEEE Computer Society Multimedia Communications Technical Committee R-Letter, Vol. 3, No 2, April 2012. (As Co-Director of the Editorial Board)

- IEEE Computer Society Multimedia Communications Technical Committee R-Letter, Vol. 3, No 1, February 2012. (As Co-Director of the Editorial Board)

- IEEE Computer Society Multimedia Communications Technical Committee R-Letter, Vol. 2, No 6, December 2011. (As Co-Director of the Editorial Board)

- IEEE Computer Society Multimedia Communications Technical Committee R-Letter, Vol. 2, No 5, October 2011. (As Co-Director of the Editorial Board)

- IEEE Computer Society Multimedia Communications Technical Committee R-Letter, Vol. 2, No 4, August 2011. (As Co-Director of the Editorial Board)

- IEEE Computer Society Multimedia Communications Technical Committee R-Letter, Vol. 2, No 3, June 2011. (As Co-Director of the Editorial Board)

- IEEE Computer Society Multimedia Communications Technical Committee R-Letter, Vol. 2, No 2, April 2011. (As Co-Director of the Editorial Board)

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- IEEE Computer Society Multimedia Communications Technical Committee R-Letter, Vol. 2, No 1, February 2011. (As Co-Director of the Editorial Board)

- IEEE Computer Society Multimedia Communications Technical Committee R-Letter, Vol. 1, No 2, December 2010. (As Co-Director Editorial Board)

- IEEE Computer Society Multimedia Communications Technical Committee R-Letter, Vol. 1, No 1, October 2010. (As Co-Director Editorial Board)

Book Chapters

- Nabil. J. Sarhan. Multimedia Streaming. In *Handbook of Computer Networks*, Editor: Hossein Bidgoli, pp. 282-292, John Wiley & Sons, Inc., 23 November 2007. Print ISBN:9780471784593, Online ISBN: 9781118256114. DOI: https://doi.org/10.1002/9781118256053.ch17.

Selected Referred Papers

Note: In computer engineering and science, premier conference publications are as important, if not more important than premier journal publications.

- Shiva Maleki Varnosfaderani, Ian McNulty, Nabil J. Sarhan, Waleed Abood, and Mohammad Alhawari. An Efficient Epilepsy Prediction Model on European Dataset with Model Evaluation Considering Seizure Types. *IEEE Journal of Biomedical and Health Informatics*, July 2024, DOI: 10.1109/JBHI.2024.3423766.

- Yousef O. Sharrab, Mohammad A. Alsmirat, Mohammad Ali H. Eljinini, and Nabil J. Sarhan. iHELP: a model for instant learning of video coding in VR/AR real-time applications. *Multimedia Tools Appl* (2024), Published: March 2024. https://doi.org/10.1007/s11042-024-18666-2.

- Hamza Al Maharmeh, Nabil J. Sarhan, Mohammed Ismail, and Mohammad Alhawari. A 116 TOPS/W Spatially Unrolled Time-Domain Accelerator Utilizing Laddered-Inverter DTC for Energy-Efficient Edge Computing in 65nm". *IEEE Open Journal of Circuits and Systems*, 2023, DOI: 10.1109/OJCAS.2023.3332853.

- Mohammad Alsmirat, Yousef Sharrab, Monther Tarawneh, Sana'a Al-shboul, and Nabil J. Sarhan. Video Coding Deep Learning-based Modeling for Long Live Video Streaming over Next Network Generation. *Cluster Computing,* 26:1159-1167, 2023, https://doi.org/10.1007/s10586-022-03948-x.

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- Melvin Edwards, Nabil J. Sarhan, and Mohammad Alhawari. Analysis of Dual-Row and Dual-Array Crossbars in Mixed Signal Deep Neural Networks. In Proceedings of the 2023 I*EEE 66th International Midwest Symposium on Circuits and Systems* (MWSCAS), August 2023.

- Shiva Maleki Varnosfaderani, Ian McNulty, Nabil J. Sarhan, Mohammad Alhawari. Artifacts Removal Techniques for the European iEEG Dataset. In Proceedings of the 2023 I*EEE 66th International Midwest Symposium on Circuits and Systems* (MWSCAS), August 2023.

- Melvin D. Edwards, Nabil J. Sarhan, and Mohammad Alhawari. A CMOS Analog Neuron Circuit with A Multi-Level Memory. In Proceedings of the *2023 International Conference on Microelectronics* (ICM) (2023): 11-15.

- Shiva Maleki Varnosfaderani, Rihat Rahman, Nabil J. Sarhan, and Mohammad Alhawari. A Self-Aware Power Management Model for Epileptic Seizure Systems Based on Patient-Specific Daily Seizure Pattern. In Proceedings of the 2023 *International Conference on Microelectronics* (ICM) (2023): 91-95.

- Sina G. Davani and Nabil J. Sarhan. Experimental Analysis of Optimal Bandwidth Allocation in Computer Vision Systems. *IEEE Transactions on Circuits and Systems for Video Technology*, Volume: 31, Issue: 10, October 2021. DOI: 10.1109/TCSVT.2020.3044015.

- Sina G. Davani, Musab Al-Hadrusi, and Nabil J. Sarhan. An Autonomous System for Efficient Control of PTZ Cameras. *ACM Transactions on Autonomous and Adaptive Systems*, Volume 16, Issue 2, June 2021, Article No.: 6, pp 1-22. DOI: https://doi.org/10.1145/3507658.

- Yousef O. Sharrab, Izzat Alsmadi, and Nabil J. Sarhan. Towards the Availability of Video Communication in Artificial Intelligence-based Computer Vision Systems Utilizing a Multi-objective Function. *Cluster Computing*, Springer, August 2021. DOI: https://doi.org/10.1007/s10586-021-03391-4.

- Ian McNulty, Shiva Maleki Varnosfaderani, Omar Makke, Nabil J. Sarhan, Eishi Asano, Aimee Luat, and Mohammad Alhawari. Analysis of Artifacts Removal Techniques in EEG Signals for Energy-Constrained Devices. In Proceedings of the *IEEE International Midwest Symposium on Circuits and Systems* (MWSCAS), August 2021. DOI: 10.1109/MWSCAS47672.2021.9531909.

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- Shiva M. Varnosfaderani, Rihat Rahman, Nabil J. Sarhan, Levin Kuhlmann, Eishi Asano, and Mohammad Alhawari. A Two-Layer LSTM Deep Learning Model for Epileptic Seizure Prediction. In Proceedings of the 3rd *IEEE International Conference on Artificial Intelligence Circuits & Systems* (AICAS 2021), June 2021. DOI: 10.1109/AICAS51828.2021.9458539.

- Hamza Al Maharmeh, Nabil J. Sarhan, Chung-Chih Hung, Mohammed Ismail, and Mohammad Alhawari. A Comparative Analysis of Time-Domain and Digital-Domain Hardware Accelerators for Neural Networks. In Proceedings of the *IEEE International Symposium on Circuits and Systems* (ISCAS), May 2021. DOI: 10.1109/ISCAS51556.2021.9401758.

- Rihat Rahman, Shiva Varnosfaderani, Omar Makke, Nabil Sarhan, Eishi Asano, Aimee Luat, and Mohammad Alhawari. Comprehensive Analysis of EEG Datasets for Epileptic Seizure Prediction. In Proceedings of the *IEEE International Symposium on Circuits and Systems* (ISCAS), May 2021. DOI: 10.1109/ISCAS51556.2021.9401766.

- Mohammad A. Alsmirat and Nabil J. Sarhan. Intelligent Optimization for Automated Video Surveillance at the Edge: A Cross-Layer Approach. *Simulation Modelling Practice and Theory*, Elsevier, Volume 105, 102171, December 2020. DOI: https://doi.org/10.1016/j.simpat.2020.102171.

- Hayder Hamandi and Nabil J. Sarhan. Novel Analytical Models of Face Recognition Accuracy in Terms of Video Capturing and Encoding Parameters. In Proceedings of the *IEEE International Conference on Multimedia and Expo* (ICME 2020), London, United Kingdom, July 2020, pp. 1-6. DOI: 10.1109/ICME46284.2020.9102791.

- Hamza Al Maharmeh, Nabil J. Sarhan, Chung-Chih Hung, Mohammed Ismail, Mohammad Alhawari. Compute-in-Time for Deep Neural Network Accelerators: Challenges and Prospects. Proceedings of the IEEE 63rd *International Midwest Symposium on Circuits & Systems* (MWSCAS 2020), pages 990-993, August 9-12, 2020. DOI: 10.1109/MWSCAS48704.2020.9184470.

- Melvin D. Edwards, Hamza Al Maharmeh, Nabil J. Sarhan, Mohammed Ismail, and Mohammad Alhawari. A Low-Power, Digitally-Controlled, Multi-Stable, CMOS Analog Memory Circuit. Proceedings of the IEEE 63rd *International Midwest Symposium on Circuits & Systems* (MWSCAS 2020), pages 872-875, August 9-12, 2020. DOI: 10.1109/MWSCAS48704.2020.9184459.

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- Mohammad A. Alsmirat and Nabil J. Sarhan. Cross-Layer Optimization for Many-to-One Wireless Video Streaming Systems. *Multimedia Tools and Applications*, Volume 77, Number 4, pages 1 - 23, Springer US, February 2018. DOI: 10.1007/s11042-018-5698-x.

- Sina G. Davani and Nabil J. Sarhan. Experimental Analysis of Bandwidth Allocation in Automated Video Surveillance Systems. In Proceedings of the 2017 *ACM Conference on Multimedia* (MM '17), pages 1457-1464, Mountain View, California, USA, October 2017. DOI: https://doi.org/10.1145/3123266.3123376. Best venue in the multimedia area.

- Yousef O. Sharrab and Nabil J. Sarhan. Modeling and Analysis of Power Consumption in Live Video Streaming Systems. *ACM Transactions on Multimedia Computing Communications and Applications* (ACM TOMM). Volume 13, Issue 4, pages 54:1-54:25, September 2017. DOI: https://doi.org/10.1145/3115505.

- Musab Al-Hadrusi, Nabil J. Sarhan, and Sina G. Davani. A Clustering Approach for Controlling PTZ Cameras in Automated Video Surveillance. In Proceedings of the *IEEE International Symposium on Multimedia* (ISM 2016), pages 333-336, San Jose, CA, USA, December 2016. DOI: 10.1109/ISM.2016.0073.

- Mohammad Alsmirat and Nabil J. Sarhan. Cross-Layer Optimization for Automated Video Surveillance. In Proceedings of the *IEEE International Symposium on Multimedia* (ISM 2016) pages 243-246, San Jose, CA, USA, December 2016. DOI: 10.1109/ISM.2016.0055.

- Kamal Nayfeh and Nabil J. Sarhan. A Scalable Solution for Interactive Near Video-on-Demand Systems. *IEEE Transactions on Circuits and Systems for Video Technology*, Volume 26, Number 10, pages 1907 - 1916, October 2016. DOI: 10.1109/TCSVT.2015.2478708.

- Kamal Nayfeh and Nabil J. Sarhan. Client-Side Cache Management for Scalable and Interactive Video Streaming. *IEEE International Conference on Multimedia and Expo* (ICME 2016), pages 1-6, Seattle, WA, 2016. DOI: 10.1109/ICME.2016.7552967.

- Musab Al-Hadrusi and Nabil J. Sarhan. A Scalable Delivery Solution and a Pricing Model for Commercial Video-on-Demand Systems with Video Advertisements. *Multimedia Tools and Applications*, Volume 73, Issue 3, pp 1417-1443, Springer US, December 2014. DOI: https://doi.org/10.1007/s11042-013-1597-3.

- Kamal Nayfeh and Nabil J. Sarhan. Design and Analysis of Scalable and Interactive Near Video-on-Demand Systems. In Proceedings of the *IEEE International Conference on*

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Multimedia and Expo, San Jose, California, July 2013. DOI: 10.1109/ICME.2013.6607540. Best Paper candidate. One of the best venues in multimedia. Acceptance rate for regular papers (with oral presentations): 12.7% (79 accepted out of 622 papers).

- Yousef Sharrab and Nabil J. Sarhan. Aggregate Power Consumption Modeling of Live Video Streaming Systems. In Proceedings of the *ACM Multimedia Systems* (MMSys 2013), Oslo, Norway, February 27 - March 1, 2013. DOI: https://doi.org/10.1145/2483977.2483983. Among the best venues in the multimedia area. Acceptance rate: 23.8%.

- Yousef Sharrab and Nabil J. Sarhan. Detailed Comparative Analysis of VP8 and H.264. In Proceedings of the *IEEE International Symposium on Multimedia* (ISM 2012), Irvine, California, December 2012. DOI: 10.1109/ISM.2012.33. Among the best venues in the multimedia area. Acceptance rate: 24.8%.

- Musab Al-Hadrusi and Nabil J. Sarhan. Efficient Control of PTZ Cameras in Automated Video Surveillance Systems. In Proceedings of the *IEEE International Symposium on Multimedia* (ISM 2012), Short Paper, Irvine, California, December 2012. DOI: https://doi.org/10.1109/ISM.2012.72.

- Mohammad Alsmirat and Nabil J. Sarhan. Cross-Layer Optimization and Effective Airtime Estimation for Wireless Video Streaming. In Proceedings of the *International Conference on Computer Communications and Networks* (ICCCN 2012), pages 1 – 7, Munich, Germany, July 2012. DOI: 10.1109/ICCCN.2012.6289275. Acceptance rate: 30%.

- Yousef Sharrab and Nabil J. Sarhan. Accuracy and Power Consumption Tradeoffs in Video Rate Adaptation for Computer Vision Applications. In Proceedings of the 2012 *IEEE International Conference on Multimedia & Expo* (ICME 2012), pages 410 - 415, Melbourne, Australia, July 2012. DOI: https://doi.org/10.1109/ICME.2012.77.

- Musab Al-Hadrusi and Nabil J. Sarhan. Client-Driven Price Selection for Scalable Video Streaming with Advertisements. In *Proceedings of the International MultiMedia Modeling Conference* (MMM 2012), pages 429 - 439, Klagenfurt, Austria, January 2012. DOI: https://doi.org/10.1007/978-3-642-27355-1_40. Acceptance rate: 34.9%.

- Nabil J. Sarhan and Musab Al-Hadrusi. Waiting-Time Prediction and QoS-Based Pricing for Video Streaming with Advertisements. In Proceedings of the *IEEE International Symposium on Multimedia* (ISM 2010), pages 17 - 24, Taichung, Taiwan, December 2010. DOI: https://doi.org/10.1109/ISM.2010.13. Acceptance rate: 31%.

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- Bashar Qudah and Nabil J. Sarhan. Efficient Delivery of On-Demand Video Streams to Heterogeneous Receivers. *ACM Transactions on Multimedia Computing, Communications, and Applications* (ACM TOMCCAP), Volume 6, Issue 3, August 2010. DOI: https://doi.org/10.1145/1823746.1823754.

- Nabil J. Sarhan, Mohammad A. Alsmirat, and Musab Al-Hadrusi. Waiting-Time Prediction in Scalable On-Demand Video Streaming. *ACM Transactions on Multimedia Computing, Communications, and Applications* (ACM TOMCCAP), Volume 6, Issue 2, March 2010. DOI: https://doi.org/10.1145/1671962.1671967.
- Mohammad Alsmirat and Nabil J. Sarhan. Detailed Performance and Waiting-Time Predictability Analysis of Scheduling Options in On-Demand Video Streaming. *EURASIP Journal on Image and Video Processing*, Springer, Volume 2010, 2010.

- Bashar Qudah and Nabil J. Sarhan. Workload-Aware Resource Sharing and Cache Management for Scalable Video Streaming. *IEEE Transactions on Circuits and Systems for Video Technology*, Vol. 19, No. 3, March 2009. DOI: 10.1109/TCSVT.2009.2013498,

- Mohammad Alsmirat and Nabil J. Sarhan. Performance and Waiting-Time Predictability Analysis of Design Options in Cost-Based Scheduling for Scalable Media Streaming. In *Proceedings of the International MultiMedia Modeling Conference* (MMM 2009), pages 150-162, Sophia-Antipolis, France, January 2009. DOI: https://doi.org/10.1007/978-3-540-92892-8_16. Accepted for oral-style presentation (as opposed to poster). Acceptance rate for oral presentations: 16%.

- Jeffrey R. Ostrowski and Nabil J. Sarhan. Characterization of Social Video. In *Proceedings of SPIE Multimedia Computing and Networking* (MMCN), San Jose, California, USA, January 2009. DOI: 10.1117/12.815535. Acceptance rate: 35%.

- Musab Al-Hadrusi and Nabil J. Sarhan. A Scalable Delivery Framework and a Pricing Model for Streaming Media with Advertisements. In *Proceedings of SPIE Multimedia Computing and Networking* (MMCN 2008), pages 68180G-68180G, San Jose, California, USA, January/February 2008. DOI: https://doi.org/10.1145/1291233.1291412. Acceptance rate for full-length papers: 26%.

- Mohammad Alsmirat and Nabil J. Sarhan. Predictive Cost-Based Scheduling for Scalable Video Streaming. In *Proceedings of the IEEE International Conference on Multimedia & Expo* (ICME 2008), pages 857 - 860, Hannover, Germany, June 2008. DOI: 10.1109/ICME.2008.4607570. Accepted as oral-style presentation (as opposed to poster). Acceptance rate for oral presentations: 20%.

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- Mohammad Alsmirat, Musab Al-Hadrusi, and Nabil J. Sarhan. Analysis of Waiting-Time Predictability in Scalable Media Streaming. In *Proceedings of ACM Multimedia*, pages 727 - 736, Augsburg, Germany, September 2007. DOI: https://doi.org/10.1145/1291233.1291398. Best venue of publication in the multimedia area. Acceptance Rate: 19%.

- Musab Al-Hadrusi and Nabil J. Sarhan. Scalable Delivery and Pricing of Streaming Media with Advertisements. In *Proceedings of ACM Multimedia*, pages 791 - 794, Augsburg, Germany, September 2007. Best venue of publication in the multimedia area. Acceptance Rate: 27%.

- Nabil J. Sarhan and Bashar Qudah. Efficient Cost-Based Scheduling for Scalable Media Streaming. In *Proceedings of the SPIE/ACM Multimedia Computing and Networking Conference* (MMCN 2007), pages 65040C-65040C, San Jose, California, USA, January/February 2007. DOI: 10.1117/12.706022.Acceptance Rate: 30%.

- Bashar Qudah and Nabil J. Sarhan. Towards Enhanced Resource Sharing in Video Streaming with Generalized Access Patterns. In *Proceedings of the IEEE International Conference on Multimedia & Expo* (ICME 2007), pages 1219 - 1222, Beijing, China, July 2007. DOI: 10.1109/ICME.2007.4284876.

- Bashar Qudah and Nabil J. Sarhan. Towards Scalable Delivery of Video Streams to Heterogeneous Receivers. In *Proceedings of ACM Multimedia*, pages 347 - 356, Santa Barbra, California, USA, October 2006. DOI: 10.1145/1180639.1180716. Best venue in the multimedia area. Acceptance Rate: 16%.

- Bashar Qudah and Nabil J. Sarhan. Analysis of Resource Sharing and Cache Management Techniques in Scalable Video-on-Demand. In *Proceedings of the 14th IEEE International Symposium on Modeling, Analysis, and Simulation of Computer and Telecommunication Systems* (MASCOTS 2006), pages 327 – 334, Monterey, California, USA, September 2006. DOI: https://doi.org/10.1109/MASCOTS.2006.13. Acceptance Rate: 36%.

- Nabil J. Sarhan and Chita R. Das. Caching and Scheduling in NAD-Based Multimedia Servers. *IEEE Transactions on Parallel and Distributed Systems*, Vol. 15, No. 10, pages 921 - 933, October 2004. DOI: 10.1109/TPDS.2004.49.

- Nabil J. Sarhan and Chita R. Das. A New Class of Scheduling Policies for Providing Time of Service Guarantees in Video-On-Demand Servers. In *Proceedings of the 7th IFIP/IEEE International Conference on Management of Multimedia Networks and Services*, (MMNS

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2004), pages 127 - 139, San Diego, California, USA, October 2004. DOI: 10.1007/978-3-540-30189-9_11. Acceptance Rate: 31%.

- Nabil J. Sarhan and Chita R. Das. Analysis of Caching Performance in Multimedia Servers. In *Proceedings of the 8th International Conference on Internet and Multimedia Systems and Applications*, pages 288 - 293, Hawaii, USA, August 2004. Acceptance rate: NA.

- Nabil J. Sarhan and Chita R. Das. An Integrated Resource Sharing Policy for Multimedia Storage Servers Based on Network-Attached Disks. In *Proceedings of the 23rd IEEE International Conference on Distributed Computing Systems* (ICDCS 2003), pages 136 - 143, Providence, Rhode Island, USA, May 2003. DOI: 10.1109/ICDCS.2003.1203460. Best venue in the distributed systems area. Acceptance Rate: 17%.

- Nabil J. Sarhan and Chita R. Das. Providing Time of Service Guarantees in Video-On-Demand Servers. In Poster *Proceedings of the Twelfth International World Wide Web Conference* (WWW 2003), Budapest, Hungary, May 2003. WWW is the best conference in the Web area.

- Nabil J. Sarhan and Chita R. Das. A Simulation-Based Analysis of Scheduling Policies for Multimedia Servers. In *Proceedings of the 36th Annual Simulation Symposium* (ANSS 2003), pages 183 - 190, Orlando, Florida, USA, March 30 - April 2, 2003. DOI: 10.1109/SIMSYM.2003.1192812. Acceptance Rate: 39%.

- Nabil J. Sarhan and Chita R. Das. Adaptive Block Rearrangement Algorithms for Video-On-Demand Servers. In *Proceedings of the 2001 International Conference on Parallel Processing* (ICPP 2001), pages 452 - 459, Valencia, Spain, September 2001. DOI: 10.1109/ICPP.2001.952092.

Magazine Articles

- Nabil. J. Sarhan. Is 3D Here to Stay? Analysis of 3D Video Projection Technologies. *ESD Technology Century*, Vol. 15 No. 3, Fall 2010.

- Nabil. J. Sarhan. Do You ... YouTube? YouTube and the Technology Behind It. *ESD Technology Century*, Vol. 14, No. 2, April-May 2009. (Featured as the main article on the cover page.)

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Invited Articles

- Nabil. J. Sarhan. Recent and Future Trends in Mobile Video Streaming. *IEEE Computer Society Multimedia Communications Technical Committee e-Letter*, Special Issue on Multimedia Streaming over Mobile Networks, Vol. 8, No. 5, September 2013.

- Nabil. J. Sarhan. Broadcast and Multicast Based Mobile Video Distribution. *IEEE Computer Society Multimedia Communications Technical Committee e-Letter*, Vol. 4, No. 8, September 2009.

Invited Panels

- Panelist, "Automated Wayne State Video Surveillance (WAVS) System", IEEE SEM Humanitarian Technology Conference, July 9, 2016.

- Panelist, "Challenges and Applications of Mobile Video Technologies", ACM Workshop on Mobile Video (MoVid), Oslo, Norway, February 2013.

- Panelist, "Content Distribution (P2P versus Infrastructure) and the Mobil Age", SPIE/ACM Multimedia Computing and Networking (MMCN), San Jose, California, USA, January 2008.

Selected Technical Presentations

- "Analysis of Deep Learning Accuracy". IEEE SEM Spring Section Conference, May 2, 2019.

- "Towards Energy Adapted Video Streaming". IEEE SEM Spring Section Conference, May 2, 2019.

- "Dependency-aware Scheduling for Tasks with Constraints in Big Data Clusters". The 6th Annual Big Data & Business Analytics Summit, March 22, 2019 (Poster).

- "Experimental Analysis of Bandwidth Allocation in Automated Video Surveillance Systems", ACM Multimedia, October 2017

- "A Clustering Approach for Controlling PTZ Cameras in Automated Video Surveillance". IEEE International Symposium on Multimedia (ISM 2016), San Jose, December 2016.

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- "Cross-Layer Optimization for Automated Video Surveillance". IEEE International Symposium on Multimedia (ISM 2016), San Jose, December 2016.

- "Design and Analysis of Scalable and Interactive Near Video-on-Demand Systems". IEEE International Conference on Multimedia and Expo, San Jose, California, July 2013.

- "Aggregate Power Consumption Modeling of Live Video Streaming Systems". ACM Multimedia Systems (MMSys 2013), Oslo, Norway, February 27 - March 1, 2013.

- "Efficient Control of PTZ Cameras in Automated Video Surveillance Systems". IEEE International Symposium on Multimedia (ISM 2012), Irvine, California, December 11, 2012.

- "Detailed Comparative Analysis of VP8 and H.264". IEEE International Symposium on Multimedia (ISM 2012), Irvine, California, December 12, 2012 (presented by my student).

- "Cross-Layer Optimization and Effective Airtime Estimation for Wireless Video Streaming". International Conference on Computer Communications and Networks (ICCCN 2012), Munich, Germany, July 2012.

- "Client-Driven Price Selection for Scalable Video Streaming with Advertisements". International MultiMedia Modeling Conference (MMM 2012), Klagenfurt, Austria, January 2012.

- "Vehicular Multimedia and Communication Systems: Recent and Future Trends". International Conference on Advanced Research & Applications in Mechanical Engineering (ICARAME 2011), Louaize, Lebanon, June 13, 2011.

- "Waiting-Time Prediction and QoS-Based Pricing for Video Streaming with Advertisements". IEEE International Symposium on Multimedia (ISM 2010), Taichung, Taiwan, December 13, 2010. (Video Presentation)

- "Characterization of Social Video". SPIE Multimedia Computing and Networking (MMCN), San Jose, California, USA, January 19, 2009.

- "Alternative Pricing and Scalable Delivery Strategies for Media Streaming with Advertisements". Workshop on Hot Topics in Multimedia Research, Darmsdat, Germany, June 21, 2008.

- "Predictive Cost-Based Scheduling for Scalable Video Streaming". IEEE International Conference on Multimedia & Expo (ICME 2008), Hannover, Germany, June 25, 2008.

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- "A Scalable Delivery Framework and a Pricing Model for Streaming Media with Advertisements". SPIE/ACM Multimedia Computing and Networking (MMCN 2008), San Jose, California, USA, January 31, 2008.

- "Analysis of Waiting-Time Predictability in Scalable Media Streaming". ACM Multimedia, Augsburg, Germany, September 2007.

- "Efficient Cost-Based Scheduling for Scalable Media Streaming". SPIE/ACM Multimedia Computing and Networking Conference (MMCN 2007), San Jose, California, USA, February 1, 2007.

- "A New Class of Scheduling Policies for Providing Time of Service Guarantees in Video-On-Demand Servers". International Conference on Management of Multimedia Networks and Services (MMNS), San Diego, California, October 5, 2004.

- "An Integrated Resource Sharing Policy for Multimedia Storage Servers Based on Network-Attached Disks". International Conference on Distributed Computing Systems (ICDCS 2003), Providence, Rhode Island, May 20, 2003.

- "On the Design of Scalable and High Performance Multimedia Servers", University of Arkansas, Little Rock, May 15, 2003.

- "A Simulation-Based Analysis of Scheduling Policies for Multimedia Servers'. Annual Simulation Symposium (ANSS 2003), Orlando, Florida, April 1, 2003.

- "Multimedia Systems and Networking: Challenges, Studies, and Future Work", ECE Seminar, Wayne State University, Detroit, Michigan, February 11, 2004.

Invited Talks

- School Presentation, "Demystifying Artificial Intelligence for Kids: How to teach computers how to do things?", STEM Night, IIA School, Detroit, MI, Sept. 26, 2019.

- "Towards Highly Scalable and Interactive Video Streaming Systems", IEEE SEM Spring Conference, University of Michigan – Dearborn, April 28, 2015.

- "Outstanding IEEE Professional Presentation: Scalable Delivery and Pricing for Streaming Media with Advertisements", IEEE Southeastern Michigan Conference (IEEE-SEM), University of Michigan, Dearborn, USA, April 2, 2008.

- "Graduate School: Is It Right for You", IEEE End of School Year Event, University of Michigan, Dearborn, USA, May 4, 2008.

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Tutorials

- Nabil. J. Sarhan. Video Streaming over the Internet and Wireless Networks: Challenges and Approaches, International Conference on Information and Communication Systems, Amman, Jordan, December 20-22, 2009.

Conference Exhibitions

- Wayne State Automated Video Surveillance System, MiSN Homeland Security Market Leadership Conference, Dearborn, Michigan, November 4, 2009.

Educational Activities

- Serving as the **Overall Coordinator** of the College of Engineering M.S. Program in Artificial Intelligence and the **Director** of Systems and Hardware Track, since August 2022.

- Led the college efforts to develop the **College of Engineering M.S. Program in Artificial Intelligence**, 2021-2022.

- Serving as the **Chair of the Computer Engineering Area Committee,** which made significant improvements in the computer engineering curricula at both the graduate and undergraduate levels, 2017 – current.

- Developed a new ECE mandatory course titled "Object-Oriented Programming for Electrical and Computer Engineering (ECE 2050)".

- Led the efforts to modernize the Introduction to Microcomputers course and lab (the ECE 3620) by using ARM-based microcontrollers, 2020 - 2021.

- Served as the **Director of the ECE Graduate Program**, 2011 – 2013 and made the following contributions.

    - Developing a new graduate curriculum for the M.S. degrees in Electrical Engineering and Computer Engineering,

    - Developing several new policies for admission, plagiarism, overrides, grade performance requirements, form submission, Ph.D. prerequisite requirements,

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and Ph.D. Prelim Exam,

  - Substantially revising and enhancing almost all graduate forms for better clarity, level of detail, and formatting,

  - Substantially revising and enhancing the graduate handbook and all other documentation, and

  - Substantially revising and enhancing the graduate website.

- Served as the **Chair of the Computer Engineering Taskforce**, 2014 – 2016, which made significant changes to the Computer Option of the B.S. Degree in Electrical Engineering and the Ph.D. Preliminary Examination requirements and outline for Computer Engineering.

- Developed a research-oriented graduate course on multimedia computing and networking.

- Transformed the senior-level computer architecture course (ECE 4680) into a research and design-oriented course with built-in labs, with the most recent changes in the title and description in May 2019 to reflect new trends in the field.

- Transformed the computer networking course (ECE 5650) into a project-oriented course with built-in labs, with the most recent changes in the title and description in May 2019 to reflect new trends in the field. The course reflects new trends in the field by covering Software-Defined Networking, OpenFlow, and Generalized Forwarding and switching to Python 3. The number of labs is increased from 3 to 5, starting Winter 2020.

- Revised the description and outline of ECE 7650 (Scalable and Secure Internet Services and Architectures", with the most change in the description in May 2019.

Courses Taught

- Advanced Computer Architecture (ECE 7660) at WSU

- Scalable and Secure Internet Services and Architectures (ECE 7650) at WSU

- Special Topics on Multimedia (ECE 7995) at WSU

- Special Topics on Multimedia Networking (ECE 7995) at WSU

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- Special Topics on Multimedia Systems and Networks (ECE 7995) at WSU
- Computer Networking and Network Programming (ECE 5650) at WSU
- Computer Architecture (ECE 4680) at WSU
- Data Structures and Algorithms (ECE 4050/CS 5050) at WSU
- Microcomputer Systems and Programming (CSE 312) At Penn State
- Computer Programming for Engineers (CMPSC 201c) at Penn State
- Introduction to Algorithmic Processes (CMPSC 101) at Penn State

Ph.D. Dissertations Supervised

- Hayder Hamandi, “Modeling and Enhancing Deep Learning Accuracy in Computer Vision Applications”, Date of defense: July 5, 2022.
- Sina Davani, “Design of Computer Vision Systems for Optimizing the Threat Detection Accuracy”, Date of defense: November 16, 2021.
- Hussein M. Khairallah, “Remote Screening and Self-Monitoring for Vision Loss Diseases based on Smartphone Applications”, Date of defense: July 23, 2018.
- Yousef Sharrab, “Video Stream Adaptation in Computer Vision Systems”, Date of Defense: January 26, 2017.
- Kamal Nayfeh, “A Scalable Solution for Interactive Video Streaming”, Date of Defense: November 29, 2016.
- Musab Al-Hadrusi, “Design and Analysis of Scalable Video Streaming Systems”, March 18, 2013.
- Mohammad Alsmirat, “Maximizing Resource Utilization in Video Streaming Systems”, March 18, 2013.
- Bashar Qudah. "Enhanced Resource Sharing for Scalable Video-on-Demand Services". Date of Defense: January 26, 2009.

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M.S. Theses Supervised

- Sina G. Davani, “Towards Optimal PTZ Camera Scheduling in Automated Video Surveillance”, Date of defense: December 18, 2017

- Loren Garavaglia, “Analysis of Cross-layer Optimization of Facial Recognition Accuracy in Automated Video Surveillance”, Date of defense: August 3, 2017

- Saleh Abdel-Gader Amareen, “Efficient Algorithms for Coding Unit Size Selection in HEVC Using Entropy and Number of Blocks”, Date of defense: January 7, 2015

- Jeffrey R. Ostrowski. “Characterization of Social Video”. Date of defense: September 15, 2008

Service on External Ph.D. Dissertation Committees

- External Evaluator, Ph.D. Dissertation, Simon Fraser University, Canada, Student Name: Mohammed Shatnawi, "Improving the Reliability of Online Multimedia Communication Services. Date of Defense: November 15, 2018

- External Committee Member, Ph.D. Dissertation, Computer Science, University of Ottawa, Student Name: Atif Alamri, Date of defense: June 30, 2010

Service on Other Ph.D. Dissertation Committees

- Hussein Kokash, “Flow Instabilities and Vortical Dynamics Analysis in the Wake of Bluff Bodies: from Cylinders to Airfoils”, Department: Mechanical Engineering, Date of Defense: May 2024.

- Shiva Maleki Varnosfaderani, “Epilepsy Prediction based on Deep Learning Techniques”, Date of Defense: October 11, 2023.

- Haysam M. Kadry, “Autonomous Spatiotemporal Magnetless Circulators for Full-Duplex Communication”, Date of Defense: October 18, 2022.

- Hamza Al-Maharmeh, “Energy-Efficient Mixed-Signal Techniques for Artificial Neural Network Accelerators in Edge Computing”, Date of Defense: October 14, 2022.

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- Mostafa Daneshgar Rahbar (Electrical and Computer Engineering), Ph.D. Dissertation, Date of Defense: October 16, 2020.
- Guoyao Xu (Electrical and Computer Engineering), Date of Defense: February 8, 2019.
- Nasser Alkhaldi (Electrical and Computer Engineering), Defense: January 24, 2019
- Kun Wang (Electrical and Computer Engineering), Date of defense: November 23, 2015.
- Yuehai Xu (Electrical and Computer Engineering), Date of defense: August 27, 2014
- Massoud Hassan Alatrash (Electrical and Computer Engineering), Date of defense: October 24, 2013
- Xiangping Bu (Electrical and Computer Engineering), Date of defense: June 25, 2013
- Xuechen Zhang (Electrical and Computer Engineering), Date of defense: August 28, 2012
- Jiayu Gong (Electrical and Computer Engineering), Date of defense: September 1, 2011
- Minghua Xu (Electrical and Computer Engineering), Date of defense: August 30, 2010
- Atif Alamri (Computer Science, University of Ottawa), Date of defense: June 30, 2010
- Nassim Khaled (Mechanical Engineering), Date of defense: June 28, 2010
- Safwan Al-Omari (Computer Science), Date of defense: December 17, 2008
- Mohammed Akkal (Electrical and Computer Engineering), Date of defense: September 4, 2008
- Minghua Xu (Electrical and Computer Engineering), Date of defense: December 6, 2006
- Song Fu (Electrical and Computer Engineering), Date of defense: May 14, 2008
- Haiying Shen (Electrical and Computer Engineering), Date of defense: March 29, 2006
- Jianbin Wei (Electrical and Computer Engineering), Date of defense: July 10, 2006
- Xiliang Zhong (Electrical and Computer Engineering), Date of defense: June 07, 2007

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Service on Other M.S. Thesis Committees

- Tareq Dardona (Electrical and Computer Engineering), December 13, 2018
- Jianqiang Ou (Electrical and Computer Engineering), Date of defense: April 6, 2016
- Yudi Xie (Electrical and Computer Engineering), Date of defense: December 14, 2015
- David Wang (Electrical and Computer Engineering), Date of defense: November 3, 2010
- Mumtaz Dawoodi (Electrical and Computer Engineering), Date of defense: February 17, 2010
- Abdurrahman Arif (Electrical and Computer Engineering), Date of defense: January 29, 2009
- Renelius Bell (Electrical and Computer Engineering), Date of defense: November 17, 2008
- Jianbin Wei (Electrical and Computer Engineering), Date of defense: November 24, 2003
- Shixiang Zou (Electrical and Computer Engineering), Date of defense: October 29, 2004
- Abhishek Jindal (Electrical and Computer Engineering), Date of defense: June 30, 2004

Membership of Professional Societies

- **Senior Member**, IEEEE

Professional Activities

Service to Professional Societies

- **Chair, Interest Group on Media Streaming**, IEEE Multimedia Communication Technical Committee, 2012 - 2014.

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Editorships

- **Guest Editor**, *Multimedia Tools and Applications Journal*, *Special Issue on Real-time Multimedia Computing*, 65(2), July 2013. (With SooKyun Kim, Henry Duh, and Vladimir Hahanov)

- **Guest Editor**, Special Issue on Cloud Computing for Multimedia, IEEE COMSOC MMTC E-Letter, Vol. 8, No. 6, November 2013.

Editorial Board Memberships

- **Editor**, *ETRI Journal*, 2017 – now.

- **Associate Editor**, *IEEE Transactions on Circuits and Systems for Video Technology*, 2012-2015.

- **Co-Director, IEEE Multimedia Communication Technical Committee Review Board**, 2010 – 2012

- **Associate Editor**, The Journal of Future Game Technology, 2011-2015

Conference Organization

- **Chair**, ACM SIGMM Workshop on Network and Operating Systems Support for Digital Audio and Video (NOSSDAV), 2018.

- **General Chair**, Fifth IEEE International Workshop on Quality of Experience for Multimedia Communications (QoEMC 2016), in conjunction with IEEE Globecom 2016, Washington DC, USA, December 8, 2016

- **Publicity Chair**, Workshop on Quality of Experience-based Management for Future Internet Applications and Services part of IEEE International Conference on Communications (ICC 2016), 2016

- **Chair**, Multimedia Computing and Communications (MCC) Symposium, 2015

- **Publicity Chair**, IEEE Workshop on Quality of Experience-based Management for Future Internet Applications and Services (QoE-FI), part of IEEE International Conference on Communications (IEEE ICC 2015), 2015

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- **Co-Chair**, Technical Program Committee, International Conference on Computing, Networking and Communication (ICNC 2014), 2014

- **Chair**, Green Computing, Networking, and Communications Symposium (GCNC 2014), 2014

- **Publicity Chair**, The 2nd International Conference on Intelligent Information System and Technology (ICIIST 2014), 2014

- **Invited Speaker and Panel Co-Chair**, IEEE Globecom 2013 Workshop on Cloud Computing Systems, Networks, and Applications (CCSNA), 2013

- **Publicity Chair**, International Conference on Intelligence Fusion (ICIF2013), 2013

- **Session Chair**, IEEE International Symposium on Multimedia (ISM 2012), 2012

- **Publicity Chair**, International Conference on Computer Convergence Technology (ICCCT 2011), 2012

- **Chair**, 14th International Conference on Internet and Multimedia Systems and Applications (IMSA 2011), 2011

- **Session Chair**, 6th International Conference on Human-Computer Interaction (HCI), 2011

- **Session Chair**, International Conference on Advanced Research & Applications in Mechanical Engineering (ICARAME 2011), 2011.

- **Publicity Chair**, International Conference on Computer Convergence Technology (ICCCT 2011), 2011

- **Track Chair**, Distributed Multimedia Track, International Conference on Embedded and Multimedia Computing (EMC-10), 2010
- **Session Chair**, Multimedia Computing and Networking (MMCN), 2009

- **Session Chair**, SPIE/ACM Multimedia Computing and Networking (MMCN), 2008

- **Session Chair**, IEEE International Conference on Multimedia & Expo (ICME), 2008

- **Session Chair**, International Conference on Internet and Multimedia Systems and Applications (IMSA), 2004

- **Publicity Chair**, International Conference on Intelligence Fusion (ICIF2013), 2013

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Service to Funding Agencies

- Proposal Reviewer, Natural Sciences and Engineering Research Council of Canada (NSERC), 2021
- Panelist, National Science Foundation (NSF, IIS Program), USA, 2014
- Panelist, National Science Foundation (NSF, NeTS Program), USA, 2014
- Grant Progress Reviewer, Strategic Network (Large Proposal), Natural Sciences and Engineering Research Council of Canada, Canada, 2013
- Reviewer, The Ontario Centres of Excellence, Canada, 2011
- Site Review Committee Member, Strategic Network (Large Proposal), Natural Sciences and Engineering Research Council of Canada, Canada, 2010
- Panelist, Phase II Contract Proposals, National Institute of Health (NIH)/ National Institute of Alcohol Abuse and Alcoholism (NIAAA), USA 2010
- Panelist, National Science Foundation (NSF), USA, 2010
- Panelist, National Science Foundation (NSF), USA, 2009
- Reviewer, Natural Sciences and Engineering Research Council, Canada, 2009
- Panelist, National Science Foundation (NSF), USA, 2008
- Panelist, Contract Proposals, National Institute of Health (NIH)/ National Institute of Alcohol Abuse and Alcoholism (NIAAA), USA, 2008
- Grant Proposal Reviewer, Kentucky Science and Technology Foundation R&D Excellence Program, USA, 2006

Other Services to Technical Journals and Magazines

- Reviewer, Analog Integrated Circuits and Signal Processing, 2020
- Reviewer, SN Applied Sciences, Springer, 2020
- Reviewer, Transactions on Multimedia Computing, Communications and Applications (ACM TOMM), 2017 (2 papers)

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- Reviewer, IEEE Transactions on Mobile Computing, 2017
- Reviewer, IEEE Transactions on Multimedia, 2016
- Reviewer, IEEE Transactions on Parallel and Distributed Systems, 2016
- Reviewer, Transactions on Multimedia Computing, Communications and Applications (ACM TOMM), 2015
- Reviewer, Science China, Information Sciences, 2014
- Reviewer, IEEE Internet Computing, 2014
- Reviewer, Transactions on Multimedia Computing, Communications and Applications (ACM TOMM), 2014
- Reviewer, ACM Transactions on Multimedia Computing Communications and Applications, Special Issue on Multiple Sensorial (MulSeMedia) Multi-modal Media: Advances and Applications, 2013
- Reviewer, IEEE Transactions on Parallel and Distributed Systems, 2013
- Reviewer, IEEE Communications Magazine, 2012
- Reviewer, ACM Transactions on Multimedia Computing Communications and Applications (3 papers), 2012
- Reviewer, IEEE Transactions on Parallel and Distributed Systems (2 papers), 2012
- Reviewer, Multimedia Systems Journal, 2012
- Reviewer, International Journal of Modeling and Simulation, 2012
- Reviewer, ACM Transactions on Multimedia Computing Communications and Applications, 2011
- Reviewer, IEEE Transactions on Parallel and Distributed Systems, 2011 (2 papers)
- Reviewer, Multimedia Systems Journal, 2011
- Reviewer, IEEE/ACM Transactions on Networking, 2010

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- Reviewer, ACM Transactions on Multimedia Computing Communications and Applications (3 papers), 2010
- Reviewer, Multimedia Systems Journal, 2010
- Reviewer, Journal of Multimedia, 2010
- Reviewer, IEEE Multimedia Magazine, 2009
- Reviewer, IEEE Transactions on Parallel and Distributed Systems, 2009
- Reviewer, ACM Transactions on Multimedia Computing Communications and Applications (3 papers), 2009
- Reviewer, IEEE/ACM Transactions on Networking, 2009
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- Reviewer, ACM Transactions on Multimedia Computing Communications and Applications, 2007 (2 papers)
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- Reviewer, IEEE Transactions on Multimedia, 2005

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- Reviewer, Journal of Parallel and Distributed Computing (JPDC), 2004

Other Conference Service

- Technical Program Committee Member, ACM Multimedia, 2023
- Technical Program Committee Member, ACM Multimedia Systems (MMSys), 2023
- Technical Program Committee Member, ACM Multimedia, 2020
- Technical Program Committee Member, ACM Multimedia, 2019
- Technical Program Committee Member, IEEE International Conference on Multimedia and Expo (ICME), 2019
- Technical Program Committee Member, ACM Multimedia Systems (MMSys), 2018
- Technical Program Committee Member, IEEE International Conference on Multimedia and Expo (ICME), 2018
- Technical Program Committee Member, ACM Multimedia, 2017
- Technical Program Committee Member, IEEE International Conference on Multimedia and Expo (ICME), 2017
- Technical Program Committee Member, ACM Multimedia Systems (MMSys), 2017
- Technical Program Committee Member, ACM SIGMM Workshop on Network and Operating Systems Support for Digital Audio and Video (NOSSDAV), 2017.
- Technical Program Committee Member, ACM Workshop on Mobile Video (MoVid), 2017.
- Technical Program Committee Member, IEEE International Conference on Multimedia & Expo (ICME), 2016
- Technical Program Committee Member, ACM Multimedia, 2016
- Technical Program Committee Member, ACM Multimedia Systems (MMSys), 2016

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- Technical Program Committee Member, ACM SIGMM Workshop on Network and Operating Systems Support for Digital Audio and Video (NOSSDAV), 2016

- Technical Program Committee Member, ACM Workshop on Mobile Video (MoVid), 2016.

- Technical Program Committee Member, IEEE Workshop on Quality of Experience-based Management for Future Internet Applications and Services (QoE-FI), part of IEEE International Conference on Communications (IEEE ICC), 2015

- Technical Program Committee Member, ACM Multimedia Systems (MMSys), 2015

- Technical Program Committee Member, IEEE International Conference on Multimedia & Expo (ICME), 2015

- Technical Program Committee Member, ACM SIGMM Workshop on Network and Operating Systems Support for Digital Audio and Video (NOSSDAV), 2015

- Technical Program Committee Member, ACM Workshop on Mobile Video (MoVid), 2015

- Technical Program Committee Member, The International Conference on Digital Telecommunications (ICDT), 2015

- Technical Program Committee Member, IEEE International Conference on Multimedia & Expo (ICME 2014), 2014

- Technical Program Committee Member, ACM Workshop on Mobile Video (MoVid), 2014

- Technical Program Committee Member, ACM Multimedia Systems (MMSys), 2014

- Technical Program Committee Member, The International Conference on Digital Telecommunications (ICDT), 2014

- Panelist, ACM Workshop on Mobile Video (MoVid), 2013

- Technical Program Committee Member, IEEE International Conference on Multimedia & Expo (ICME 2013), 2013

- Technical Program Committee Member, ACM Multimedia Systems (MMSys), 2013

- Technical Program Committee Member, ACM Workshop on Mobile Video (MoVid), 2013

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- Technical Program Committee Member, International Conference on Advances in Computing, Communications and Informatics (ICACCI-2013), 2013

- Technical Program Committee Member, The Eighth International Conference on Digital Telecommunications (ICDT 2013), 2013

- Technical Program Committee Member, IEEE International Conference on Multimedia & Expo (ICME 2012), 2012

- Technical Program Committee Member, ACM Multimedia Systems (MMSys), 2012

- Technical Program Committee Member, ACM Workshop on Mobile Video (MoVid'12), 2012

- Technical Program Committee Member, The Seventh International Conference on Digital Telecommunications (ICDT 2012), 2012

- Technical Program Committee Member, ACM Multimedia, 2011

- Technical Program Committee Member, International Workshop on Network and Operating Systems Support for Digital Audio and Video (NOSSDAV 2011), 2011

- Technical Program Committee Member, IEEE International Conference on Multimedia & Expo (ICME 2011), 2011

- Technical Program Committee Member, International Workshop on Pervasive Computing and Multimedia Systems (IEEE-PCMS 2011), 2011

- Technical Program Committee Member, Sixth International Conference on Digital Telecommunications (ICDT 2011), 2011

- Technical Program Committee Member, IEEE Wireless Communications and Networking Conference (IEEE WCNC 2011), 2011

- Technical Program Committee Member, International Workshop on Semantic Computing and Multimedia Systems (IEEE-SCMS), 2010

- Technical Program Committee Member, ACM Multimedia Systems (MMSys), 2011

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- Technical Program Committee Member, International Workshop on Network and Operating Systems Support for Digital Audio and Video (NOSSDAV 2010), 2010
- Technical Program Committee Member, ACM Multimedia Systems (MMSys), 2010
- Technical Program Committee Member, ACM Multimedia, 2009
- Technical Program Committee Member, AfricaIMSA2010, 2010
- Technical Program Committee Member, IEEE Wireless Communications and Networking Conference (IEEE WCNC 2010), 2010
- Technical Program Committee Member, Multimedia Computing and Networking (MMCN), 2009
- Technical Program Committee Member, International Workshop on Semantic Computing and Multimedia Systems (SCMS), 2009
- Technical Program Committee Member, ACM Multimedia, 2008
- Panelist, "Content Distribution (P2P versus Infrastructure) and the Mobil Age", SPIE/ACM Multimedia Computing and Networking (MMCN), 2008
- Technical Program Committee Member, World Wide Web Conference (WWW), 2006
- Technical Program Committee Member, World Wide Web Conference (WWW), 2005
- Technical Program Committee Member, International Conference on Internet and Multimedia Systems and Applications (IMSA), 2009
- Technical Program Committee Member, International Conference on Optical and Wireless Communications (WOC), 2009
- Technical Program Committee Member, International Conference on Distributed and Intelligent Multimedia Systems (DIMS), 2008
- Technical Program Committee Member, International Conference on Optical and Wireless Communications (WOC), 2008
- Technical Program Committee Member, International Conference on Internet and Multimedia Systems and Applications (IMSA), 2008

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- Technical Program Committee Member, International Conference on Optical and Wireless Communications (WOC), 2007

- Technical Program Committee Member, International Conference on Internet and Multimedia Systems and Applications (IMSA), 2007

- Technical Program Committee Member, International Workshop on Systems and Network Security (SANS), 2005

- Reviewer, IEEE Wireless Communications and Networking Conference (WCNC), 2007

- Reviewer, IEEE International Symposium on Modeling, Analysis, and Simulation of Computer and Telecommunication Systems (MASCOTS), 2006

- Reviewer, IEEE Wireless Communications and Networking Conference (WCNC), 2005

- Reviewer, International Parallel and Distributed Processing Symposium (IPDPS), 2003

- Reviewer, International Conference on Parallel Processing (ICPP), 2001

Service to External Universities

- External Tenure and Promotion Evaluator, Oakland University, 2020

- External Evaluator, Ph.D. Dissertation, Simon Fraser University, Canada, Student Name: Mohammed Shatnawi, "Improving the Reliability of Online Multimedia Communication Services. Date of Defense: November 15, 2018

- External Reviewer, Faculty Reappointment, Oakland University, 2017

- External Reviewer, Tenure and Promotion Faculty Application, University of Michigan-Dearborn, 2013

- External Ph.D. Dissertation Committee Member, Computer Science, University of Ottawa, Student Name: Atif Alamri, Date of defense: June 30, 2010

Service to Publishers

- Book Reviewer, Thomson Learning, High Holborn House, London, Book Title: “Foundations of Multimedia, by Michael Macaulay”, 2007.

- Book Proposal Reviewer, Elsevier, 2015

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Service on University Committees

- Member, **WSU Academy of Teachers**, since Fall 2022.
- Member, President's Award for Excellence in Teaching Selection Committee, Winter 2012
- Member, University Educational Development Grant, Winter 2014
- Member, University Academic Senate, Fall 2008 – Winter 2010.
- Member, University Facilities, Support Services, and Technology Committee, Fall 2008 – Winter 2010.
- Member, College of Engineering Director of Business Search Committee, Fall 2009 – Winter 2010.
- Member, University Graduate Professional Fellowship Review Panel, 2008

College/Department Committee Chaired

- **Overall Coordinator**, Interdisciplinary M.S. in AI Program, College of Engineering, Wayne State University, Detroit, August 2022 – Now.
- **Director**, Interdisciplinary M.S. in AI Program (Systems and Hardware Track), College of Engineering, Wayne State University, Detroit, August 2022 – Now
- **Team Leader of college efforts to develop the interdisciplinary M.S. in AI Program**, 2021 – current
- **Chair**, Computer Engineering Area Committee, 2017 – current.
- **Coordinator,** Computer Engineering Graduate Programs, 2021 – current
- Coordinator, Prelim Exam Committee on Computer Organization, since 2003
- Coordinator, Prelim Exam Committee on Data Structures and Algorithms, since 2015
- **Chair,** Faculty Search Committee, 2017/2018
- **Chair**, College Faculty Assembly, Fall 2010 – Winter 2012

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- **Director of the Graduate Program** and the **Chair of Graduate Committee**, Electrical and Computer Engineering Department, August 2011 - January 2013.

- **Chair**, College Bylaws Subcommittee, Fall 2011 - Winter 2012.

- **Chair**, Graduate Committee, August 2011 – January 2013

- **Chair**, Computer Engineering Taskforce, 2014- 2016

College Committee Membership

- Member College Academic Operations Committee, 2022/2023, 2021/2022, 2020/2021, 2019/2020

- Member, College Ranking/Reputation Committee, 2020/2021

- Member, ECE-CS Curriculum Collaboration Committee, 2015/2016 – 2017/2018.

- Member, ECE-CS Curriculum Collaboration Committee, 2015/2016 – Current

- Member, College Graduate Program Committee, 2012 - 2014.

- Member, College Faculty Assembly Executive Committee, Fall 2008 – Winter 2010

- Member, Director of Business Affairs Search Committee, Fall 2009 – Winter 2010

- Member, College of Engineering Distance Learning Task Force, Winter 2010

- Member, College of Engineering Strategic Planning, Winter 2010.

- Member, College Computer Advisory Committee, 2003-2004, 2005-2006, 2006-2007, 2007-2008

- Member, College Retention Committee, 2006-2007

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Department Committee Membership

- Member, Salary Committee, 2022/2023, 2020/2021
- Member, Faculty Search Committee, 2019/2020, 2016/2017
- Member, Graduate Curriculum Committee, almost regularly since 2003
- Member, Salary Committee, 2020/2021
- Member, ECE Budget Advisory Committee, 2015/2016
- Member, Undergraduate Curriculum Committee, 2022/2023, 2004- 2016.
- Member, ECE Future Directions Taskforce, 2014/2015, 2014/2016
- ECE Seminar Coordinator, 2014/2015
- IEEE Faculty Counselor, 2006 – 2014
- Member, Tenure, Promotion, Budget, and Salary Committee, 2006-2007
- Member, Faculty Search Committee, 2004-2005, 2005-2006

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Appendix B

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(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2003/0151663 A1

Lorenzetti et al. (43) Pub. Date: Aug. 14, 2003

(54) VIDEO STORAGE AND DELAY DEVICE FOR USE WITH AN IN-CAR VIDEO SYSTEM

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(21) Appl. No.: **10/055,629**

(22) Filed: **Jan. 23, 2002**

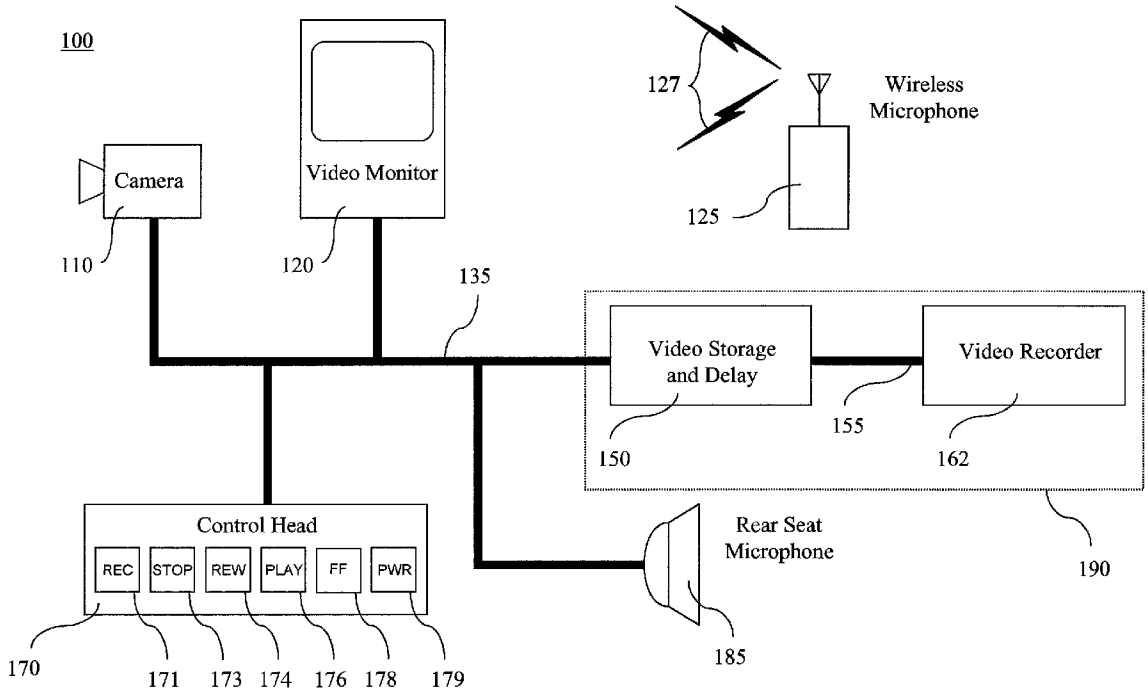
Publication Classification

(51) **Int. Cl.**[7] **H04N 7/18**; H04N 9/47

(52) **U.S. Cl.** **348/148**; 340/937

(57) **ABSTRACT**

An in-car video apparatus and method is provided where a real time continuous video supplied by a vehicle-mounted camera and an audio microphone is processed for storage in a memory in a time-sequential manner for a pre-set time interval to create a time-delayed video stream. Upon activation of the in-car video system by a law enforcement officer (which occurs at an arbitrary reference time), a vehicle-mounted recording device records the time-delayed video stream to create a video recording of the events captured by the video camera. Because the time-delayed video stream is recorded rather than the real time video stream, the start time of the video recording precedes the reference time by the pre-set time interval. The invention provides an ability to create a complete record of a police-citizen encounter, including the initial incident that prompted the officer's subsequent activation of the in-car video system.



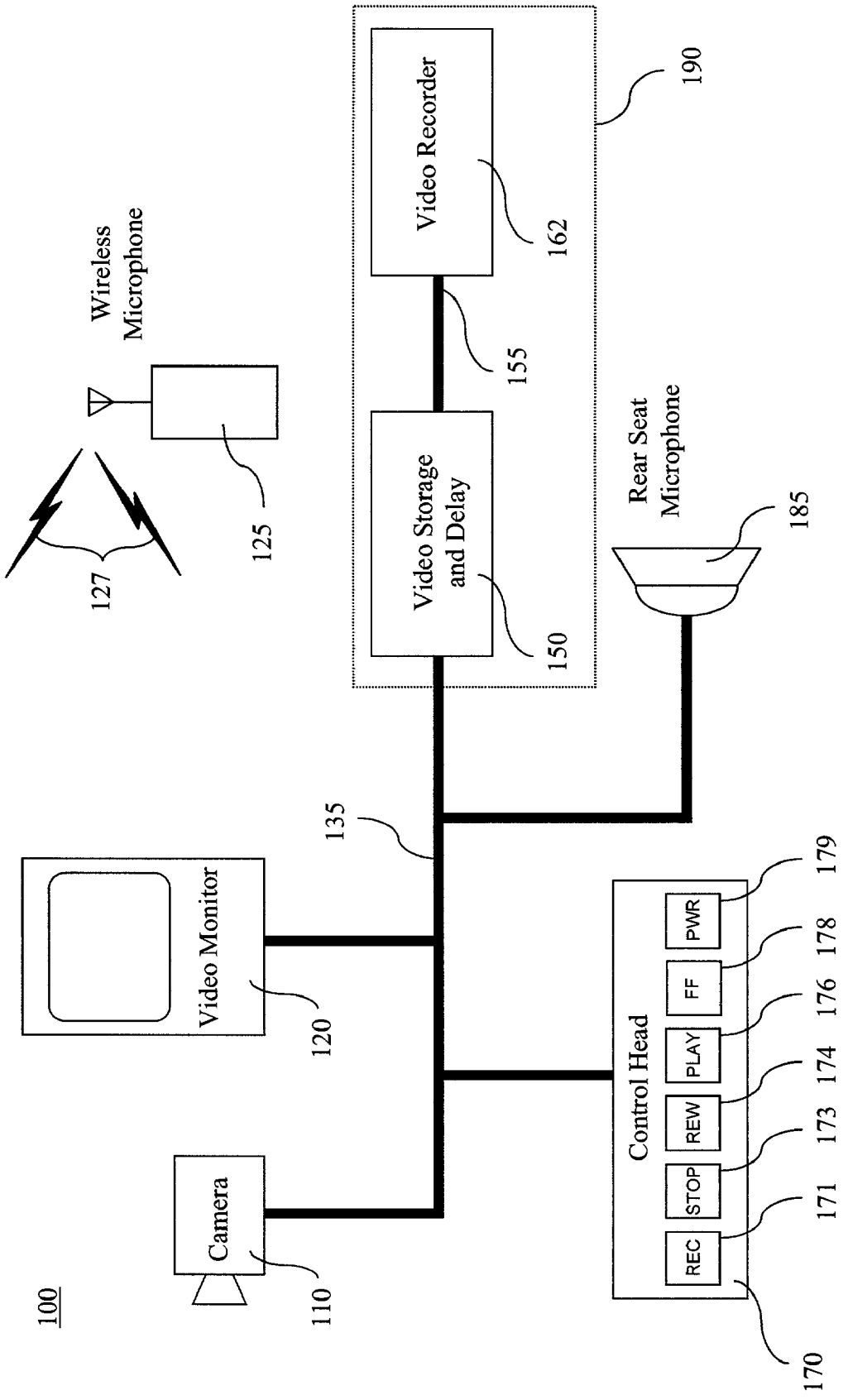

100
Camera
110
Video Monitor
120
135
Video Storage and Delay
150
Video Recorder
162
155
190
Wireless Microphone
125
127
Rear Seat Microphone
185
Control Head
REC
STOP
REW
PLAY
FF
PWR
171
173
174
176
178
179
170

FIG 1

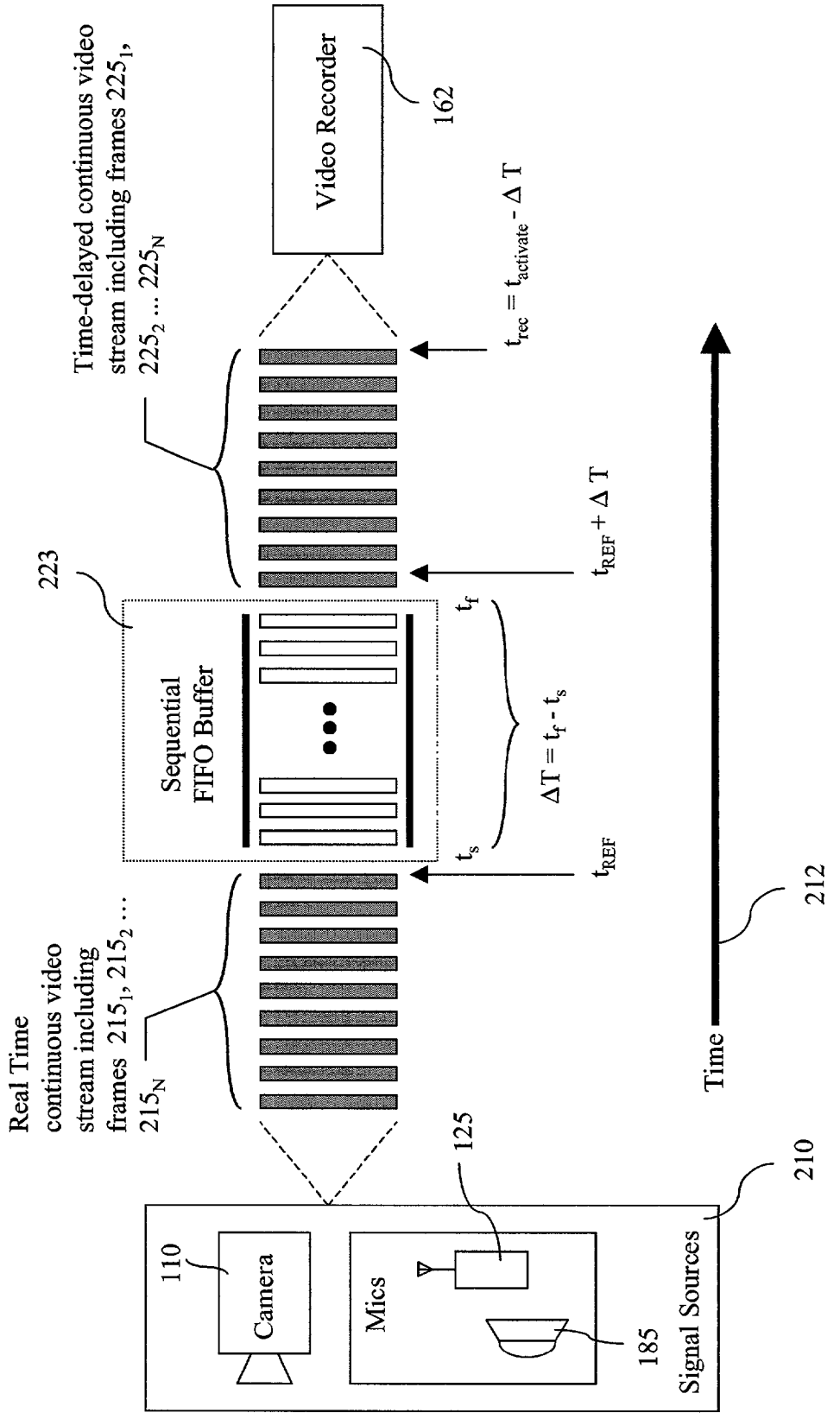

Real Time
continuous video
stream including
frames 215_1, 215_2 ...
215_N
Time-delayed continuous video
stream including frames 225_1,
225_2 ... 225_N
223
Sequential
FIFO Buffer
Video Recorder
162
110
Camera
Mics
125
185
Signal Sources
210
212
Time
t_{REF}
t_s
t_f
$\Delta T = t_f - t_s$
$t_{REF} + \Delta T$
$t_{rec} = t_{activate} - \Delta T$

FIG 2

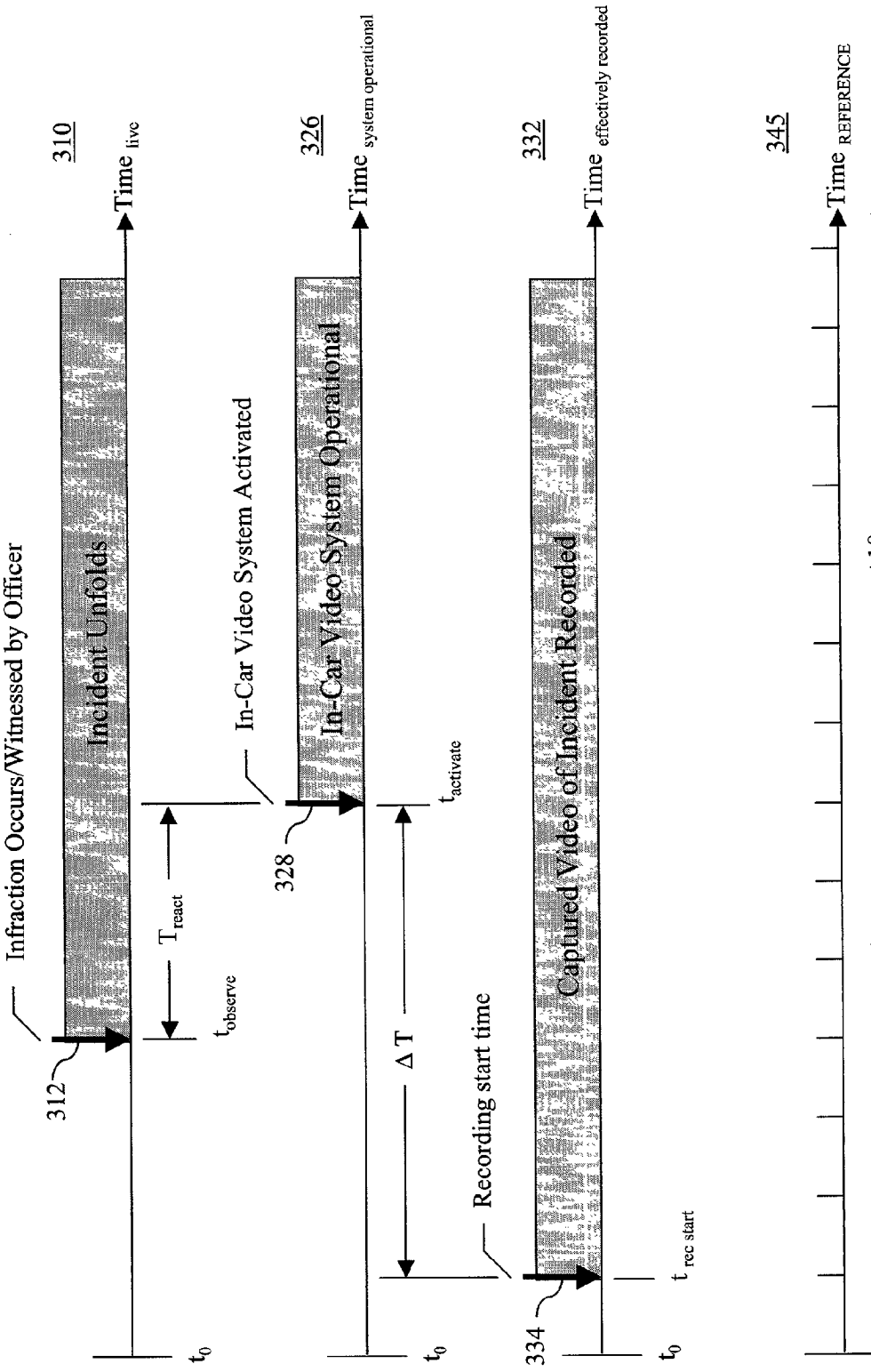

310
Time live
Infraction Occurs/Witnessed by Officer
312
Incident Unfolds
T react
t observe
t0
In-Car Video System Activated
326
Time system operational
328
In-Car Video System Operational
t activate
Δ T
Recording start time
t0
332
Time effectively recorded
Captured Video of Incident Recorded
334
t rec start
t0
345
Time REFERENCE
+5
+10
seconds
t0

FIG 3

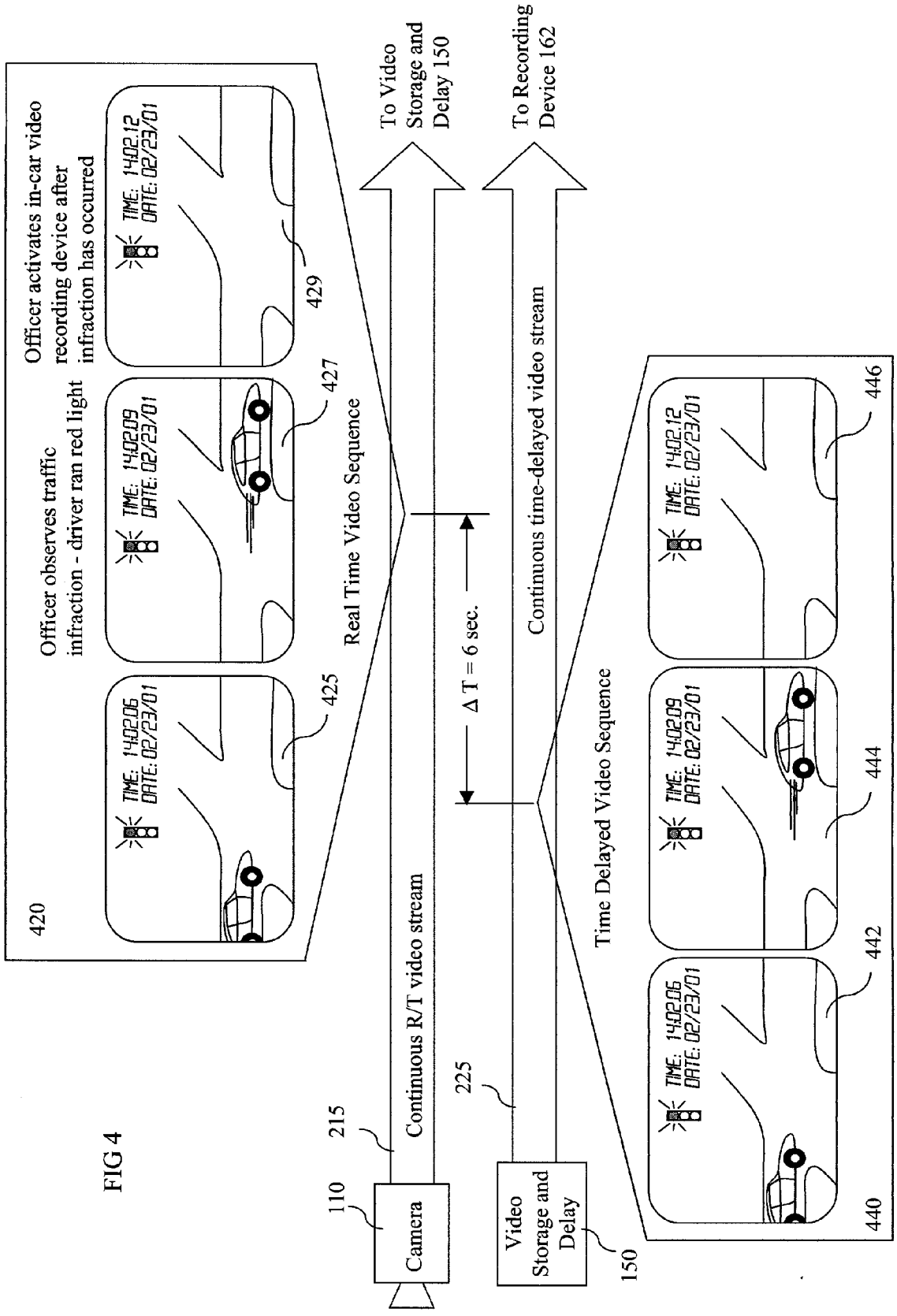

420
Officer observes traffic infraction - driver ran red light
Officer activates in-car video recording device after infraction has occurred
TIME: 14:02:06 DATE: 02/23/01
TIME: 14:02:09 DATE: 02/23/01
TIME: 14:02:12 DATE: 02/23/01
425
427
429
Real Time Video Sequence
To Video Storage and Delay 150
To Recording Device 162
Δ T = 6 sec.
Continuous time-delayed video stream
Continuous R/T video stream
215
225
110
Camera
Video Storage and Delay
150
Time Delayed Video Sequence
440
442
444
446

FIG 4

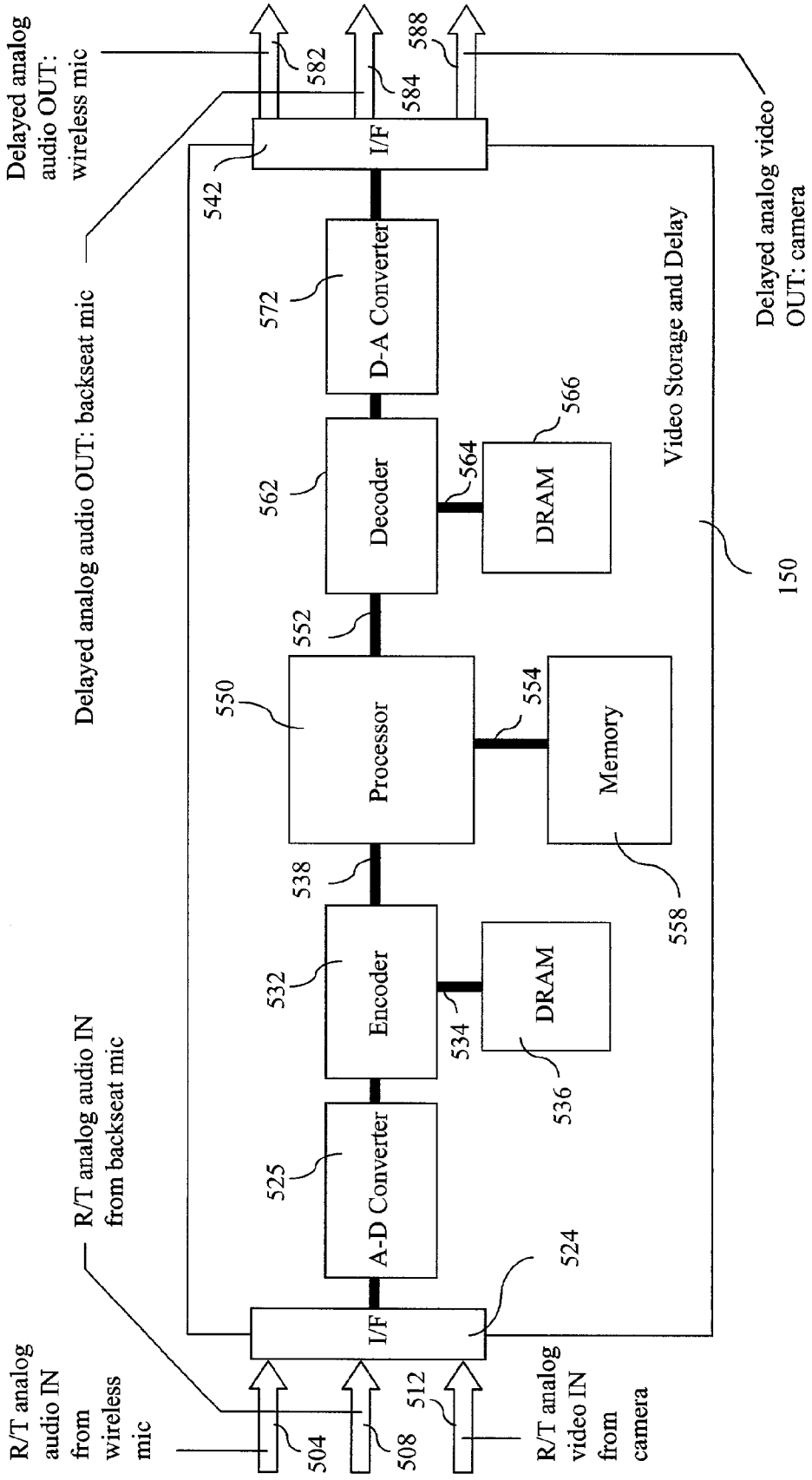

R/T analog audio IN from wireless mic
R/T analog audio IN from backseat mic
R/T analog video IN from camera
Delayed analog audio OUT: wireless mic
Delayed analog audio OUT: backseat mic
Delayed analog video OUT: camera
I/F
A-D Converter
Encoder
DRAM
Processor
Memory
Decoder
DRAM
D-A Converter
I/F
Video Storage and Delay
150
504
508
512
524
525
532
534
536
538
542
550
552
554
558
562
564
566
572
582
584
588

FIG 5

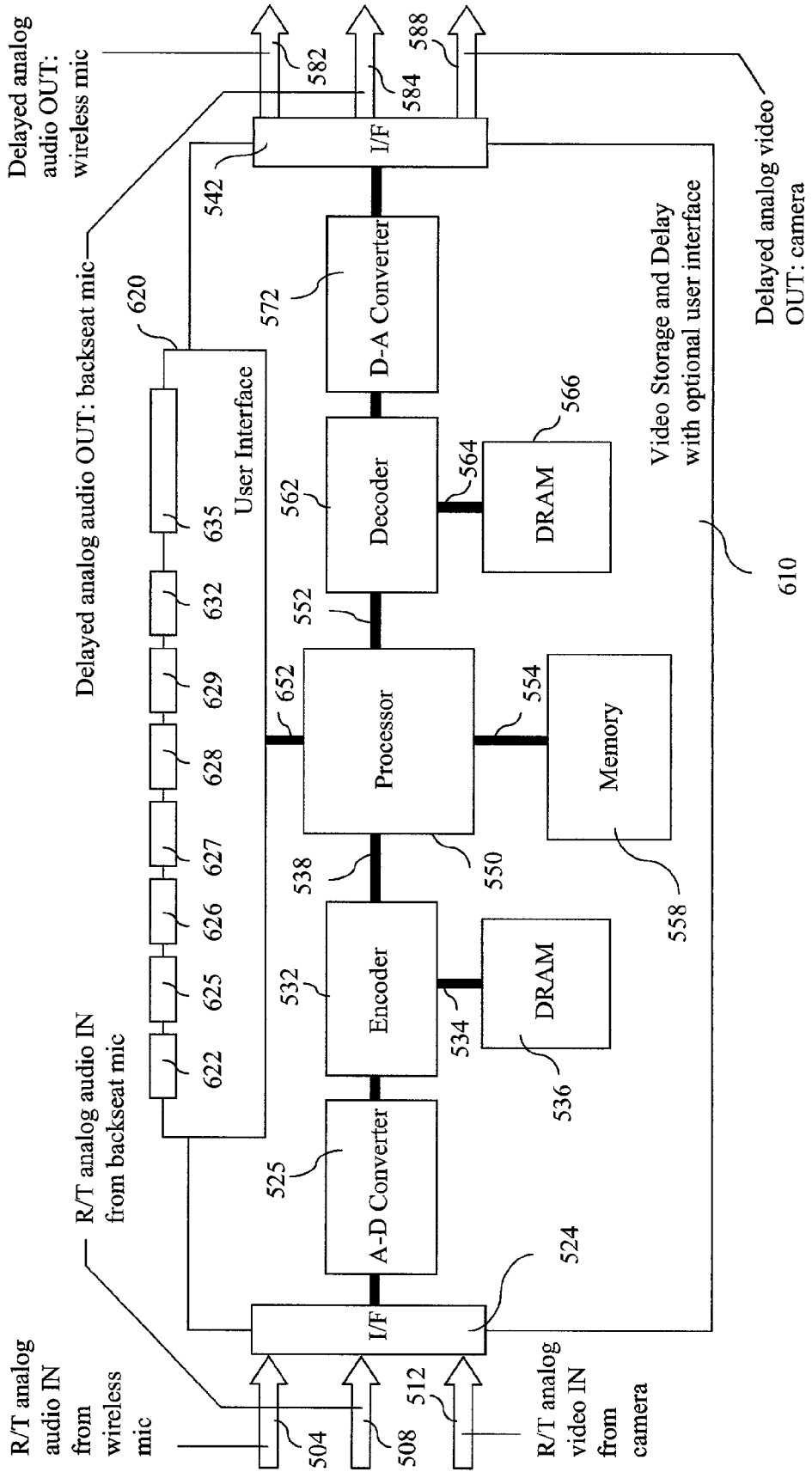

Delayed analog audio OUT: wireless mic
582
584
588
I/F
542
Delayed analog audio OUT: backseat mic
620
572
D-A Converter
User Interface
562
Decoder
564
DRAM
566
Video Storage and Delay with optional user interface
Delayed analog video OUT: camera
635
632
629
628
627
626
625
622
652
552
Processor
554
Memory
610
538
550
558
R/T analog audio IN from backseat mic
532
Encoder
534
DRAM
536
525
A-D Converter
524
I/F
R/T analog audio IN from wireless mic
504
508
512
R/T analog video IN from camera

FIG 6

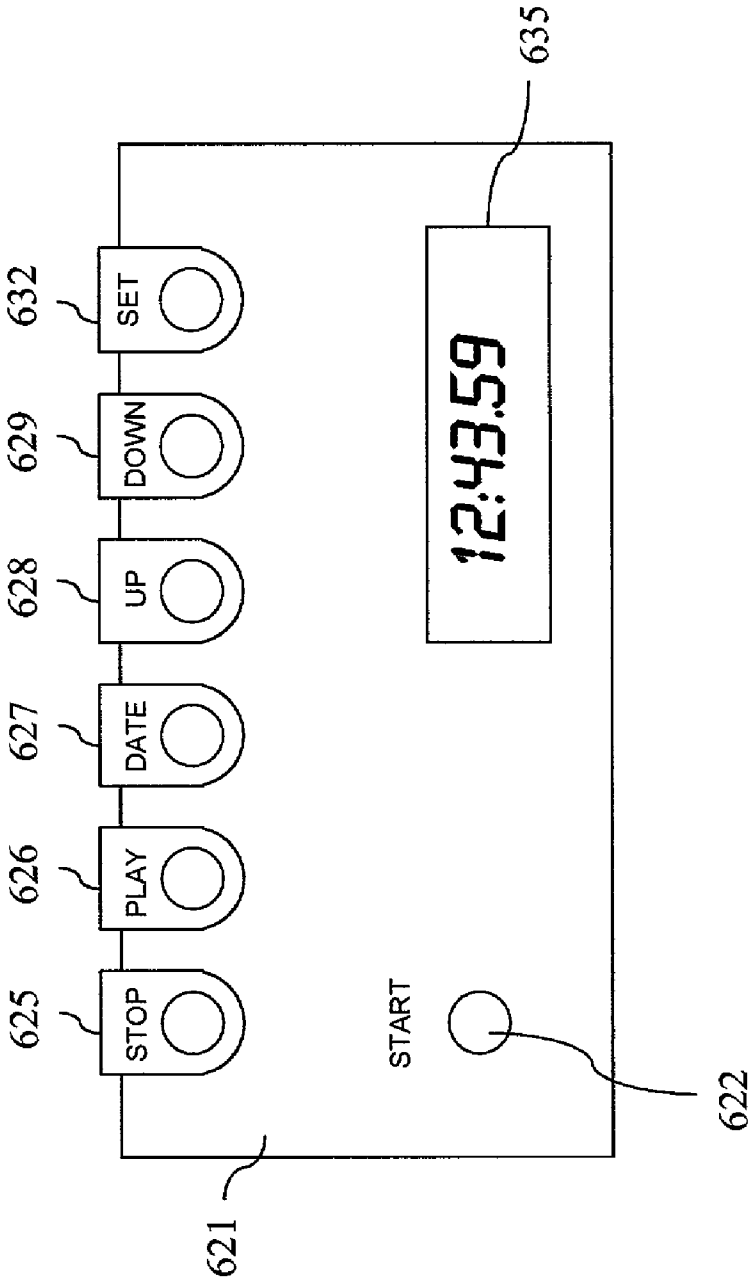

635
632
SET
629
DOWN
628
UP
627
DATE
626
PLAY
625
STOP
12:43:59
START
622
621

FIG 7

VIDEO STORAGE AND DELAY DEVICE FOR USE WITH AN IN-CAR VIDEO SYSTEM

BACKGROUND OF THE INVENTION

[0001] This invention is related generally to surveillance systems, and more particularly to a video storage and delay device for use with an in-car video system.

[0002] Vehicle-mounted surveillance systems, including in-car video systems, are seeing increased use in the security industry and law enforcement community as an effective means to provide an indisputable video and audio record of encounters involving officers and citizens. In these systems, a video camera is typically mounted on the police car's dashboard or windshield and is generally arranged to have a field of view of the area to the immediate front of the car. The field of view approximately corresponds to what an officer would see when seated in the car's front seat.

[0003] The video camera is operably coupled to a recording device, such as a video cassette recorder ("VCR"), mounted in the police car, often in the trunk. Generally, video recordings are not made continuously during routine police patrol. Instead, to reduce videotape costs and avoid excessive wear and tear on the recording equipment (particularly, the recording heads), recordings are made only during incidents of interest, such as traffic stops and pursuits, for which an evidentiary record is desired. A videotape recording may be started manually by the officer, or in some systems, the videotaping is started automatically when, for example, the officer activates the police car's emergency systems (such as overhead lights and/or sirens), or when a vehicle speed-measuring radar unit is operated.

[0004] In-car video systems generally employ a wireless microphone carried on the person of a law enforcement officer to record an audio soundtrack that accompanies the visual scene captured on videotape. The audio soundtrack is an extremely valuable complement to the recorded video because it acts as a transcript of what was said, by whom and when. In some systems, additional wired microphones may be deployed in other locations within the car, such as the rear seat passenger area, to record sounds and conversations emanating from those locations.

[0005] In-car video systems serve to enhance prosecution of traffic, DWI/DUI and controlled dangerous substances offenses (to name just a few) by contributing detailed graphical and auditory evidence in a time-sequential manner that is inherently unbiased and objective. Such evidence is a valuable adjunct to eyewitness and officer testimony. Videotaped evidence is also increasingly used to substantiate the legal basis, referred to as "probable cause," for a stop, arrest, search, or the issuance of a citation (i.e., ticket).

[0006] In addition, as with other quality-improvement initiatives where conduct is surveyed and recorded, in-car video system usage has been shown to assist in the maintenance of high professional standards among law enforcement personnel. Police-community relations have improved and citizen complaints of police misconduct have lessened in many jurisdictions where in-car video systems are used, often as a result of the inherently high-quality evidence provided by such systems. Videos taken with in-car video systems are also valuable training aids to law enforcement personnel.

[0007] Videotape evidence is protected (and the evidentiary chain of custody readily established) because the video cassette recorder and video recording medium (i.e., videotape) are typically "locked", often both mechanically and electronically, within a tamperproof security enclosure in the car that is only accessible by law enforcement command personnel. In addition, the in-car systems are configured to prevent erasure or over-recording of a recorded encounter to ensure the integrity of the videotaped evidence. In-car video systems may superimpose time and date stamps on the recorded video image as a further enhancement to the evidentiary strength of the videotape.

[0008] Current in-car video systems perform very well in many applications. However, the fact that most systems are not videotaping continuously means that some evidence may miss being recorded before the officer has the chance to activate the video recorder. For example, a car driving through a stop light or weaving erratically through traffic may prompt the officer to hit the "record" button to manually begin a video recording, or activate the emergency lights to automatically start the recording in anticipation of effecting a car stop. Unfortunately, by the time the video recording starts, the initial incident (i.e., the disregarded traffic control device or erratic driving) that prompted the officer's attention has already occurred and can not be recorded. If the driver does not engage in additional unlawful behavior, then current in-car video systems will only capture a record of the vehicle pulling over and the officer's subsequent interaction with the suspect. However, the probable cause to support the car stop, and any subsequent traffic ticket, search or arrest may not necessarily be part of the videotaped record.

SUMMARY OF THE INVENTION

[0009] An in-car video apparatus and method is provided where a real time (i.e., "live") continuous video stream supplied by a vehicle-mounted camera is processed for storage in a memory in a time-sequential manner for a pre-set time interval to create a time-delayed video stream. Upon activation by a law enforcement officer (which occurs at an arbitrary reference time), a vehicle-mounted recording device records the time-delayed video stream to create a video recording of the events captured by the video camera. Because the time-delayed video stream is recorded rather than the real time video stream, the start time of the video recording precedes the reference time by the pre-set time interval. The invention thus provides an ability to record an event after it has already occurred.

[0010] In an exemplary embodiment of the invention, an in-car video camera sends a continuous analog real time video stream to a video delay and storage device. An audio microphone captures an analog audio soundtrack that accompanies the video images. The audio and video streams are received through an input interface at the video delay and storage device. An analog-to-digital converter digitizes the analog video and audio streams into a digital data stream that is then compressed by a digital encoder. A central processor in the video delay and storage device sequentially processes the compressed digital data stream for storage in a coupled memory. The compressed digital data is temporarily held in the memory for a pre-set time interval and is then sequentially output to a digital decoder that decompresses the digital data. A digital-to-analog converter converts the digital data into analog form. Analog video and audio streams

that are time-delayed by the pre-set interval (compared with the real time video and audio streams) are output through an output interface of the video delay and storage device. The central processor controls the overall signal flow and processing throughout the video delay and storage device. Upon activation, a vehicle-mounted recording device, such as a VCR, records the time-delayed video stream from the video delay and storage device.

[0011] In other embodiments of the invention, a discrete (i.e., self-contained and requiring only external power and signal connections) video storage and delay device is provided with a pre-set time interval (i.e., the amount of time-delay) that is user-definable. In addition, either analog or digital signals may be accepted at a standard input interface of the video storage and delay device, and both digital and analog time-delayed output streams are provided. Two audio tracks—one for a wireless microphone and the other for a rear seat microphone—are also processed and output via a standard interface by an embodiment of the digital storage and delay device.

[0012] The invention provides many advantages. By buffering the real time video and audio streams to create the time-delayed video and audio stream, the officer has a period of time equal to the pre-set time interval to react to a witnessed event, such as a traffic infraction, and activate the video recorder. For example, if the time-delay is six seconds, then the officer is provided with up to six seconds in which to activate the video recorder and still be able to record the witnessed event on videotape. Accordingly, the invention provides a complete record of a police-citizen encounter, including the initial incident, event or behavior that captured the officer's attention in the first place. The odds that evidence supporting probable cause is contained in the videotaped record are thus greatly enhanced.

[0013] When the principles of the invention are embodied in the self-contained video storage and delay device, further advantages are realized. Once connected to the real time video and audio sources and external power, the video storage and delay device operates transparently without requiring any extra user intervention or attention. By using standard I/O interfaces, the inventive arrangement may be simply serially connected between the signal sources (i.e., video camera and microphone) and the video recorder using standard signal connections. Advantageously then, the video storage and delay device may be retrofitted to existing in-car video systems to thereby realize the benefits in the ability provided by the invention to record an event after it has occurred.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] **FIG. 1** is a simplified functional block diagram of an illustrative arrangement of the present invention and depicts an in-car video surveillance system including a windshield mounted camera and trunk-mounted video recorder, a wireless microphone, a rear seat microphone, a control head, a video monitor, and a video storage and delay device;

[0015] **FIG. 2** depicts the sequential storage of a real time video stream used to create a time-delayed video stream, in accordance with the invention;

[0016] **FIG. 3** depicts a group of timelines showing that the present invention provides an ability to create a permanent record of an event that begins prior to the activation of the in-car video recorder;

[0017] **FIG. 4** shows a real time video stream, a time-delayed video stream and an exemplary video sequence, in accordance with the invention;

[0018] **FIG. 5** is a simplified block diagram of a video storage and delay device, in accordance with the invention;

[0019] **FIG. 6** is a simplified block diagram of a video storage and delay device having an optional user interface, in accordance with the invention; and

[0020] **FIG. 7** is a pictorial representation of a user interface having user-accessible controls and a visual display.

DETAILED DESCRIPTION

[0021] Referring now to **FIG. 1**, there is shown a simplified functional block diagram of an illustrative arrangement of the present invention. Shown is in-car video system **100** that includes a camera **110** that is typically mounted to look out through the windshield and/or rear window of the car. The in-car video system **100** further includes a rear seat microphone **185**, video monitor **120**, control head **170**, and a video storage and delay device **150**. Each of these components is coupled via a wiring bus **135**, as shown in **FIG. 1**, that provides signal and power connections in a conventional manner.

[0022] A video recorder **162**, for example a VCR, is coupled to the video storage and delay device **150** by wiring bus **155**. Thus, in accordance with the invention, video storage and delay device **150** may be arranged to be connected serially between the signal sources (i.e., camera **110** and microphones **125** and **185**) and video recorder **162**, as shown in **FIG. 1**. Video storage and delay device **150** is typically embodied in a small enclosure that may be located in a convenient area of the vehicle including the passenger compartment (such as in glove box, under the dashboard or front seat, or in the electronic and emergency equipment console that is typically located in the center area of the vehicle by the front seats) or in the trunk.

[0023] In an alternative arrangement of the invention, the features and functions of video storage and delay device **150** may be directly incorporated (i.e., "built-in") to other components of the in-car video system **100**. For example, a video recorder and the video storage and delay device of the present invention may be combined into a single unit. Thus, in accordance with the invention, video storage and delay device **150** may be a discrete, self-contained device, or be integrated as a functional module at the front end (i.e., located at the input) of a video recorder. The integrated arrangement is represented by reference numeral **190** in **FIG. 1** where both a video recording mechanism and a video storage and delay device of the present invention are combined within a common enclosure represented by the dashed rectangle.

[0024] The video recorder **162** is typically located in secure enclosure that may be contained in the trunk of the car. In addition, depending upon the requirements of the specific application, the video recorder **162** may also be

located within the passenger compartment of the vehicle. For example, video recorder **162** may be mounted in an overhead console, under the front seat, in or under the dashboard, in the glove box, or in the electronic and emergency equipment console. Some of these mounting locations may be facilitated by the use of a video recorder that uses small form-factor videotape such as 8 mm videotape.

[**0025**] The enclosure containing the video recorder **162** is generally quite rugged, both to provide deterrents against tampering or improper access to the videotape, and also to protect the tape in the event that the vehicle is involved in a crash. The enclosure may also be environmentally controlled to keep the video recorder **162** and videotape within acceptable operating conditions. It is noted that video recorder **162** is merely representative of any of a number of recording devices that are arranged to record video and audio, either as a single device or a combination of devices. Such recording devices include those that record on tape as well as those that use other media, such magnetic media (including disk-drives and cartridge drives), electronic media (including volatile and non-volatile memory), and optical media (including optically writeable disks). Video recorder may thus be configured, for example, as a digital video recorder or a conventional analog VCR.

[**0026**] The control head **170** is located in the vehicle near the driver and is operably coupled to video recorder **162** via bus **135** and bus **155** to allow the video recorder **162** to be conveniently controlled by the officer from within the vehicle. Control head **170**, in this illustrative embodiment, is arranged with typical controls such as "RECORD", "STOP", "REWIND", "PLAY", "FORWARD" and "POWER" buttons which operate the video recorder **162** accordingly. These controls are indicated by reference numerals **171**, **173**, **174**, **176**, **178** and **179**, respectively, in **FIG. 1**.

[**0027**] Camera **110** may be selected from the wide variety of available cameras. Preferably, camera **110** is a compact camera (to reduce the likelihood of obstructing the officer's view out the windshield) with color capabilities such as a solid-state CCD ("charge-coupled device") camera that can operate in low-light environments. Camera **110** may be optionally configured with digital and/or optical zoom capabilities. Camera **110**, in the illustrative arrangement shown in **FIG. 1**, is an analog video camera with low-light color capabilities. In most applications, camera **110** is vehicle-mounted, however other camera arrangements may also be used (alone or in combination with a vehicle-mounted camera) including portable, hand held, remote, and officer-worn cameras that operate in an extra-vehicular manner.

[**0028**] A wireless microphone **125** is depicted in **FIG. 1**. Wireless microphone **125** is typically carried on the person of the officer, and thus, may be located both inside and outside of the vehicle at any given time. Wireless microphone **125** may be a conventional uni-directional (i.e., transmit-only) microphone or, as disclosed in our co-pending U.S. patent application Ser. No. 09/911,086, filed Jul. 23, 2001, be equipped with bi-directional RF communications capabilities. Wireless microphone **125** communicates with in-car video system **100** via a wireless link that is identified by reference numeral **127** in **FIG. 1**.

[**0029**] Video monitor **120** may be selected from the available pool of small and lightweight monitors, but typically comprises a color liquid crystal flat panel display ("LCD") having an active or passive matrix display. Video monitor **120** may be mounted in the car to allow the operator to monitor either the real time video feed from the camera, or to view a previously recorded tape.

[**0030**] The in-car video system **100** is typically mounted in a vehicle (not shown in **FIG. 1**) such as a police cruiser. However, it is emphasized that the features and benefits of the present invention may be equally applicable to a wide variety of vehicle types, and further that the invention is not limited to law enforcement applications. Applications of the invention to the security and the transportation industries may be readily made, for example. Therefore, the term "officer" in the description that follows should be understood to refer to the user or operator of the inventive in-car video system in non-law enforcement applications.

[**0031**] Turning now to **FIG. 2**, there is shown a simplified diagram of the sequential storage of the real time video stream that is used to create a time-delayed video stream, in accordance with the invention. Signal sources **210**, comprising camera **110** and microphones **125** and **185** provide a real time video stream **215**. Thus, video stream **215** includes three signal components—one video component and two audio components (one corresponding to each microphone **125** and **185**). In this illustrative embodiment, the real time video stream **215** is in a conventional analog format.

[**0032**] It is noted that the term "video" as used in this detailed description means a sequence of images that is used to display full motion on equipment such as television and video monitors, along with an associated soundtrack having one or more channels. However, it is emphasized that the principles of the invention apply equally well to video or audio alone. Therefore, while the term "video" is used in this detailed description as a convenient way to describe a combined signal having a video component and one or more audio components, a combined signal is not required by the invention, nor should the use of a combined signal in this illustrative embodiment be construed as a limitation on the invention.

[**0033**] The term "video stream" refers to video that is continuous over some time period. The term "real time video" refers to video that corresponds to a live event (i.e., the video images of the event are created as the event occurs in actual time) but without taking into account latency and other time delays that are inherent in electronic devices.

[**0034**] Referring back to **FIG. 2**, real time video stream **215** includes video frames **1** to N that represent a NTSC (National Television Standards Committee) analog video signal having a rate of 30 frames per second, each having two interlaced fields. It is noted that the use of NTSC-defined video is merely illustrative and other formats or frame rates (e.g., PAL and SECAM) may be advantageously used in some applications of the invention. A sequential buffer **223**, the function of which is incorporated in video storage and delay device **150** (**FIG. 1**), utilizes a First In First Out ("FIFO") methodology to hold each frame of video for a time period ΔT:

$$\Delta T = t_f - t_s \quad (1)$$

[**0035**] where t_f is defined as the time a video frame **215** is read from the buffer **223** and t_s is the time the video frame **215** is written to the buffer. For example, as shown in **FIG.**

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2, if frame **215**$_1$ is written to the buffer **223** at some arbitrary reference time $t=t_{REF}$, then it is read out from the buffer **223** at time $t=t_{REF}+\Delta T$. In many applications, a time-delay ΔT of between 5 and 10 seconds is a sufficient period of time for an officer to react to a witnessed event and activate the video recorder. Thus, for a five second delay, approximately 150 frames of video are buffered at any given point in time based on the standard NTSC-defined video signal used in this illustrative example.

[**0036**] As time progresses, each real time video frame **215** is written to the buffer **223** in time-sequential fashion. That is, each frame follows it predecessor in the real time-time video stream **215** into the buffer **223**. As indicated by reference numeral **212** in **FIG. 2**, the video frames translate from left to right as time progresses. After being held for the time-delay period ΔT, each frame is read from the buffer **225** in a time-sequential fashion to generate a time-delayed video stream **225** that, except for the time offset ΔT from actual time, corresponds to the real time video stream **215** in sequence and content.

[**0037**] In accordance with the invention, the time-delayed video stream **225** may be selectively recorded by video recorder **162**, as shown in **FIG. 2**. When the video recorder **162** is activated at time $t=t_{activate}$, the effective start time of the video recording, $t_{rec\ start}$, is offset by the time-delay period ΔT:

$$t_{rec\ start}=t_{activate}-\Delta T \quad (2)$$

[**0038**] **FIG. 3** depicts a group of exemplary timelines showing that the present invention provides an ability to create a permanent record of an event that begins prior to the activation of the in-car video recorder. **FIG. 3** includes a live timeline **310**, an in-car video system operation timeline **326**, and a timeline **332** representing the effective time of recording made by video recorder **162**. At the bottom of **FIG. 3, a** reference timeline **345** is shown. Each timeline is given an arbitrary initial time $t=t_0$.

[**0039**] Referring to timeline **310**, a traffic infraction occurs that is observed by an officer on patrol in vehicle equipped with the inventive in-car video system **100**. As depicted on timeline **310** at reference numeral **312** (and referring to the reference timeline **345**) the infraction occurs at time $t_{observe}=t_0+4$ seconds. As the incident continues to unfold, after witnessing infraction and determining that a traffic stop is called for, the officer reacts and activates the emergency lights and video recorder **162** of the in-car video system so that the incident is recorded on videotape. As shown at reference numeral **328** on timeline **326** (and referring to reference timeline **345**) the officer takes three seconds to make the decision to effectuate a traffic stop and activate the video recorder **162**, thus $t_{activate}=t_0+7$ seconds. From the time $t=t_{activate}$ onward, the in-car video system **100** is operational, as shown by timeline **326** in **FIG. 3**.

[**0040**] Referring now to timeline **332** which is the effective recording time, reference numeral **334** indicates that $t_{rec\ start}=t_0+1$ second, based on a time-delay period ΔT of six seconds in this illustrative example. From the time $t=t_{rec\ start}$ onward, the video recorder **162** is making a permanent videotaped record of the incident where start time of the recording, $t_{rec\ start}$, precedes the time that the infraction is observed by the officer, $t_{observe}$, by three seconds, in this illustrative example.

[**0041**] **FIG. 4** shows a real time video stream, a time-delayed video stream and an exemplary video sequence, in accordance with the invention. A continuous real time video stream **215** (also shown in **FIG. 2** and described in the accompanying text) is generated by camera **110** and is provided to video storage and delay device **150** via bus **135** (**FIG. 1**). The continuous real time video stream **215** includes an exemplary video sequence **420** including frames **425**, **427**, and **429**, as shown in **FIG. 4**. As indicated by the superimposed time and date in the upper right hand comer of the video image, frames **425**, **427** and **429** are several illustrative frames within a video sequence that spans a time period that starts at 14:02.06 (i.e., six seconds past 2:02 p.m.) and ends at 14:02.12 (i.e., 12 seconds past 2:02 p.m.). In frame **425**, a vehicle is shown approaching a red light at an intersection. In frame **427**, which depicts the scene several seconds later, the vehicle has driven through the intersection in apparent disregard of the traffic signal. In frame **429**, which depicts the scene six seconds after that depicted in frame **425**, the car has moved outside the field of view of the camera.

[**0042**] As with the example provided in the text accompanying **FIG. 3**, the officer determines that a car stop is called for after the infraction is witnessed at 14:02.09. Assuming a three-second reaction time as with the previous example, the officer activates the video recorder at 14:02.12, as shown in **FIG. 4**.

[**0043**] **FIG. 4** also depicts a time-delayed video stream **225** (also shown in **FIG. 2** and described in the accompanying text). The time-delayed video stream **225** is generated by the video storage and delay device **150** from real time video stream **215** received at its input, as described above, in accordance with the invention. The time-delayed video stream **225** includes an exemplary video sequence **440**, including frames **442**, **444**, and **446**, that is the same as video sequence **420** in sequence and content, but is offset from actual time by the time delay period ΔT.

[**0044**] The time-delayed video stream **225** is buffered in the video storage and delay device **150** so that it has a time delay ΔT of six seconds, as shown in **FIG. 4**. Accordingly, upon activation of the video recorder **162** by the officer at 14:02.12, the effective start time of the video recording, $t_{rec\ start}$, is 14:02.06 which precedes the time of the observed infraction, $t_{observe}$, by three seconds.

[**0045**] Referring now to **FIG. 5, a** simplified functional block diagram of an exemplary video storage and delay device **150** is shown. Video storage and delay device **150** includes an input interface **524** and an output interface **542**. These I/O interfaces include signal connections for one video signal and two audio signals. In many applications, and in this exemplary embodiment, the two audio signal connections are used for audio streams associated with the wireless microphone **125** and rear seat microphone **185**. The I/O interfaces **524** and **542** may also include control signal connections so that control signals from control head **170** may be passed through to the video recorder **162** that is coupled to the video storage and delay device **150** (as shown in **FIG. 1** and described in the accompanying text). In addition, it may be desirable to adapt the I/O interfaces **524** or **542** with a power connection, for example, to accept +12V DC power from the vehicle. The signal connections at both the input interface **524** and the output interface **542** are

realized, in this exemplary embodiment of the invention, using standard RCA-type co-axial connectors. Video and audio pass through connections (not shown in **FIG. 5**) may be optionally provided at the I/O interfaces **524** and **542** to implement a straight through signal path that bypasses the functions of the video storage and delay device **150**.

[**0046**] The input interface **524** is adapted to receive real time analog signals in the exemplary embodiment of the invention depicted in **FIG. 5**. However, in some applications of the invention it may be desirable to accept digital signals, both digital and analog signals, or either digital or analog signals in a switchable input mode arrangement. In this exemplary embodiment, at input connection **504**, a real time analog audio stream is received from the wireless microphone **125**. At input connection **508**, a real time analog audio stream is received from rear seat microphone **185**. At input connection **512**, a real time analog video stream is received from camera **110**.

[**0047**] The following description relates to the processing of the real time video stream received at input connection **512**. The processing of the two audio streams received at input connections **504** and **508** is performed in a similar (but parallel) process. The received video stream is passed from the input to an analog-to-digital converter **525** (sometime referred to as an analog decoder). The analog-to-digital converter **525** converts the NTSC-formatted analog video stream into a digitized component data stream (having color difference and luminance components, Cb, Cr and Y, respectively) that complies with the CCIR **601** digital coding standard (Consultative Committee for International Radio, also commonly referred to as the International Telecommunications Union recommendation ITU-R BT.601-5). In this exemplary embodiment of the invention, the video image has a field size of 720×243 pixels.

[**0048**] The output of the analog-to-digital converter **525** is fed to a digital encoder **532** as shown in **FIG. 5**. The digital encoder **525** takes the CCIR **601** digitized data stream and compresses the stream to reduce downstream storage and processing requirements using conventional entropy coding schemes. A dynamic random access memory ("DRAM") device **536** is coupled to the digital encoder **525** via bus **534**, as shown in **FIG. 5**, to provide a temporary buffer for transform and other transient data that is generated during the compression process.

[**0049**] Those skilled in the art will recognize that the level of compression can be chosen according to the requirements of the particular application. In some applications it may be desirable to implement low loss or loss-less compression levels, while other applications may be less sensitive to the signal degradation that typically accompanies higher compression ratios.

[**0050**] A central processor **550** receives the compressed digitized data stream from the encoder **532** on bus **538**. The central processor **550** writes data from the received stream into a memory **558** that is coupled to the central processor **550** through bus **554**. The memory **558** is preferably implemented using static RAM ("SRAM"). After data has been held in the memory **558** for a pre-set time interval, the central processor **550** reads the data out of the memory **558** and forwards the data to decoder **562** over bus **552**. The central processor sequentially and continuously processes the received data stream through the memory **558** (including the steps of writing, holding and reading) and outputs a continuous compressed digitized data stream that is time-delayed compared with the received stream. Accordingly, central processor **550**, in combination with memory **558**, implements the FIFO buffer arrangement shown in **FIG. 2** and described in the accompanying text. In addition to performing the write and read functions, the central processor **550** controls the overall signal flow and data processing throughout the video storage and delay device **150**.

[**0051**] The decoder **562** and digital-to-analog converter **572** work in a reverse manner as encoder **532** and analog-to-digital converter **525** to restore the data stream received from the central processor **550** to substantially its original uncompressed analog form (although the stream remains time-delayed). The decoding and digital-to-analog conversion is implemented in a conventional fashion. As with the encoder **532**, a DRAM device **566** is coupled through bus **564** to decoder **562** to provide a buffer for transient data that is generated during the decoding process.

[**0052**] The resultant time-delayed analog video stream is output on interface **542** via connections **582**, **584**, and **588**. Connection **582** provides a time-delayed analog output stream associated with the wireless microphone **125**. Connection **584** provides a time-delayed analog output stream associated with the rear seat microphone **185**. Connection **588** provides a time-delayed analog video stream associated with the camera **110**.

[**0053**] The video storage and delay device **150** may be advantageously configured as a self-contained unit which, once installed and set-up, will operate transparently in the background without requiring additional user intervention. That is, the video storage and delay device **150** needs only signal inputs and an output connection to a video recorder to create the time-delayed video stream. No modifications to the other components in the in-car video system **100** (**FIG. 1**) are required in order to implement the invention. The use of standard interfaces, for example the RCA co-axial connectors of the exemplary embodiment shown in **FIG. 5**, facilitates the use of the invention in retrofit scenarios with existing in-car video systems. In addition, very little extra training is required for an officer to be able to effectively operate the in-car video system **100** equipped with the video storage and delay device of the invention because the physical operation of the system is the same as with current in-car video systems. The officer need only be trained to understand that the selected duration of the pre-set time delay equals the amount of reaction time the officer has to activate the video recorder after witnessing an event of interest. Once this training is provided, it can be expected that officers will quickly realize the benefit provided by the invention in its ability to record an event after it has already occurred in actual time.

[**0054**] **FIG. 6 a** simplified functional block diagram of an exemplary video storage and delay device **610** equipped with an optional user interface **620**. User interface **620** is optionally utilized in some applications of the invention to implement user-selected control of certain operating parameters of the video storage and delay device **610**. The other elements shown in **FIG. 6** are similar in form and operation to those depicted in **FIG. 5**. It is noted that the optional user interface **620** may also be utilized in embodiments of the invention where the video storage and delay device is

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physically integrated with a video recorder. In such a case, the user interface **620** may be used alone or in combination with other controls that may be located on the video recorder itself, or with controls that are located on the remote control head (for example, control head **170** in **FIG. 1**).

[**0055**] By interacting with the controls, the user may set-up and configure the video storage and delay device **610**, in accordance with the invention. For example, in some applications it may be particularly advantageous to allow a user to define the amount of time-delay ΔT. Thus, police departments are able to fine-tune the particular amount of time-delay implemented in their in-car video systems to their specific needs or operational environment. In other applications, it may be desirable for video storage and delay device **610** to selectively supply a date and time stamp that is superimposed onto the recorded video image (as shown in exemplary video sequences **420** and **440** in **FIG. 4**). Video storage and delay device **610** may supply such information in those instances where other components of an in-car video system would not otherwise have the capability to record the date and time of the captured scene. Thus, video storage and delay device **610** may be retrofitted to provide the additional date/time feature upgrade to older in-car video systems.

[**0056**] The user interface **620** is shown in **FIG. 6** as being disposed on an external surface of the video storage and delay device **610**. However, in some applications of the invention, it may be desirable to arrange the user interface **620** as a module that may be located remotely from the main body of the video storage and delay device. For example, the video storage and delay device **610** may be located in the trunk of the car, while the user interface is located remotely in the passenger compartment.

[**0057**] User interface **620** includes a group of user-accessible controls, such as buttons, that are located on a panel **621**. The controls are indicated by reference numerals **622**, **625**, **626**, **626**, **627**, **628**, **629**, and **632**, respectively, for controls "START,""STOP,""PLAY,""DATE,""UP," DOWN," and "SET." The "START" and "STOP" buttons **622** and **625** turn on and off the video storage and buffering feature on the invention. In some applications of the inventions it may be desirable to arrange the video storage and delay device **610** so that it is always operational upon power up. In such a case, the "START" and "STOP" buttons **622** and **625** would be deleted from user interface **620** or otherwise made inoperative.

[**0058**] A user-viewable digital display **635**, such as an LCD display, is also included in the user interface **620**. **FIG. 7** shows a pictorial representation of the user interface panel **621** with user-accessible controls and LCD display **635**.

[**0059**] A user interacts with the controls on user interface **620** to set up (i.e., configure) the video storage and delay device **610**. Such set up may be facilitated by the display and use of an appropriate interactive menu provided LCD display **635** in a conventional manner. For example, the menu may include selections pertaining to setting of the date and time, enabling and disabling the date/time superimposition feature, positioning the superimposed digits to a desired location on the video image (e.g., left or right, top or bottom), and setting the time delay ΔT.

[**0060**] The menu may be displayed on LCD display **635**, for example, by pressing and holding "SET" button **632**. The user may navigate through various menu selections using the "UP" and "DOWN" buttons **628** and **629** and choose a setting by pressing the "SET" button **632**. To change a numerical setting, the user may position a blinking cursor (or other visual indicator) on LCD display **635** over a digit to be changed using multiple presses of the "SET" button **632**. The "UP" and "DOWN" buttons **628** and **629** may be pressed accordingly to increment or decrement the digit as desired.

[**0061**] A user may press a button directly to set up a function as an alternative to a menu-driven set up. For example, LCD display **635** will display the last set time and date when the "DATE" button **627** is pressed. The user may change or correct the date and time by pressing and holding the "DATE" button **627**. A blinking cursor is then positioned over the appropriate digit that may then be changed up or down with the "UP" and "DOWN" buttons **628** and **629**.

[**0062**] Other features of the invention are contained in the claims that follow.

What is claimed is:

1. A method of operating a vehicle-mounted surveillance system including a camera and vehicle-mounted recording device that creates video recordings having a start time and a stop time, the method comprising the steps of:

capturing a stream of live video of an area of surveillance using the camera;

processing the live video stream to impose a delay of pre-set time interval on the live video stream to generate a time-delayed video stream; and

activating the recording device, upon an occurrence of an event at a reference time, to record the time-delayed video stream so that a video recording is created of the surveillance area and the start time of the video recording precedes the reference time by the pre-set time interval.

2. The method of claim 1 where the step of processing includes sequentially writing data representative of the live video stream into a FIFO buffer.

3. The method of claim 2 where the step of processing further includes holding the data in the FIFO buffer for the pre-set time interval.

4. The method of claim 2 where the step of processing further includes compressing the data that is written into the FIFO buffer.

5. The method of claim 3 where the time-delayed video stream is generated by reading the data out of the FIFO buffer upon expiration of the pre-set time interval.

6. The method of claim 1 where the live video stream is received as an analog-formatted stream and converted into a digitized stream.

7. The method of claim 6 where the analog-formatted stream is an NTSC-defined video stream.

8. The method of claim 1 where the live video stream is received as a digitally-formatted stream.

9. The method of claim 1 where the live video stream includes an image component and an audio component.

10. A video data storage and delay device arranged to provide a delay of a pre-set time interval to a real time video stream received from a vehicle-mounted video system, the vehicle-mounted video system including a video camera and recording device, comprising:

an input interface for receiving the real time video stream from the video camera;

a processor to process data representative of the received real time video stream and for writing the data to storage and reading the data from storage so as to create the time delay between the input and output of the video data storage and delay device;

a memory coupled to the processor to temporarily store the processed data for the pre-set time interval; and

an output interface for transmitting the delayed video signal to the recording device.

11. The video data storage and delay device of claim 10 further including a data encoder interposed between the input interface and the processor.

12. The video data storage and delay device of claim 11 wherein the data encoder compresses data in accordance with CCIR-601.

13. The video data storage and delay device of claim 10 wherein the field size associated with the data encoder is 720 pixels by 243 pixels.

14. The video data storage and delay device of claim 10 further including an analog-to-digital converter interposed between the input interface and the data encoder.

15. The video data storage and delay device of claim 10 further including a data decoder interposed between the processor and output interface.

16. The video data storage and delay device of claim 15 further including a digital-to-analog converter interposed between the the data decoder and the output interface.

17. The video data storage and delay device of claim 10 wherein the input interface and output interface include standard connections.

18. The video data storage and delay device of claim 17 wherein the connections comprise RCA-type co-axial connectors.

19. The video data storage and delay device of claim 10 wherein the processor is user-controllable to adjust processing parameters.

20. The video data storage and delay device of claim 19 wherein the processing parameters include the length of the pre-set time interval.

21. The video data storage and delay device of claim 19 further including a user interface for controlling adjustable processing parameters.

22. The video data storage and delay device of claim 21 wherein the user interface includes an interactive menu displayed on a user-viewable display.

23. The video data storage and delay device of claim 22 further including user-activated controls.

24. The video data storage and delay device of claim 10 wherein the real time video stream includes video and audio components.

25. The video data storage and delay device of claim 24 wherein the processor processes the video and audio components in separate parallel processes.

26. The video data storage and delay device of claim 24 wherein the audio component includes a first and a second audio track.

27. The video data storage and delay device of claim 26 wherein the first audio track corresponds to audio captured from a user-worn wireless microphone.

28. The video data storage and delay device of claim 10 wherein the second audio track corresponds to audio captured from a vehicle-mounted microphone.

29. The video data storage and delay device of claim 10 further including a self-contained enclosure requiring only external power and signal connections and that is adapted for retrofitting to existing in-car video installations.

30. The video data storage and delay device of claim 29 further including a signal pass-through path.

31. The video data storage and delay device of claim 10 wherein the memory is arranged from static random access memory.

32. The video data storage and delay device of claim 11 further including a first transient data buffer for temporarily storing data creating during operation of the data encoder.

33. The video data storage and delay device of claim 32 wherein the first transient data buffer is arranged from dynamic random access memory.

34. The video data storage and delay device of claim 15 further including a second transient data buffer for temporarily storing data creating during operation of the data decoder.

35. The video data storage and delay device of claim 34 wherein the second transient data buffer is arranged from dynamic random access memory.

36. The video storage and delay device of claim 10 wherein the recording device is a VCR.

37. The video storage and delay device of claim 10 wherein the recording device is a digital video recorder.

38. A method of operating a vehicle-mounted recording device, the method comprising the steps of:

capturing a stream of real time video of an area of surveillance using a video camera;

buffering the stream of real time video in a time-sequential manner for a pre-set time interval to create a buffered stream of video that is time delayed compared with the real time video stream; and

outputting the buffered and time delayed video stream to a vehicle-mounted recording device that is adapted to selectively record the buffered and time delayed video stream.

39. A method of operating a vehicle-mounted surveillance system including a camera and vehicle-mounted recording device, the method comprising the steps of:

capturing a continuous stream of real time video of an area of surveillance using the camera;

imposing a delay of pre-set time interval on the real time video stream to create a time delayed video stream; and

recording the time delayed video stream onto a storage medium using the recording device.

40. A video recorder adapted for use in a vehicle-mounted surveillance system, comprising

an input interface for receiving a real time video stream from a video source;

a processor to process data representative of the received real time video stream and for writing the data to storage and reading the data from storage so as to create a time delayed version of the real time video stream;

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a memory coupled to the processor to temporarily store the processed data for the set time interval; and

a recording device for recording video and audio onto a storage medium, the recording device being coupled to the processor for receiving the time delayed version of the real time video stream.

* * * * *

Appendix C

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(12) **United States Patent**
Etcheson

(10) **Patent No.: US 7,804,426 B2**
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(54) **SYSTEM AND METHOD FOR SELECTIVE REVIEW OF EVENT DATA**

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(51) **Int. Cl.**
G08G 1/017 (2006.01)

(52) **U.S. Cl.** **340/937**; 348/148; 701/35

(58) **Field of Classification Search** 701/35; 340/439, 576, 937; 348/148; 702/188; 709/219; 725/86, 91, 93, 94, 143–146
See application file for complete search history.

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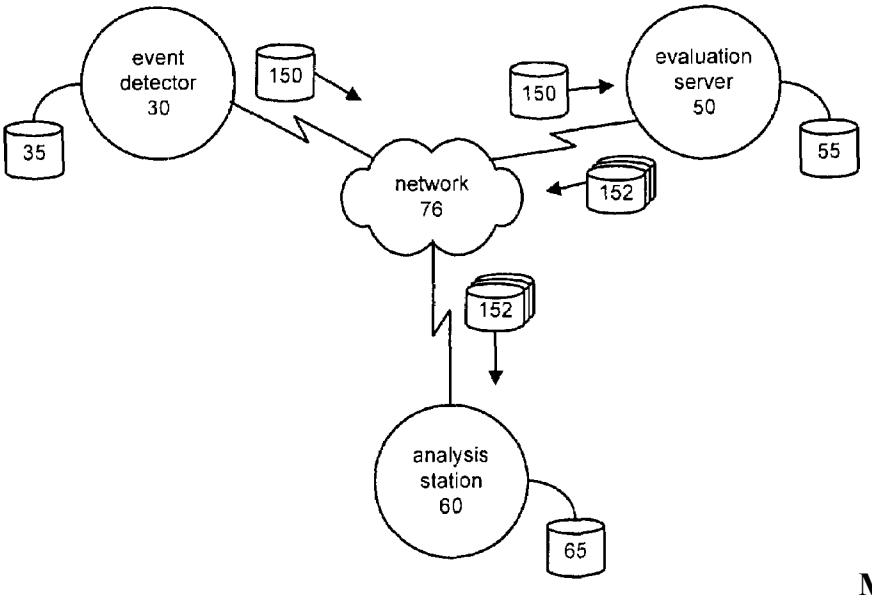
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(57) **ABSTRACT**

Systems and methods for computer assisted cueing and selective reviewing of driving data in order to save time in the data review process are provided. The method allows identifying essential portions of the data, selecting the essential portions, reviewing the selected data and retrieving additional data leading to the event if necessary. At least one event capture device continuously captures data into a buffer. The data are sent to an event detector communicatively coupled to the event capture device only when the event detector requests them. After receiving the data, the event detector selects and indexes a pre-event portion, during-event portion and post-event portion, combines the portions of captured data into a single driving event record and sends the driving event record to the evaluation server. From the server, the driving event record is sent to the analysis station for review and analysis.

33 Claims, 8 Drawing Sheets



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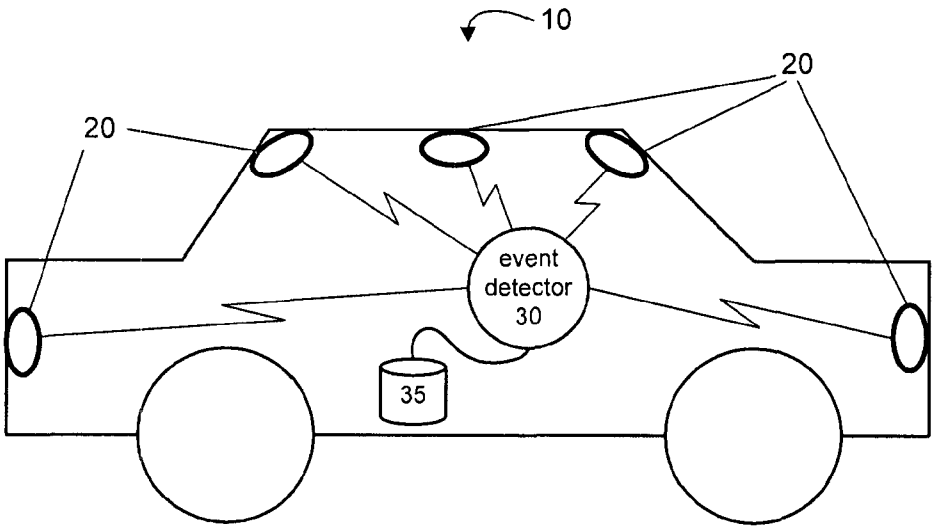


FIG. 1

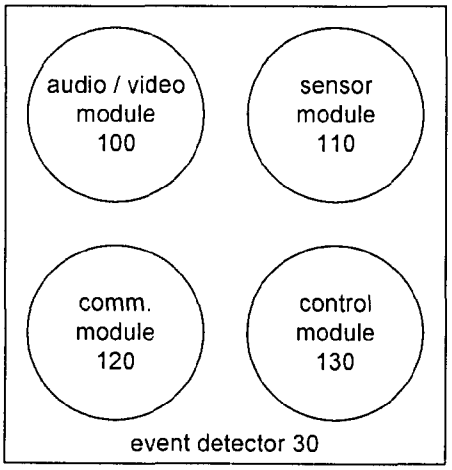


FIG. 2

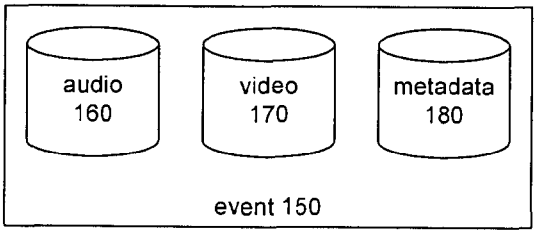


FIG. 3

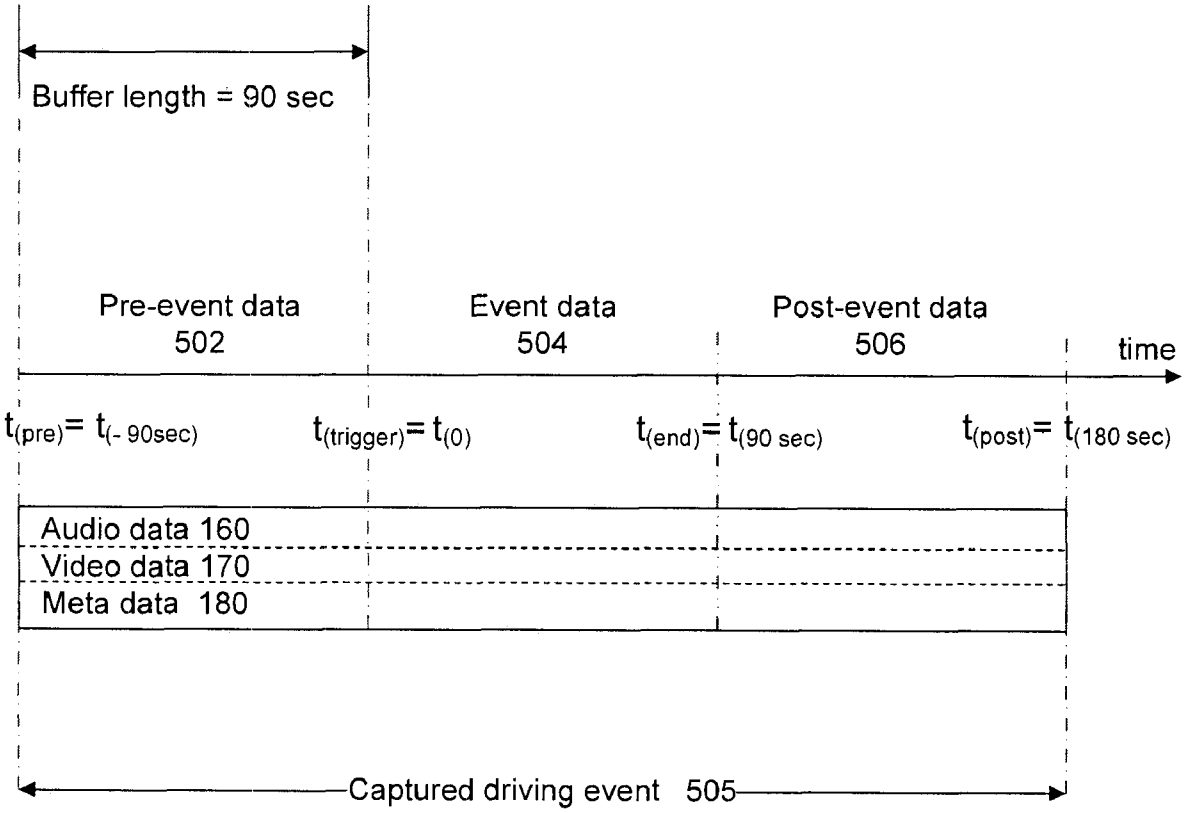

Buffer length = 90 sec
Pre-event data
502
Event data
504
Post-event data
506
time
$t_{(pre)} = t_{(-90sec)}$
$t_{(trigger)} = t_{(0)}$
$t_{(end)} = t_{(90\ sec)}$
$t_{(post)} = t_{(180\ sec)}$
Audio data 160
Video data 170
Meta data 180
Captured driving event 505

FIG. 4

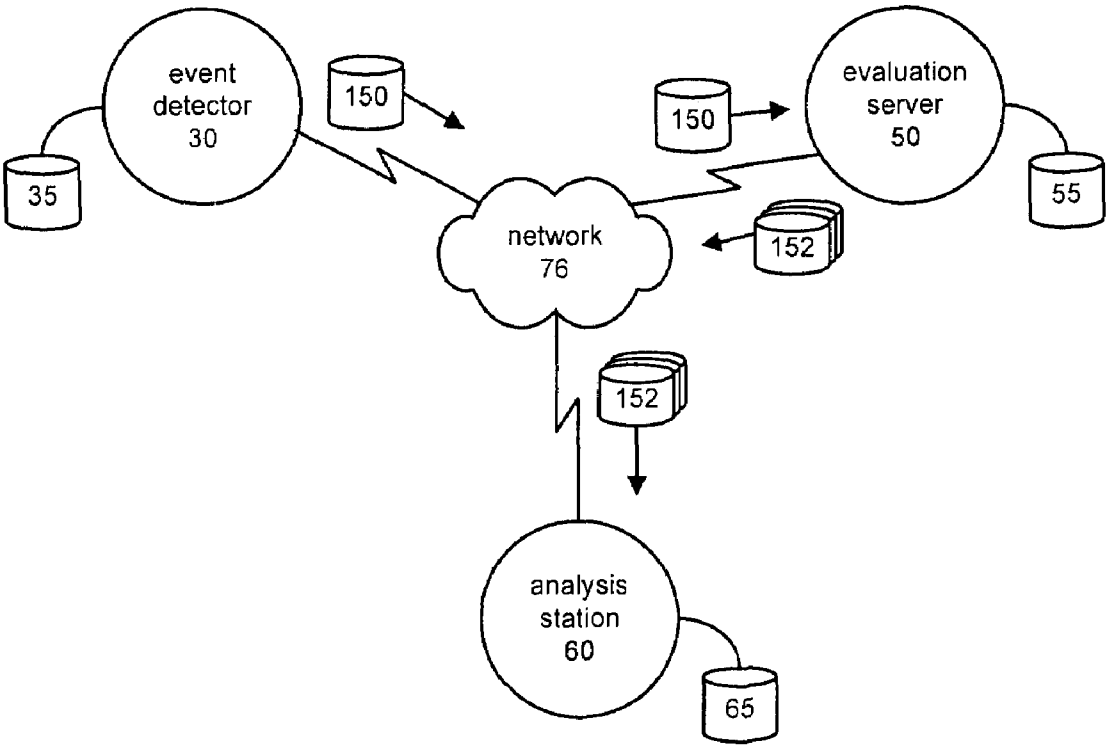

event
detector
30
35
150
150
evaluation
server
50
55
network
76
152
152
analysis
station
60
65

FIG. 5

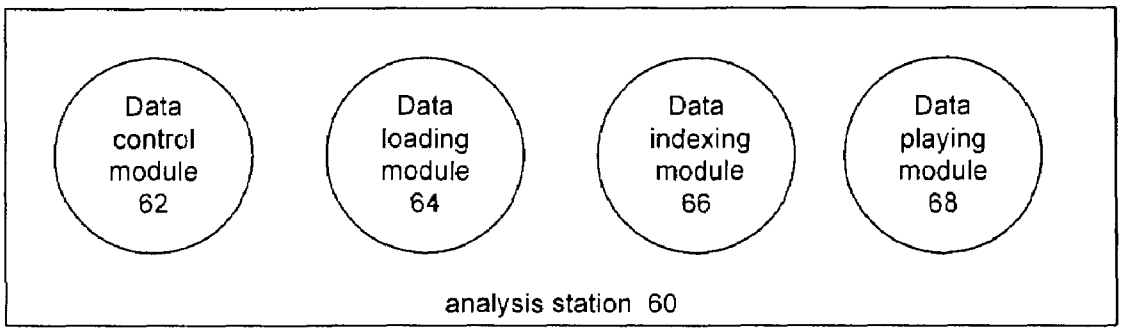

Data
control
module
62
Data
loading
module
64
Data
indexing
module
66
Data
playing
module
68
analysis station 60

FIG. 6

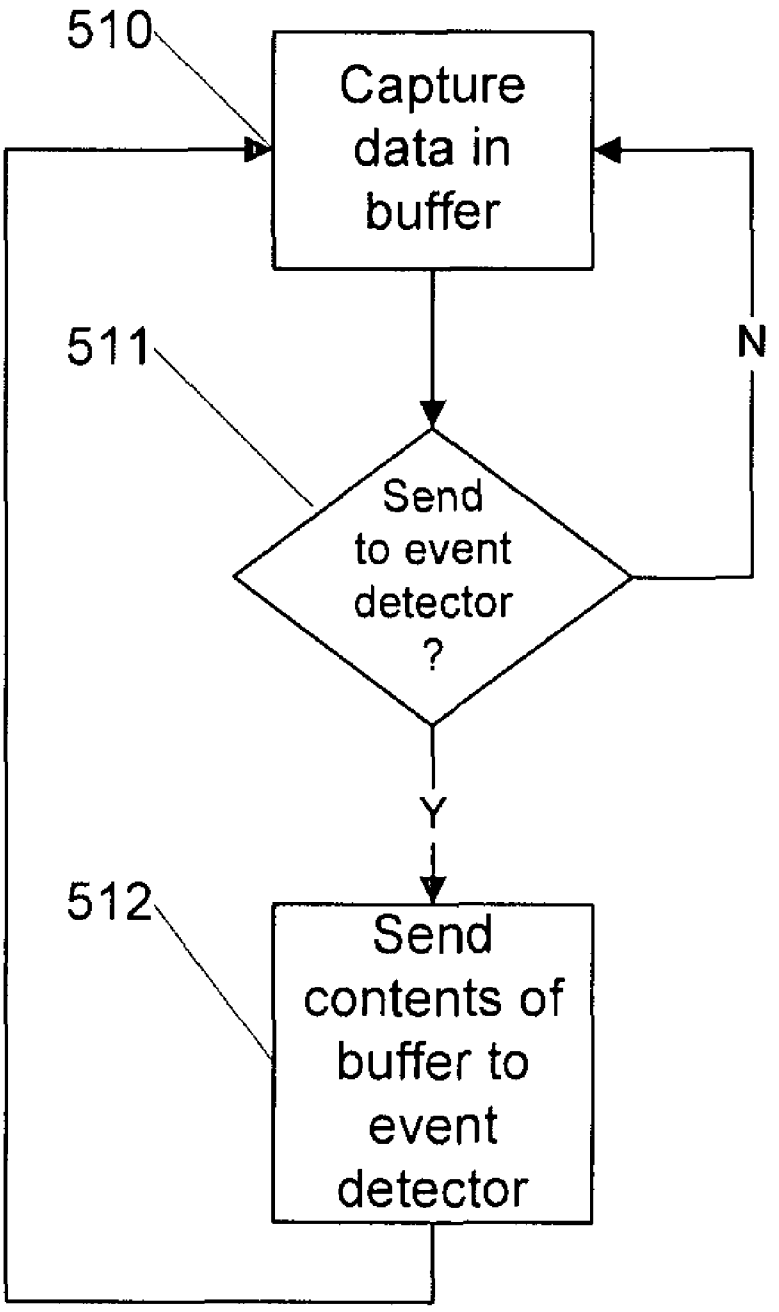

510
Capture data in buffer
511
Send to event detector ?
N
Y
512
Send contents of buffer to event detector

FIG. 7A

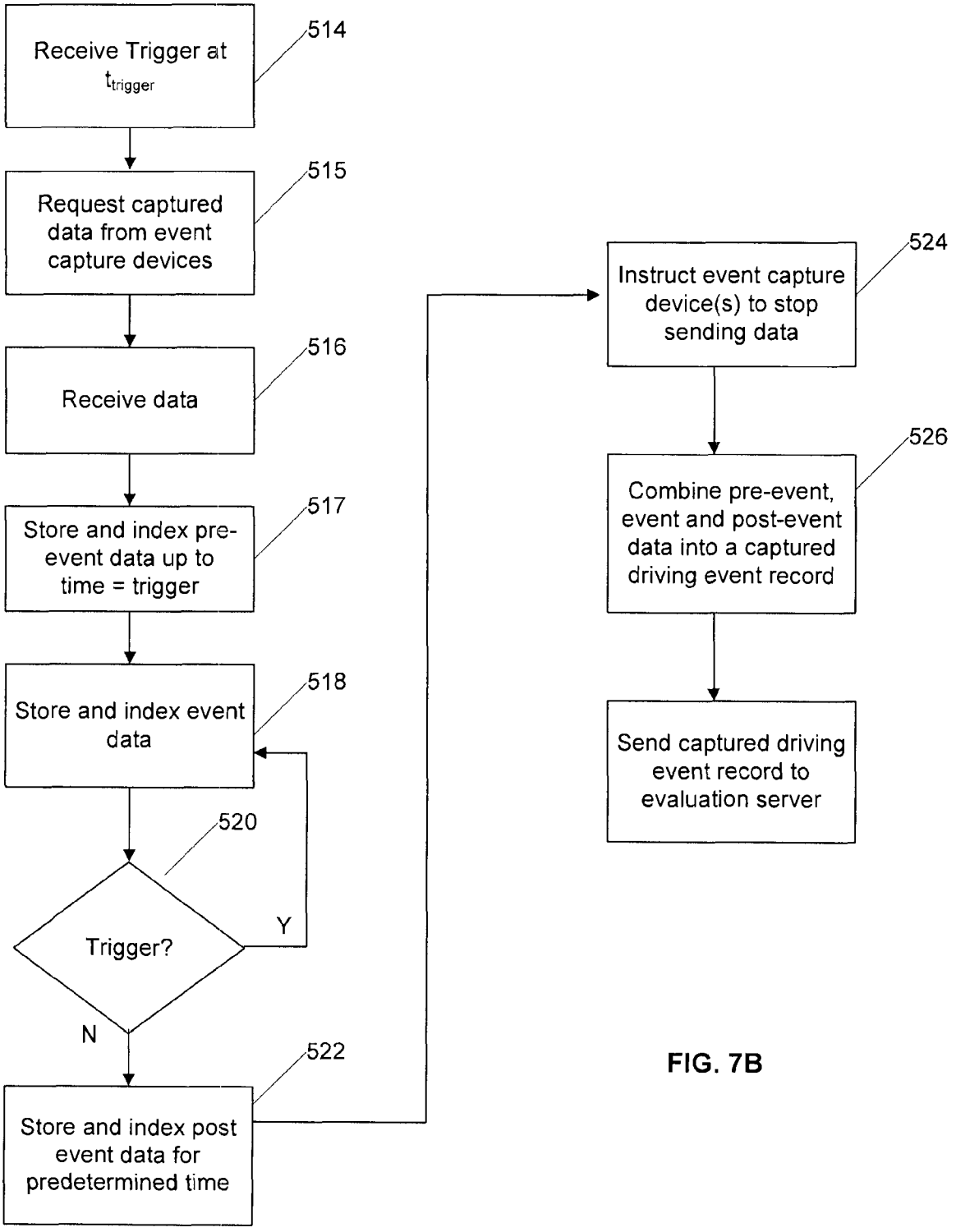

Receive Trigger at $t_{trigger}$
514
Request captured data from event capture devices
515
Receive data
516
Store and index pre-event data up to time = trigger
517
Store and index event data
518
520
Trigger?
Y
N
Store and index post event data for predetermined time
522
Instruct event capture device(s) to stop sending data
524
Combine pre-event, event and post-event data into a captured driving event record
526
Send captured driving event record to evaluation server

FIG. 7B

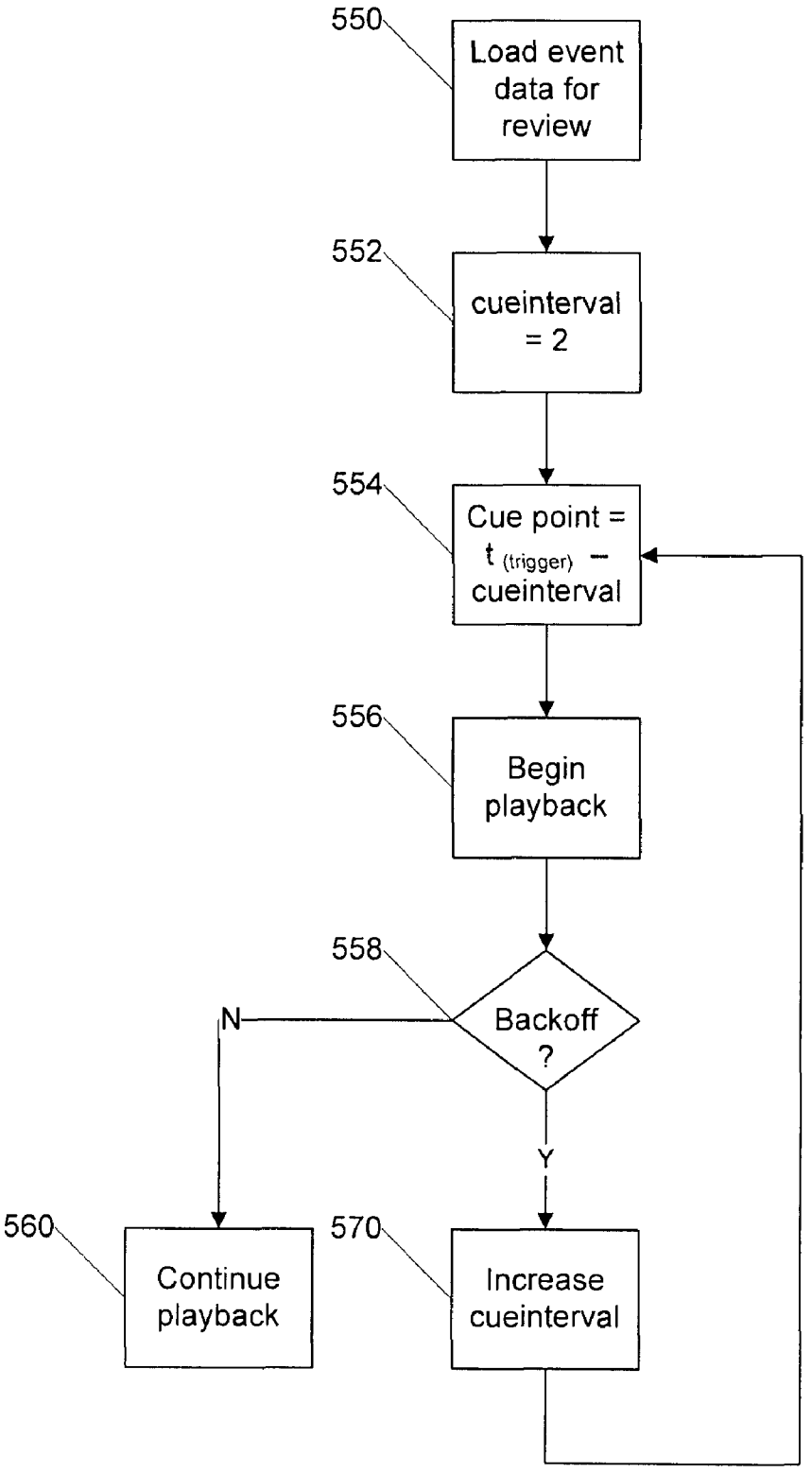

550
Load event data for review
552
cueinterval = 2
554
Cue point = t (trigger) – cueinterval
556
Begin playback
558
Backoff ?
N
Y
560
Continue playback
570
Increase cueinterval

FIG. 8

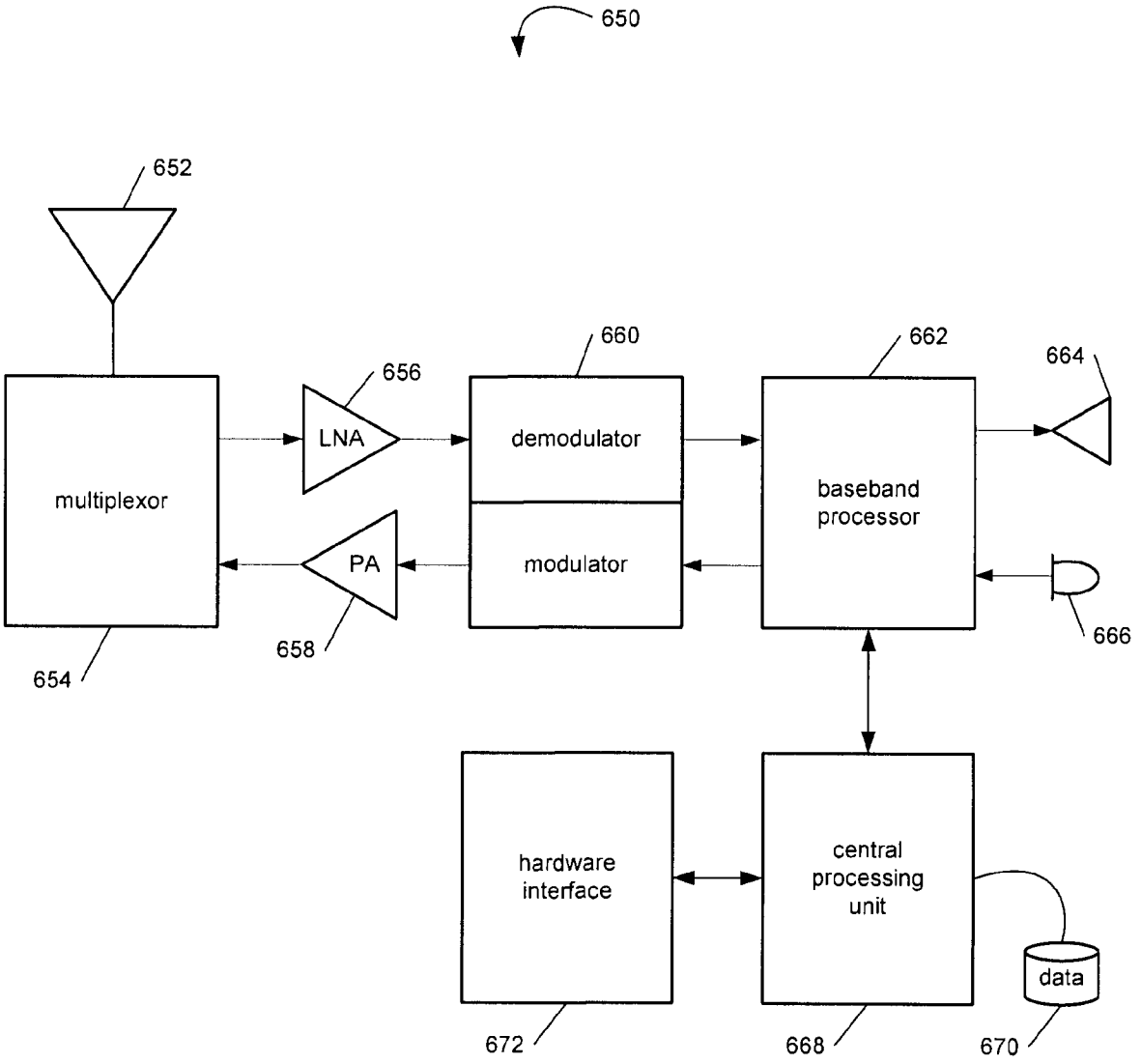

650
652
multiplexor
654
LNA
656
PA
658
demodulator
660
modulator
baseband processor
662
664
666
hardware interface
672
central processing unit
668
data
670

FIG. 9

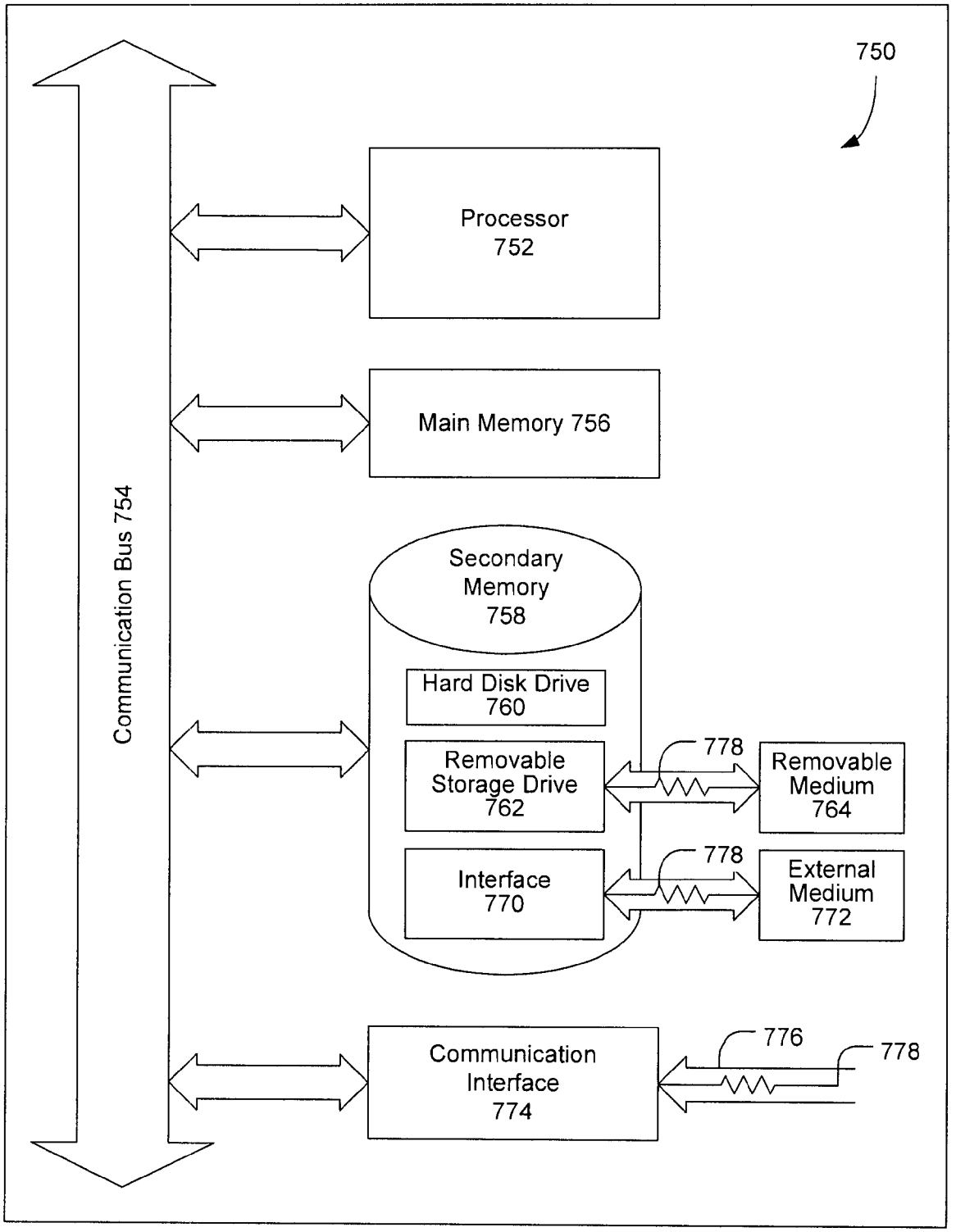

750
Processor
752
Main Memory 756
Communication Bus 754
Secondary
Memory
758
Hard Disk Drive
760
Removable
Storage Drive
762
778
Removable
Medium
764
Interface
770
778
External
Medium
772
Communication
Interface
774
776
778

FIG. 10

SYSTEM AND METHOD FOR SELECTIVE REVIEW OF EVENT DATA

RELATED APPLICATION

The present application is a continuation-in-part of co-pending U.S. patent application Ser. Nos. 11/382,222 and 11/382,239, filed May 8, 2006; and Ser. Nos. 11/382,325 and 11/382,328, filed May 9, 2006, of concurrent ownership, all of which are incorporated herein by reference in their entirety.

BACKGROUND

1. Field of the Invention

The present invention generally relates to reviewing of driving events and more specifically relates to capturing driving event data and selecting essential parts of the data for review.

2. Related Art

Typical systems for review of captured driving event data usually require reviewing of a significant amount of "raw" data. One of the problems with reviewing voluminous "raw" data is that it involves reviewing essential as well as non-essential data, and separating essential data from non-essential data (e.g. non-essential pre-event data, etc.). Both, the reviewing and separating of the data can be very time consuming. Since watching the non-essential pre-event data by an operator is usually a waste of time, the review process can be inefficient and time consuming.

Today, there is no system in place that can efficiently shorten the review process by helping to determine which portion of the captured data is essential, selecting the essential portion of data, cueing the selected data for review, and retrieving additional data leading to the event if it is necessary.

Accordingly, what is needed is an efficient system and method for selective cueing and reviewing of the driving event data that allow to index playback of the captured data just prior to the beginning of the essential event data so the non-essential data can be skipped during the review.

SUMMARY

Accordingly, systems and methods for computer assisted cueing and selective reviewing of event data to save time in the data review process are provided.

In one aspect, the system for selective review of event data comprises at least one event capture device, an event detector, an evaluation server and an analysis station. The event capture device continuously captures driving event data in a buffer. While capturing the data, the event capture device also checks the status of a trigger which can be set by the event detector to either "on" or "off." If the trigger is "on," the event capture device sends driving event data to the event detector continuously. If the trigger is "off," the event capture device only keeps capturing event data and filling the buffer, and writing over the previously captured data when the buffer is full.

In one aspect, when a driving event starts, an operator sends an event trigger to the event detector, or a detector configured to detect a driving event which potentially requires evaluation sends a trigger to the event detector. Upon receiving the trigger, the event detector passes the trigger to at least one event capture device. In response to the trigger, the event capture device sends data to the event detector.

In one aspect, the event detector collects three types of data: pre-event data, event data and post-event data. The event detector then indexes the beginning and end of the pre-event data, event data and post-event data.

In one aspect, the event detector combines the pre-event data, during-event data and post-event data into a single driving event and stores the events in the evaluation server. From the server, the data are sent to the analysis station where they are cued, reviewed and analyzed.

Other features and advantages of the present invention will become more readily apparent to those of ordinary skill in the art after reviewing the following detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The details of the present invention, both as to its structure and operation, may be gleaned in part by study of the accompanying drawings, in which like reference numerals refer to like parts, and in which:

FIG. **1** is a block diagram illustrating an example event detector in control of a plurality of event capture devices deployed in a vehicle according to an embodiment of the present invention;

FIG. **2** is a block diagram illustrating an example event detector according to an embodiment of the present invention;

FIG. **3** is a block diagram illustrating an example event according to an embodiment of the present invention;

FIG. **4** is a block diagram illustrating an example of captured driving event data according to an embodiment of the present invention;

FIG. **5** is a network diagram illustrating an example system for selective reviewing of driving event data according to an embodiment of the present invention;

FIG. **6** is a block diagram illustrating an example analysis station according to an embodiment of the present invention;

FIG. **7**A is a flow diagram illustrating an example process for capturing driving data according to an embodiment of the present invention;

FIG. **7**B is a flow diagram illustrating an example process for receiving, combining and storing driving data according to an embodiment of the present invention;

FIG. **8** is a flow diagram illustrating an example process for cueing and playing driving event data according to an embodiment of the present invention;

FIG. **9** is a block diagram illustrating an exemplary wireless communication device that may be used in connection with the various embodiments described herein; and

FIG. **10** is a block diagram illustrating an exemplary computer system as may be used in connection with various embodiments described herein.

DETAILED DESCRIPTION

Certain embodiments as disclosed herein provide for systems and methods for computer assisted cueing and selective reviewing of driving data in order to save time in the review process. For example, the method for selective cueing and reviewing of the driving events allows an operator to select a part of the captured driving event data, review the data and, if it is needed, retrieve more data leading to the event.

In one embodiment, the system for selective reviewing of driving event data comprises an event detector coupled with a vehicle, an evaluation server, an analysis station and at least one event capture device. The event capture device captures driving event data and sends the data to the event detector upon receiving a request from the event detector. The event detector is configured to receive, index and store driving events. The events data are indexed using a pre-event time index, a trigger time index, and a post-event time index. The

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evaluation server receives driving events from the event detector, stores them and provides them to the analysis station where the data are cued, reviewed and analyzed.

In one embodiment, the analysis station comprises a data loading module, a data indexing module, a data control module, and a data playing module. The data loading module is configured to receive the driving event data from the evaluation server and load the data for review. The data indexing module is configured to cue up the driving event at a cue time set substantially close, but prior to the trigger time. The data playing module is configured to play the driving event from the cue time to the post-event time.

In one embodiment, the method for selective reviewing of driving event data comprises capturing and indexing a driving event at an event detector, sending the driving event from the event detector to an evaluation server, receiving and storing a plurality of driving events at the evaluation server, sending the driving event from the evaluation server to an analysis station, receiving the driving event at the analysis station and loading the driving event for review. Once the driving event data are cued, the data are played from the cue time to the end of the event data (indexed by the post-event time).

After reading this description it will become apparent to one skilled in the art how to implement the invention in various alternative embodiments and alternative applications. However, although various embodiments of the present invention will be described herein, it is understood that these embodiments are presented by way of example only, and not limitation. As such, this detailed description of various alternative embodiments should not be construed to limit the scope or breadth of the present invention as set forth in the appended claims.

FIG. **1** is a block diagram illustrating an example event detector **30** in control of a plurality of event capture devices **20** deployed in a vehicle **10** according to an embodiment of the present invention. In the illustrated embodiment, the event detector **30** is integrated with the vehicle **10** and is communicatively coupled with the event capture devices **20**. The event detector **30** is also configured with data storage **35**.

The event detector **30** can be any of a variety of types of computing devices with the ability to execute programmed instructions, receive input from various sensors, and communicate with one or more internal or external event capture devices **20** and other external devices (not shown). An example of a general purpose computing device that may be employed as all or a portion of an event detector **30** is later described with respect to FIG. **10**.

In one embodiment, the event detector **30** monitors its sensor to detect a driving event. When the event detector **30** detects a sensor output or trigger indicting the start of a driving event, the event detector **30** instructs one or more event capture devices **20** to send pre-event data, during the event data, and post-event data to the event detector **30**. Then, the event detector **30** stores the data in the data storage area **35** as an event. Events may comprise a variety of situations, including automobile accidents, reckless driving, rough driving, or any other type of stationary or moving occurrence that the owner of a vehicle **10** may desire to know about.

The vehicle **10** may have a plurality of event capture devices **20** placed in various locations around the vehicle **10**. An event capture device **20** may comprise a video camera, still camera, microphone, and other types of data capture devices. For example, an event capture device **20** may include an accelerometer that senses changes in speed or direction. Additional sensors and/or data capture devices may also be incorporated into an event capture device **20** in order to provide a rich set of information about a detected event.

The data storage area **35** can be any sort of internal or external, fixed or removable memory device and may include both persistent and volatile memories. The function of the data storage area **35** is to maintain data for long term storage and also to provide efficient and fast access to instructions, applications and/or modules that are executed by the event capture device **30**.

In one embodiment, the event detector **30** in combination with the one or more event capture devices **20** identifies an event and stores certain audio and video data along with related information about the event. For example, related information may include the speed of the vehicle when the event occurred, the direction the vehicle was traveling, the location of the vehicle (e.g., from a global positioning system ("GPS") sensor), and other information from sensors located in and around the vehicle or from the vehicle itself (e.g., from a data bus integral to the vehicle such as a J-1850 vehicle bus). This combination of audio, video, and other data is compiled into one event. The event can be stored in data storage **35** onboard the vehicle for later delivery to an evaluation server.

FIG. **2** is a block diagram illustrating an example event detector **30** according to an embodiment of the present invention. In the illustrated embodiment, the event detector **30** comprises an audio/video ("AV") module **100**, a sensor module **110**, a communication module **120**, and a control module **130**. Additional modules may also be employed to carry out the various functions of the event detector **30**, as will be understood by those having skill in the art.

In one embodiment, the AV module **100** is configured to manage the audio and video input from one or more event capture devices and storage of the audio and video input. The sensor module **110** is configured to manage one or more sensors that can be integral to the event detector **30** or external from the event detector **30**. For example, an accelerometer may be integral to the event detector **30** or it may be located elsewhere in the vehicle. The sensor module **110** may also manage other types of sensor devices such as a GPS sensor, temperature sensor, moisture sensor, or the like (all not shown).

The communication module **120** can be configured to manage communications between the event detector **30** and other devices and modules. For example, the communication module **120** may handle communications between the event detector **30** and the various event capture devices. The communication module **120** may also handle communications between the event detector **30** and a memory device, a docking station, or a server such as an evaluation server. The communication module **120** is configured to communicate with these various types of devices and other types of devices via a direct wire link (e.g., USB cable, firewire cable), a direct wireless link (e.g., infrared, Bluetooth), or a wired or wireless network link such as a local area network ("LAN"), a wide area network ("WAN"), a wireless wide area network ("WWAN"), or an IEEE 802 wireless network such as an IEEE 802.16 ("WiFi") network.

The control module **130** can be configured to control the actions or remote devices such as the one or more event capture devices. For example, the control module **130** may be configured to instruct the event capture devices to capture an event and return the data to the event detector when it is informed by the sensor module **110** that certain trigger criteria have been met that identify an event.

FIG. **3** is a block diagram illustrating an example event **150** according to an embodiment of the present invention. In the illustrated embodiment, the event **150** comprises audio data **160**, video data **170**, and metadata **180**. Audio data **160** can be collected from inside the vehicle, outside the vehicle, and

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may include information from an internal vehicle bus about the baseline noise level of the operating vehicle, if such information is available. Additional information about baseline noise level, radio noise level, conversation noise level, or external noise level may also be included in audio data **160**.

Video data **170** may include still images or moving video captured by one or more cameras in various locations in and around the vehicle. Video data **170** may include images or video from inside the vehicle, outside the vehicle, or both. In one particularly advantageous embodiment, still images and moving video that illustrate the entire area inside the vehicle and the entire 360 degree area surrounding the vehicle are captured by a plurality of image capture devices and included in video data **170**.

Metadata **180** may include a variety of additional information that is available to the event detector at the time of an event. Such additional data may include the velocity and direction of the vehicle, the GPS location of the vehicle, elevation, time, temperature, and vehicle engine and electrical component information captured from an internal vehicle bus, just to name a few. Additional information may also be included such as the number of occupants in the vehicle, whether seatbelts were fastened, whether airbags deployed, and whether evasive maneuvering was attempted as determined by the route of the vehicle prior to the event. As will be understood by those skilled in the art, metadata **180** may include an extremely rich variety of information limited only by the scope and type of information obtained prior to, during, and after an event.

FIG. **4** is a block diagram illustrating an example of captured driving event data or driving event record **505** according to an embodiment of the present invention. In the illustrated embodiment, the captured event data **505** comprises audio data **160**, video data **170**, and metadata **180**.

In one embodiment, the event detector receives buffers of the captured event data **505**. The length of a buffer may vary. In the illustrated embodiment, the buffer can capture ninety seconds of data.

The captured event data **505** may comprise three data segments: pre-event data **502**, event data **504** and post-event data **506**. Although the three data segments are the same length in the illustrated embodiment, they may be of different lengths in other embodiments. The pre-event data **502** comprises the data captured just before the driving event was triggered. The event data **504** comprises the driving event data captured from the beginning of the event to the end of the event. The post-event data **506** comprises the data captured after the driving event ended.

In one embodiment, the event detector is configured to create metadata tags, and use those tags to index the beginning and the end of the pre-event data, event data and post-event data. For example, the beginning of the pre-event data can be indexed with a pre-event time tag set to the beginning of the pre-event data, whereas the end of the pre-event data can be indexed with a trigger time tag set to the end of the pre-event data. Similarly, the beginning of the event data can be indexed with the trigger time tag set to the beginning of the event data, whereas the end of the event data can be indexed with an end time tag set to the end of the event data. Correspondingly, the beginning of a post-event data can be indexed with the end time tag set to the beginning of the event data, whereas the end of the post-event data can be indexed with a post-event time tag set to the end of the post-event data.

In one embodiment, the event detector is configured to concatenate a number of data buffers. For example, the event detector can concatenate pre-event data with event data and with post-event data.

In the embodiment illustrated in FIG. **4**, a captured driving event or driving event record **505** comprises three consecutive buffers of collected data. Each buffer is indexed using metadata tags and then concatenated to form the event **505**. More specifically, the pre-event data **502** was collected during a period of time which started at a "pre time" (indicated as $t_{(pre)}$) and ended at the trigger time (indicated as $t_{(trigger)}$). Similarly, the event data **504** was collected during a period of time which started at the trigger time (indicated as $t_{(trigger)}$) and ended at an "end time" (indicated as $t_{(end)}$). Correspondingly, the post-event data **506** was collected during a period of time which started at the end time (indicated as $t_{(end)}$) of the event data and ended at a "post time" (indicated as $t_{(post)}$). Then, the pre-event data **502** was concatenated with the event data **504** and with the event data **506**.

FIG. **5** is a network diagram illustrating an example system for selective reviewing of driving event data in communication via a network according to an embodiment of the present invention. In the illustrated embodiment, the system includes an event detector **30**, an evaluation server **50**, and an analysis station **60**, each communicating with another via a network **76**, and each coupled with a data storage area **35**, **55**, and **65**, respectively. Additional event detectors **30**, evaluation servers **50**, and analysis stations **60** may also be included.

The function of the event detector **30** is to identify and capture a plurality of events and send data structures representing the audio, video, and other related data, collectively called an "event," to the evaluation server **50**. The evaluation server maintains the captured events and provides them to the analysis station **60** where the events are reviewed. The analysis station **60** may be configured with certain hardware and software modules that allow an operator to review event data (e.g., audio, video, and metadata) in order to make an analysis related to the event and create summary reports and the like.

After an event is reviewed, it may be discarded, flagged for follow up, flagged for inclusion in one or more reports, or otherwise maintained for later reporting or analysis. In one embodiment; certain portions of one or more events may be incorporated into a report and then sent to the evaluation server **50** for storage.

In one embodiment, an event **150** is captured by an event detector **30** and stored until it is provided to the evaluation server **50**. The means by which an event **150** can be provided to the evaluation server **50** can vary. For example, an event **150** may be provided from event detector **30** to the evaluation server **50** by way of a portable media device, a direct wire link, a direct wireless link, an indirect wire link, an indirect wireless link, or any combination of these. Event **150** may be secured by encryption of the event data structure and/or a secure channel between the event detector **30** and the evaluation server **50**.

For example, a portable media device may include a USB drive, compact disc, thumb drive, media card, or other similar type of device. A direct wire link may include a USB cable, a firewire cable, an RS-232 cable, or the like. A direct wireless link may include an infrared link, a Bluetooth link, or an IEEE 802.11 point-to-point link, just to name a few. An indirect wired link may include a packet switched or circuit switched network connection configured for conveyance of data traffic. An Ethernet network connection is an example of a packet switched indirect wired link and a dial up modem connection is an example of a circuit switched indirect wired link, both of which may be configured for conveyance of data traffic.

In the illustrated embodiment, the event **150** travels over the network **76** from the event detector **30** to the evaluation server **50**. The network **76** may comprise any of a variety of network types and topologies and any combination of such

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types and topologies. For example, the network **76** may comprise a plurality of networks including private, public, circuit switched, packet switched, personal area networks ("PAN"), local area networks ("LAN"), wide area networks ("WAN"), metropolitan area networks ("MAN"), or any combination of these. The network **76** may also include that particular combination of networks universally known as the Internet.

The event **150** may travel to the wireless network **76** by way of an access point (not shown) and then on to the evaluation server **50** via the wireless network **76** in one embodiment. The access point may provide access via many different wireless network protocols as will be well understood by those having skill in the art. The wireless network may be a WWAN or a WiFi network. The link between the event detector **30** and the access point may be a short range direct link or a wide range direct link. The access point may be a large radio tower device or a small in-home wireless appliance. The wireless network **76** may include over the air segments and also wired segments. For example, the last mile segments of wireless network may be over the air while internal and back end segments may be wired segments. In one embodiment, the wireless network **76** may provide a wireless interface to the event detector and then have a wired interface on the back end to the Internet, which in turn connects to the evaluation server **50**.

In one embodiment, an event **150** may be provided from the event detector **30** to a docking station, (not shown) then to the network **76**, and then to the evaluation server **50**. Providing the event **150** from the event detector **30** to the docking station can be accomplished via a variety of means as described above, including portable media, direct wired or wireless link, and indirect wired or wireless link. The event detector **30** may also be physically coupled with the docking station to convey the event **150** from the event detector **30** to the docking station. Once the event **150** is received by the docking station, the event **150** is sent over the network **76** to the evaluation server **50**.

The network **76** may be a wired or wireless network or a combination of the two. The network **76** may also be private or public in whole or in part and may also include the Internet.

In one embodiment, the evaluation server **50** is configured to save the event data in a data buffer, create groups of events, and concatenate data from a number of data buffers.

The event detector **30** may be configured to create metadata tags and assign them to a variety of points in one embodiment. A metadata tag correlates to a particular moment in time and can be linked to a corresponding portion of a video and/or audio buffer. For example, for a given event, one metadata tag can be assigned to the beginning of the event, and another metadata tag can be assigned to the end of the event.

In one embodiment, a group of events **152** traveling from the evaluation server **50** can be routed to the analysis station **60**. The means by which the group of events **152** can be provided to the analysis station **60** can vary. In various embodiments (or in a single embodiment), the group of events **152** can be provided by the evaluation server **50** to the analysis station **60** via the network **76**.

The group of events **152** may be identified, for example, by searching for all events that pertain to a particular driver. This may be accomplished by associating each event at the time it is captured with a particular driver. For example, the driver of a vehicle may have a unique identifier and that unique identifier may be included as part of the metadata for each event that is captured while that driver is operating the vehicle.

Groups of events **152** may also be identified by all events associated with a particular company, a particular shift, a particular supervisor, or other reporting structure or working structure combinations. Such a group of events **152**, once provided to the analysis station **60**, can then be analyzed by an operator who reviews each event and identifies those events that need to be reported or shown to the driver.

FIG. **6** is a block diagram illustrating an example analysis station **60** according to an embodiment of the present invention. In the illustrated embodiment, the analysis station **60** includes a data control module **62**, a data loading module **64**, a data indexing module **66** and a data playing module **68**.

The function of the data control module **62** is to receive a driving event from the evaluation server, identify a trigger time in the metadata associated with the event and send the driving event to the data loading module **64**. The data loading module **64** loads the driving event data to a playing device for review.

Before the data are played, the data have to be properly cued by the data indexing module **66**. The data indexing module **66** determines the cue point for the cueing of the driving event by selecting a cue interval and computing the cue point in time. As a first approximation, the data indexing module **66** presets the cue interval to a relatively small time interval, such as, e.g. 2 seconds. Then, the data indexing module **66** determines the cue point by subtracting in time the cue interval from the trigger time.

In one embodiment, the cue point is adjusted until the playing of the driving event starts at a desired point in time. The adjusting of the cue point time can be an iterative process. It can involve a repetitive adjustment of the cue interval and a repetitive recalculation of the new cue point.

The main function of the data playing module **68** is to play the event for review. The data playing module **68** plays the data from the cue point to the end of event data or until an operator stops the playing.

FIG. **7**A is a flow diagram illustrating an example process for capturing driving data according to an embodiment of the present invention. In the illustrated embodiment, the event capture device continuously captures driving data, puts the data in a buffer, and sends the data to the event detector if the event detector requests that.

At a step **510**, the event capture device receives data. The data is captured continuously by filling the data buffer with incoming data starting from the beginning of the buffer to the end of the buffer.

At a step **511**, the event capture device monitors a trigger to find out whether the event detector requested the data. As soon as a trigger or request is received from the event detector asking the event capture device to send captured data, the event capture device sends the contents of the buffer to the event detector (step **512**), and continues to send buffers of captured data to the event capture device until the event detector asks it to stop. If no trigger or request to send data is received and the buffer is full, the event capture device continues to capture data by overwriting the buffer with new data (step **510**).

The length of the buffer may vary. In one embodiment, the size of the buffer allows storing of ninety seconds of video data, audio data, or meta data.

At a step **512**, the event capture device sends the whole buffer of data to the event detector after receiving a request or trigger. As soon as the buffer is sent, the event capture device proceeds to overwrite the bits and bytes of the buffer with new data, in step **510**, and sends the next buffer of data to the event detector unless a request to stop sending data is received.

FIG. **7**B is a flow diagram illustrating an example process for receiving, combining and storing driving data at an event detector according to an embodiment of the present invention. In the illustrated embodiment, once the event detector detects

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a driving event or receives an event trigger, the event detector requests data from at least one event capture device, receives buffers with data from the event capture device, indexes appropriate portions of data as pre-event data, during-event data and post-event data, and concatenates the portions into one event. For example, for a given driving event, the event detector can concatenate pre-event data, during-the-event data and post-event data into a single driving event. The trigger which indicates the start of a driving event which may require analysis may be based on the output of a g-force sensor, audio data, or application of a brake pedal or the like. In one embodiment, the event detector may monitor for a predetermined output or event trigger from a sensor or the like, and on receipt of this output sends a trigger or request to one or more event capture devices to send data captured in their buffers to the event detector, and stores the time of receipt of the trigger as the event trigger time.

At a step **514**, the event detector receives a trigger at time $t_{trigger}$. A request is then sent to one or more event capture devices to send captured data (step **515**). The captured data in the buffer includes pre-event data, i.e. the data that the event capture device had stored in the buffer prior to the trigger time.

The event detector then receives buffers of captured data from the event capture device (step **516**), or several event capture devices when the event detector has instructed more than one device to send its captured data. At a step **517**, the event detector stores its own buffer with pre-event data and assigns a meta tag "$t_{(pre)}$" to the beginning of the pre-event data and a meta tag "$t_{(trigger)}$" to the end of the pre-event data.

At a step **518**, the event detector stores received event data (i.e. data received from the event capture devices starting at the trigger time $t_{(trigger)}$) and assigns the meta tag "$t_{(trigger)}$" to the beginning of the event data. While collecting event data, the event detector continuously monitors the trigger status (**520**), and continues to store event data while the trigger remains on. The trigger state changes to "off" when the driving event is over (i.e. the trigger conditions are no longer in effect, or a sensor output or end trigger indicates that the event is at an end, or a predetermined time period has expired). The actual event duration may be controlled by an ON and OFF trigger status, i.e. the event detector requests data from event capture devices when the trigger status changes to ON, and assigns an end time to the event when the trigger status changes to OFF. At this point, the event detector assigns a meta tag "$t_{(end)}$" to the end of the event data, and continues to store and receive post-event data from the or each event capture device for a predetermined time period (step **522**). In step **522**, the event detector stores one or more buffers with the post-event data and assigns the meta tag "$t_{(end)}$" to the beginning of the post-event data and a meta tag "$t_{(post)}$" to the end of the post-event data. When the desired amount of post event data has been received by the event detector, the event capture device is instructed to stop sending data (step **524**). This may done by changing a trigger status to OFF. It will be understood that any desired pre-event and post-event time period may be selected for completing the captured driving event

The data are indexed in steps **517**, **518** and **522** as follows: the beginning and the end of the pre-event data are indexed by meta-tags "$t_{(pre)}$" and "$t_{(trigger)}$," the beginning and the end of the event data are indexed by meta-tags "$t_{(trigger)}$" and "$t_{(end)}$," and the beginning and the end of the post-event data are indexed by meta-tags "$t_{(end)}$" and "$t_{(post)}$."

At a step **526**, the event detector combines the pre-event data, during-the-event-data and post-event data with the appropriate metadata tags into a single event record. Then, at a step **528**, the event detector sends the single event record to the evaluation server. The buffers are concatenated as it was described in FIG. **4**.

FIG. **8** is a flow diagram illustrating an example process for cueing and playing driving event data according to an embodiment of the present invention. In the illustrated embodiment, an analysis station loads the captured driving event data to a playing device, cues the data and plays the data for review. If necessary, the driving data may be iteratively re-cued and re-played until the review is completed.

At a step **550**, the analysis station loads the captured driving event data to a playing device for review. The concatenated captured driving event data may comprise the pre-event data, during-the-event data and post-event data.

At a step **552**, the analysis station sets a cue interval. The cue interval is a leading time used to determine how many seconds of pre-event data are going to be played before the playing of the during-the-event data starts. The size of the cue interval depends on the type of the driving event and the circumstances of the review. Usually, at first, the cue interval is ad hoc selected to be a small period of time, and later it is refined to a more accurate time interval. For example, the cue interval may be at first set to two seconds. If the two-second-cue interval is acceptable, the last two seconds of the pre-event data are going to be played before the playing of the event data. In an alternative embodiment, the cue interval may be set to a period of time measured in minutes, etc.

At a step **554**, the analysis station determines the cue point for the playing of the captured driving event data. The cue point is computed by subtracting the cue interval from the trigger time. For example, if the cue interval is two seconds, then the cue point is set to two seconds prior to the trigger time.

At a step **556**, the analysis station initiates the playing of the captured event data starting from the cue point. Then, if a reviewer requests that the data be backed off (step **558**), the analysis station increases the cue interval (step **570**), adjusts the cue point to reflect the new cue interval (step **554**), and restarts the playback from the new cue point (step **556**).

The process of adjusting the cue point and playing back is repeated until further adjustments of the cue point are unnecessary. Once that is achieved, at step **560**, the playing of the captured driving event data is continued until the end of the driving event or until an operator stops the playing. For example, the operator may want to view at least part of the post-event data **506** before stopping the playback.

FIG. **9** is a block diagram illustrating an exemplary wireless communication device **650** that may be used in connection with the various embodiments described herein. For example, the wireless communication device **650** may be used in conjunction with an event detector previously described with respect to FIGS. **1-2**, or an evaluation server or an analysis station previously described with respect to FIGS. **5-6**. However, other wireless communication devices and/or architectures may also be used, as will be clear to those skilled in the art.

In the illustrated embodiment, wireless communication device **650** comprises an antenna **652**, a multiplexor **654**, a low noise amplifier ("LNA") **656**, a power amplifier ("PA") **658**, a modulation circuit **660**, a baseband processor **662**, a speaker **664**, a microphone **666**, a central processing unit ("CPU") **668**, a data storage area **670**, and a hardware interface **672**. In the wireless communication device **650**, radio frequency ("RF") signals are transmitted and received by antenna **652**. Multiplexor **654** acts as a switch coupling antenna **652** between the transmit and receive signal paths. In the receive path, received RF signals are coupled from a

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multiplexor **654** to LNA **656**. LNA **656** amplifies the received RF signal and couples the amplified signal to a demodulation portion of the modulation circuit **660**.

Typically modulation circuit **660** combines a demodulator and modulator in one integrated circuit ("IC"). The demodulator and modulator can also be separate components. The demodulator strips away the RF carrier signal leaving a base-band receive audio signal, which is sent from the demodulator output to the base-band processor **662**.

If the base-band receive audio signal contains audio information, then base-band processor **662** decodes the signal and converts it to an analog signal. Then the signal is amplified and sent to the speaker **664**. The base-band processor **662** also receives analog audio signals from the microphone **666**. These analog audio signals are converted to digital signals and encoded by the base-band processor **662**. The base-band processor **662** also codes the digital signals for transmission and generates a base-band transmit audio signal that is routed to the modulator portion of modulation circuit **660**. The modulator mixes the base-band transmit audio signal with an RF carrier signal generating an RF transmit signal that is routed to the power amplifier **658**. The power amplifier **658** amplifies the RF transmit signal and routes it to the multiplexor **654** where the signal is switched to the antenna port for transmission by antenna **652**.

The baseband processor **662** is also communicatively coupled with the central processing unit **668**. The central processing unit **668** has access to a data storage area **670**. The central processing unit **668** is preferably configured to execute instructions (i.e., computer programs or software) that can be stored in the data storage area **670**. Computer programs can also be received from the baseband processor **662** and stored in the data storage area **670** or executed upon receipt. Such computer programs, when executed, enable the wireless communication device **650** to perform the various functions of the present invention as previously described.

In this description, the term "computer readable medium" is used to refer to any media used to provide executable instructions (e.g., software and computer programs) to the wireless communication device **650** for execution by the central processing unit **668**. Examples of these media include the data storage area **670**, microphone **666** (via the baseband processor **662**), antenna **652** (also via the baseband processor **662**), and hardware interface **672**. These computer readable mediums are means for providing executable code, programming instructions, and software to the wireless communication device **650**. The executable code, programming instructions, and software, when executed by the central processing unit **668**, preferably cause the central processing unit **668** to perform the inventive features and functions previously described herein.

The central processing unit is also preferably configured to receive notifications from the hardware interface **672** when new devices are detected by the hardware interface. Hardware interface **672** can be a combination electromechanical detector with controlling software that communicates with the CPU **668** and interacts with new devices.

FIG. **10** is a block diagram illustrating an exemplary computer system **750** that may be used in connection with the various embodiments described herein. For example, the computer system **750** may be used in conjunction with an event detector previously described with respect to FIGS. **1-2**, or an evaluation server or an analysis station previously described with respect to FIGS. **5-6**. However, other computer systems and/or architectures may be used, as will be clear to those skilled in the art.

The computer system **750** preferably includes one or more processors, such as processor **752**. Additional processors may be provided, such as an auxiliary processor to manage input/output, an auxiliary processor to perform floating point mathematical operations, a special-purpose microprocessor having an architecture suitable for fast execution of signal processing algorithms (e.g., digital signal processor), a slave processor subordinate to the main processing system (e.g., back-end processor), an additional microprocessor or controller for dual or multiple processor systems, or a coprocessor. Such auxiliary processors may be discrete processors or may be integrated with the processor **752**.

The processor **752** is preferably connected to a communication bus **754**. The communication bus **754** may include a data channel for facilitating information transfer between storage and other peripheral components of the computer system **750**. The communication bus **754** further may provide a set of signals used for communication with the processor **752**, including a data bus, address bus, and control bus (not shown). The communication bus **754** may comprise any standard or non-standard bus architecture such as, for example, bus architectures compliant with industry standard architecture ("ISA"), extended industry standard architecture ("EISA"), Micro Channel Architecture ("MCA"), peripheral component interconnect ("PCI") local bus, or standards promulgated by the Institute of Electrical and Electronics Engineers ("IEEE") including IEEE 488 general-purpose interface bus ("GPIB"), IEEE 696/S-100, and the like.

Computer system **750** preferably includes a main memory **756** and may also include a secondary memory **758**. The main memory **756** provides storage of instructions and data for programs executing on the processor **752**. The main memory **756** is typically semiconductor-based memory such as dynamic random access memory ("DRAM") and/or static random access memory ("SRAM"). Other semiconductor-based memory types include, for example, synchronous dynamic random access memory ("SDRAM"), Rambus dynamic random access memory ("RDRAM"), ferroelectric random access memory ("FRAM"), and the like, including read only memory ("ROM").

The secondary memory **758** may optionally include a hard disk drive **760** and/or a removable storage drive **762**, for example a floppy disk drive, a magnetic tape drive, a compact disc ("CD") drive, a digital versatile disc ("DVD") drive, etc. The removable storage drive **762** reads from and/or writes to a removable storage medium **764** in a well-known manner. Removable storage medium **764** may be, for example, a floppy disk, magnetic tape, CD, DVD, etc.

The removable storage medium **764** is preferably a computer readable medium having stored thereon computer executable code (i.e., software) and/or data. The computer software or data stored on the removable storage medium **764** is read into the computer system **750** as electrical communication signals **778**.

In alternative embodiments, secondary memory **758** may include other similar means for allowing computer programs or other data or instructions to be loaded into the computer system **750**. Such means may include, for example, an external storage medium **772** and an interface **770**. Examples of external storage medium **772** may include an external hard disk drive or an external optical drive, or an external magneto-optical drive.

Other examples of secondary memory **758** may include semiconductor-based memory such as programmable read-only memory ("PROM"), erasable programmable read-only memory ("EPROM"), electrically erasable read-only memory ("EEPROM"), or flash memory (block oriented

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memory similar to EEPROM). Also included are any other removable storage units **772** and interfaces **770**, which allow software and data to be transferred from the removable storage unit **772** to the computer system **750**.

Computer system **750** may also include a communication interface **774**. The communication interface **774** allows software and data to be transferred between computer system **750** and external devices (e.g. printers), networks, or information sources. For example, computer software or executable code may be transferred to computer system **750** from a network server via communication interface **774**. Examples of communication interface **774** include a modem, a network interface card ("NIC"), a communications port, a PCMCIA slot and card, an infrared interface, and an IEEE 1394 fire-wire, just to name a few.

Communication interface **774** preferably implements industry promulgated protocol standards, such as Ethernet IEEE 802 standards, Fiber Channel, digital subscriber line ("DSL"), asynchronous digital subscriber line ("ADSL"), frame relay, asynchronous transfer mode ("ATM"), integrated digital services network ("ISDN"), personal communications services ("PCS"), transmission control protocol/Internet protocol ("TCP/IP"), serial line Internet protocol/point to point protocol ("SLIP/PPP"), and so on, but may also implement customized or non-standard interface protocols as well.

Software and data transferred via communication interface **774** are generally in the form of electrical communication signals **778**. These signals **778** are preferably provided to communication interface **774** via a communication channel **776**. Communication channel **776** carries signals **778** and can be implemented using a variety of wired or wireless communication means including wire or cable, fiber optics, conventional phone line, cellular phone link, wireless data communication link, radio frequency (RF) link, or infrared link, just to name a few.

Computer executable code (i.e., computer programs or software) is stored in the main memory **756** and/or the secondary memory **758**. Computer programs can also be received via communication interface **774** and stored in the main memory **756** and/or the secondary memory **758**. Such computer programs, when executed, enable the computer system **750** to perform the various functions of the present invention as previously described.

In this description, the term "computer readable medium" is used to refer to any media used to provide computer executable code (e.g., software and computer programs) to the computer system **750**. Examples of these media include main memory **756**, secondary memory **758** (including hard disk drive **760**, removable storage medium **764**, and external storage medium **772**), and any peripheral device communicatively coupled with communication interface **774** (including a network information server or other network device). These computer readable mediums are means for providing executable code, programming instructions, and software to the computer system **750**.

In an embodiment that is implemented using software, the software may be stored on a computer readable medium and loaded into computer system **750** by way of removable storage drive **762**, interface **770**, or communication interface **774**. In such an embodiment, the software is loaded into the computer system **750** in the form of electrical communication signals **778**. The software, when executed by the processor **752**, preferably causes the processor **752** to perform the inventive features and functions previously described herein.

Various embodiments may also be implemented primarily in hardware using, for example, components such as application specific integrated circuits ("ASICs"), or field programmable gate arrays ("FPGAs"). Implementation of a hardware state machine capable of performing the functions described herein will also be apparent to those skilled in the relevant art. Various embodiments may also be implemented using a combination of both hardware and software.

Furthermore, those of skill in the art will appreciate that the various illustrative logical blocks, modules, circuits, and method steps described in connection with the above described figures and the embodiments disclosed herein can often be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled persons can implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the invention. In addition, the grouping of functions within a module, block, circuit or step is for ease of description. Specific functions or steps can be moved from one module, block or circuit to another without departing from the invention.

Moreover, the various illustrative logical blocks, modules, and methods described in connection with the embodiments disclosed herein can be implemented or performed with a general purpose processor, a digital signal processor ("DSP"), an ASIC, FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor can be a microprocessor, but in the alternative, the processor can be any processor, controller, microcontroller, or state machine. A processor can also be implemented as a combination of computing devices, for example, a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

Additionally, the steps of a method or algorithm described in connection with the embodiments disclosed herein can be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module can reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium including a network storage medium. An exemplary storage medium can be coupled to the processor such that the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium can be integral to the processor. The processor and the storage medium can also reside in an ASIC.

The above description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the invention. Various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles described herein can be applied to other embodiments without departing from the spirit or scope of the invention. Thus, it is to be understood that the description and drawings presented herein represent a presently preferred embodiment of the invention and are therefore representative of the subject matter which is broadly contemplated by the present invention. It is further understood that the scope of the present invention fully encompasses other embodiments that may become obvious to those skilled in the art and that the scope of the present invention is accordingly limited by nothing other than the appended claims.

The invention claimed is:

1. A system for selective reviewing of driving event data comprising: an event detector coupled with a vehicle, configured to capture and store driving events, each said captured

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and stored driving event having a pre-event time, a trigger time and a post-event time; an evaluation server configured to receive and store a plurality of said driving events from the event detector and provide said driving events for analysis; and an analysis station comprising a data loading module, a data indexing module, a data control module, and a data playing module, wherein the data loading module is configured to receive the captured driving event from the evaluation server and load the captured driving event for review, the data indexing module is configured to cue up the captured driving event at a selected cue time that is prior to the trigger time, and to adjust the cue time within the range between the pre-event time and the trigger time, and the data playing module is configured to play the cued up driving event from the cue time to the post-event time.

2. The system of claim **1**, wherein the data control module is configured to stop the playing of the cued up driving event, request an adjustment of the cue time, and request the playing of the driving event from a new cue time.

3. The system of claim **1**, wherein the captured driving event comprises information collected from inside the vehicle.

4. The system method of claim **1**, wherein the captured driving event comprises information collected from outside the vehicle.

5. The system of claim **1**, wherein the captured driving event comprises information from an internal vehicle bus about the baseline noise level of the operating vehicle.

6. The system of claim **1**, wherein the captured driving event comprises video data.

7. The system of claim **6**, wherein the video data comprises stilt images.

8. The system of claim **6**, wherein the video data comprises moving images.

9. The system of claim **1**, wherein the captured driving event comprises audio data.

10. The system of claim **1**, wherein the captured driving event comprises metadata.

11. The system of claim **1**, wherein the event detector further comprises at least one event capture device for capturing driving events.

12. The system of claim **11**, wherein the event capture device comprises a video camera.

13. The system of claim **11**, wherein the event capture device comprises a still camera.

14. The system of claim **11**, wherein the event capture device comprises a microphone.

15. The system of claim **1**, further comprising a plurality of event capture devices communicatively coupled with the event detector and configured to capture and store driving event data, the event detector being configured to receive captured data from selected event capture devices on detection of a driving event.

16. The system of claim **15**, wherein the event capture devices are selected from a group consisting of: image capture devices, audio data capture devices, and meta data capture devices.

17. The system of claim **15**, wherein the event capture devices comprise at least a video camera, an audio data capture device, and a meta data capture device.

18. A method for selective reviewing of driving event data, comprising: capturing and indexing a driving event at an event detector, wherein the event detector is coupled with a vehicle, and wherein the captured driving event has a trigger time; sending the captured driving event from the event detector to an evaluation sewer; receiving and storing a plurality of said driving events at the evaluation server; sending the captured driving event from the evaluation server to an analysis station; receiving the captured driving event at the analysis station and loading the captured driving event for review; cueing up the captured driving event at a cue time set prior to the trigger time; and playing the cued up driving event from the cue time, further comprising adjusting the cue time within the range between a pre-event time and the trigger time, and playing the captured event from a new cue time.

19. The method of claim **18**, wherein capturing and indexing a driving event comprises capturing and indexing information collected from inside the vehicle.

20. The method of claim **18**, wherein capturing and indexing a driving event comprises capturing and indexing information collected from outside the vehicle.

21. The method of claim **18**, wherein capturing and indexing a driving event comprises capturing and indexing information collected from an internal vehicle bus about the baseline noise level of the operating vehicle.

22. The method of claim **18**, wherein capturing and indexing a driving event comprises capturing and indexing still images.

23. The method of claim **18**, wherein capturing and indexing a driving event comprises capturing and indexing moving images.

24. The method of claim **18**, wherein capturing and indexing a driving event comprises capturing and indexing metadata.

25. The method of claim **18**, wherein capturing and indexing a driving event comprises capturing and indexing audio data.

26. The method of claim **18**, wherein capturing and indexing a driving event comprises capturing and indexing data from at least one event capture device.

27. The method of claim **26**, wherein capturing and indexing a driving event comprises capturing and indexing data from a plurality of event capture devices.

28. The method of claim **27**, wherein capturing and indexing a driving event comprises capturing and indexing data from at least an image recording device, a microphone, and a meta data capture device.

29. The method of claim **18**, wherein the event detector indexes the captured driving event with an event trigger time, a selected pre-event start time prior to the trigger time, an event end time, and a post-event end time at a predetermined time interval after the event end time, and the captured driving event comprises pre-event data from the pre-event start time to the trigger time, event data from the trigger time to the event end time, and post-event data from the event end time to the post-event end time.

30. The method of claim **29**, wherein the cue time is at a selected time between the pre-event start time and the trigger time.

31. The method of claim **29**, wherein the event detector further indexes the captured driving event with a post-event time, and the post-event time is a selected time between the event end time and the post-event end time.

32. The method of claim **18**, wherein capturing and indexing a driving event further comprises the steps of: capturing data in buffers; detecting an event start trigger; identifying buffered data received prior to the event start trigger as pre-event data; identifying buffered data received from the event start trigger until detection of an event end trigger as event data; detecting the event end trigger; and identifying buffered data received after the event end trigger as post-event data.

33. The method of claim **32**, wherein capturing and indexing a driving event further comprises the step of: combining the pr-event data, event data, and post-event data into a single diving event record.

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United States Patent
Etcheson

(10) Number: US 7,804,426 C1
(45) Certificate Issued: Mar. 18, 2013

(54) **SYSTEM AND METHOD FOR SELECTIVE REVIEW OF EVENT DATA**

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(51) **Int. Cl.**
G08G 1/017 (2006.01)

(52) **U.S. Cl.** **340/937**; 348/148; 701/35; 340/439; 340/576; 702/188; 709/219; 725/86; 725/91; 725/93; 725/94; 725/143; 725/144; 725/145; 725/146

(58) **Field of Classification Search** ..... None
See application file for complete search history.

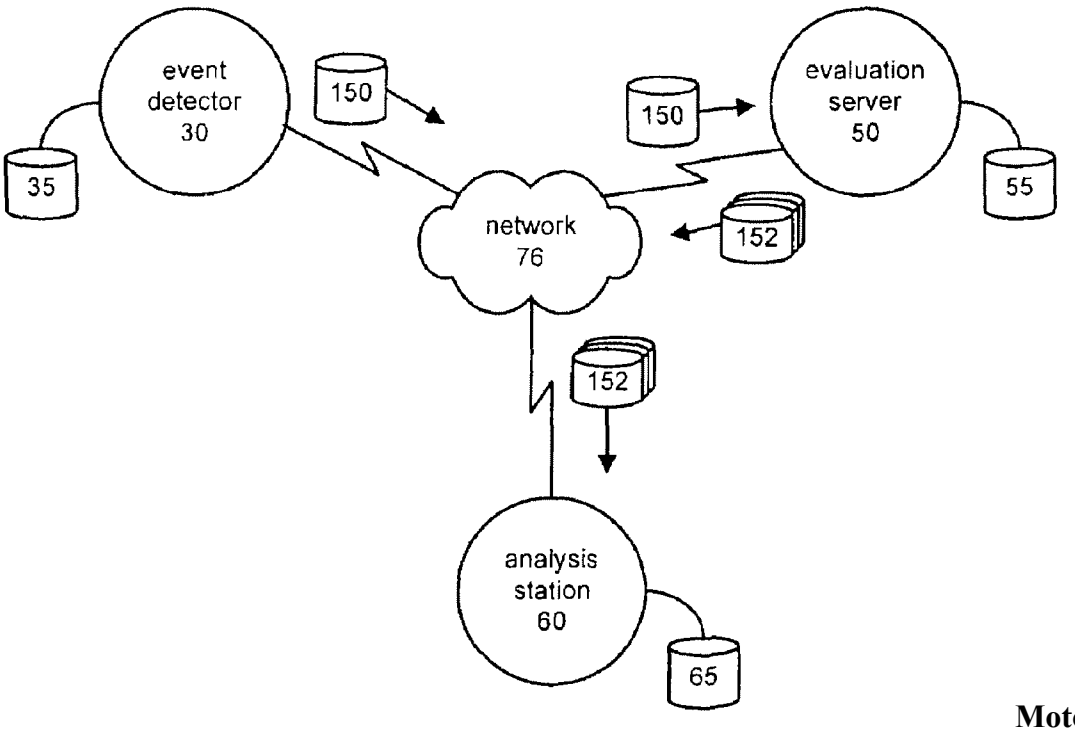
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To view the complete listing of prior art documents cited during the proceedings for Reexamination Control Numbers 95/001,781 and 95/001,802, please refer to the USPTO's public Patent Application Information Retrieval (PAIR) system under the Display References tab.

Primary Examiner — Jalatee Worjloh

(57) **ABSTRACT**

Systems and methods for computer assisted cueing and selective reviewing of driving data in order to save time in the data review process are provided. The method allows identifying essential portions of the data, selecting the essential portions, reviewing the selected data and retrieving additional data leading to the event if necessary. At least one event capture device continuously captures data into a buffer. The data are sent to an event detector communicatively coupled to the event capture device only when the event detector requests them. After receiving the data, the event detector selects and indexes a pre-event portion, during-event portion and post-event portion, combines the portions of captured data into a single driving event record and sends the driving event record to the evaluation server. From the server, the driving event record is sent to the analysis station for review and analysis.



INTER PARTES REEXAMINATION CERTIFICATE ISSUED UNDER 35 U.S.C. 316

THE PATENT IS HEREBY AMENDED AS INDICATED BELOW.

Matter enclosed in heavy brackets [ ] appeared in the patent, but has been deleted and is no longer a part of the patent; matter printed in italics indicates additions made to the patent.

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

The patentability of claims **1-33** is confirmed.

New claims **34-85** are added and determined to be patentable.

34. The system of claim 1, wherein the analysis station is configured to provide a report generated at least in part by using the analysis station.

35. The system of claim 34, wherein a portion of the captured driving event is incorporated in the report.

36. The system of claim 34, wherein the analysis station is configured to provide the report to the evaluation server for storage.

37. The system of claim 1, wherein the cue time is set to be at a start point in time for a portion of the captured driving event to be played for analysis, and wherein certain portions of the captured driving event are incorporated into a report.

38. The system of claim 1, wherein the cue time is determined to be prior to the trigger time.

39. The system of claim 1, wherein the data indexing module is configured to adjust the cue time within the range between the pre-event time and the trigger time such that the interval between the adjusted cue time and the trigger time includes essential data from the captured driving event that precedes the trigger time, and wherein the essential data comprises data that is not skipped during a review.

40. The system of claim 1, wherein the data indexing module is configured to adjust the cue time within the range between the pre-event time and the trigger time such that the interval between the adjusted cue time and the trigger time excludes non-essential data from the captured driving event that precedes the trigger time, and wherein the non-essential data comprises data that is pre-event data that is skipped during a review.

41. The system of claim 1, wherein the data indexing module is configured to adjust the cue time within the range between the pre-event time and the trigger time to indicate a portion of the captured driving event to be shown to a driver.

42. The system of claim 1, wherein the interval between the selected cue time and the trigger time is based at least in part on a type of the captured driving event.

43. The system of claim 1, wherein the interval between the selected cue time and the trigger time is based at least in part on a circumstance of reviewing the captured driving event.

44. The system of claim 1, wherein the event detector is configured to concatenate a plurality of data buffers.

45. The system of claim 44, wherein the event detector is configured to concatenate data of the captured driving event.

46. The system of claim 1, wherein the analysis station is configured to receive a group of driving events from the evaluation server.

47. The system of claim 46, wherein the analysis station is configured to provide the group of driving events to an operator for identification of any number of events in the group of driving events that need to be reported.

48. The system of claim 46, wherein the analysis station is configured to provide the group of driving events to an operator for identification of any number of events in the group of driving events that need to be shown to a driver.

49. The system of claim 46, wherein the group pertains to a particular driver.

50. The system of claim 46, wherein the group pertains to a particular company.

51. The system of claim 46, wherein the group pertains to a particular supervisor.

52. The system of claim 46, wherein the group pertains to a particular shift.

53. The system of claim 46, wherein the group pertains to a particular reporting structure.

54. The system of claim 46, wherein the group is based at least in part on a search for events that pertain to a particular driver.

55. The system of claim 46, wherein the group is based at least in part on a search for events that pertain to a particular company.

56. The system of claim 46, wherein the group is based at least in part on a search for events that pertain to a particular supervisor.

57. The system of claim 46, wherein the group is based at least in part on a search for events that pertain to a particular shift.

58. The system of claim 46, wherein the group is based at least in part on a search for events that pertain to a particular reporting structure.

59. The system of claim 1, wherein the cue time is selected by subtracting a cue interval from the trigger time and the cue time is adjusted by increasing the cue interval.

60. The method of claim 18, further comprising providing a report generated at least in part by using the analysis station.

61. The method of claim 60, wherein a portion of the captured driving event is incorporated in the report.

62. The method of claim 60, wherein providing the report includes providing the report to the evaluation server for storage.

63. The method of claim 18, wherein the cue time is set to be at a start point in time for a portion of the captured driving event to be played for analysis, and wherein certain portions of the captured driving event are incorporated into a report.

64. The method of claim 18, wherein the cue time is determined to be prior to the trigger time.

65. The method of claim 18, wherein adjusting the cue time includes adjusting the cue time such that the interval between the adjusted cue time and the trigger time includes essential data from the captured driving event that precedes the trigger time.

66. The method of claim 18, wherein adjusting the cue time includes adjusting the cue time such that the interval between the adjusted cue time and the trigger time excludes non-essential data from the captured driving event that precedes the trigger time.

67. The method of claim 18, wherein adjusting the cue time includes adjusting the cue time to indicate a portion of the captured driving event to be shown to a driver.

68. The method of claim 18, wherein the interval between the cue time set prior to the trigger time and the trigger time is based at least in part on a type of the captured driving event.

69. The method of claim 18, wherein the interval between the cue time set prior to the trigger time and the trigger time is based at least in part on a circumstance of reviewing the captured driving event.

70. The method of claim 18, wherein the event detector is configured to concatenate a plurality of data buffers.

71. The method of claim 70, wherein the event detector is configured to concatenate data of the captured driving event.

72. The method of claim 18, wherein the analysis station is configured to receive a group of driving events from the evaluation server.

73. The method of claim 72, wherein the analysis station is configured to provide the group of driving events to an operator for identification of any number of events in the group of driving events that need to be reported.

74. The method of claim 72, wherein the analysis station is configured to provide the group of driving events to an operator for identification of any number of events in the group of driving events that need to be shown to a driver.

75. The method of claim 72, wherein the group pertains to a particular driver.

76. The method of claim 72, wherein the group pertains to a particular company.

77. The method of claim 72, wherein the group pertains to a particular supervisor.

78. The method of claim 72, wherein the group pertains to a particular shift.

79. The method of claim 72, wherein the group pertains to a particular reporting structure.

80. The method of claim 72, wherein the group is based at least in part on a search for events that pertain to a particular driver.

81. The method of claim 72, wherein the group is based at least in part on a search for events that pertain to a particular company.

82. The method of claim 72, wherein the group is based at least in part on a search for events that pertain to a particular supervisor.

83. The method of claim 72, wherein the group is based at least in part on a search for events that pertain to a particular shift.

84. The method of claim 72, wherein the group is based at least in part on a search for events that pertain to a particular reporting structure.

85. The method of claim 18, wherein the cue time is set prior to the trigger time by subtracting a cue interval from the trigger time and the cue time is adjusted by increasing the cue interval.

* * * * *

Appendix D

US 20020131768A1

(19) **United States**

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Gammenthaler (43) **Pub. Date: Sep. 19, 2002**

(54) **IN-CAR DIGITAL VIDEO RECORDING WITH MPEG-4 COMPRESSION FOR POLICE CRUISERS AND OTHER VEHICLES**

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Morgan Hill, CA 95038 (US)

(21) Appl. No.: **09/812,412**

(22) Filed: **Mar. 19, 2001**

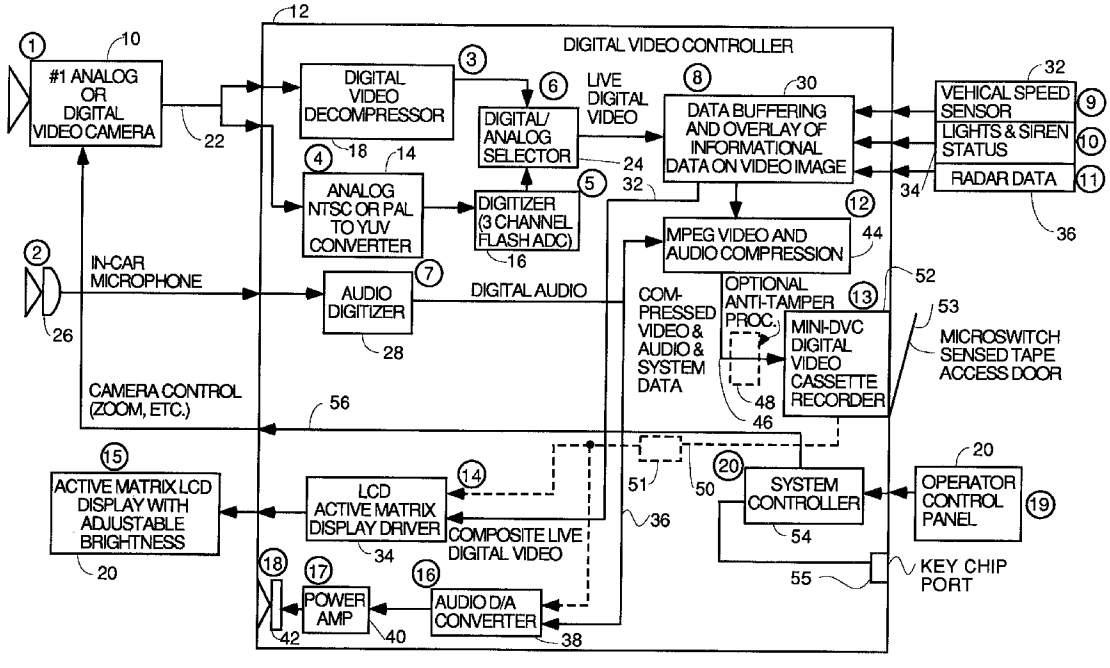
Publication Classification

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(52) **U.S. Cl.** **386/107**; 386/104

(57) **ABSTRACT**

An in-car video system with inputs for one or more analog or digital video cameras, one or more of which may be wireless, and having inputs for one or more microphones, one or more of which may be wireless. The system includes circuitry to digitize the input signals, if necessary, merge the data with system status data and compress the resulting data with any algorithm, preferably MPEG 4. A digital data cassette recorder records the compressed data, and a decompression circuit and active matrix display and audio channel provide monitoring capability of live video and audio. In some embodiments, a hard disk continuously records all data and archives previously recorded data to tape when so ordered to provide after-the-fact recording capability. In some embodiments, anti-tampering circuitry renders the recorded data tamper-proof, and a local playback circuit allows local playback of either live or previously recorded video.



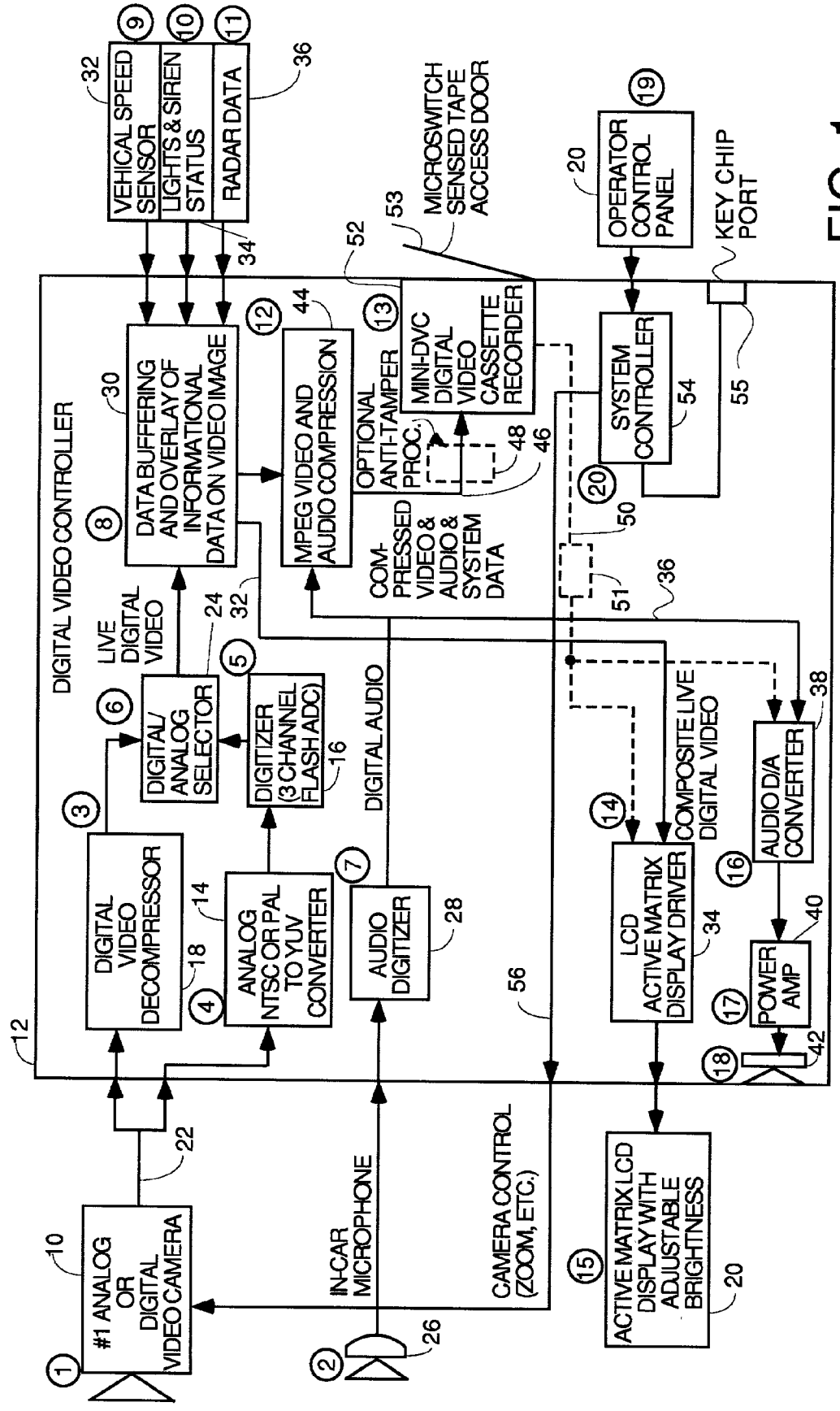

DIGITAL VIDEO CONTROLLER
#1 ANALOG OR DIGITAL VIDEO CAMERA
IN-CAR MICROPHONE
CAMERA CONTROL (ZOOM, ETC.)
ACTIVE MATRIX LCD DISPLAY WITH ADJUSTABLE BRIGHTNESS
DIGITAL VIDEO DECOMPRESSOR
ANALOG NTSC OR PAL TO YUV CONVERTER
AUDIO DIGITIZER
DIGITAL/ ANALOG SELECTOR
DIGITIZER (3 CHANNEL FLASH ADC)
LIVE DIGITAL VIDEO
DIGITAL AUDIO
DATA BUFFERING AND OVERLAY OF INFORMATIONAL DATA ON VIDEO IMAGE
MPEG VIDEO AND AUDIO COMPRESSION
OPTIONAL ANTI-TAMPER PROC.
MINI-DVC DIGITAL VIDEO CASSETTE RECORDER
COM-PRESSED VIDEO & AUDIO & SYSTEM DATA
SYSTEM CONTROLLER
LCD ACTIVE MATRIX DISPLAY DRIVER
COMPOSITE LIVE DIGITAL VIDEO
AUDIO D/A CONVERTER
POWER AMP
VEHICAL SPEED SENSOR
LIGHTS & SIREN STATUS
RADAR DATA
MICROSWITCH SENSED TAPE ACCESS DOOR
OPERATOR CONTROL PANEL
KEY CHIP PORT

FIG. 1

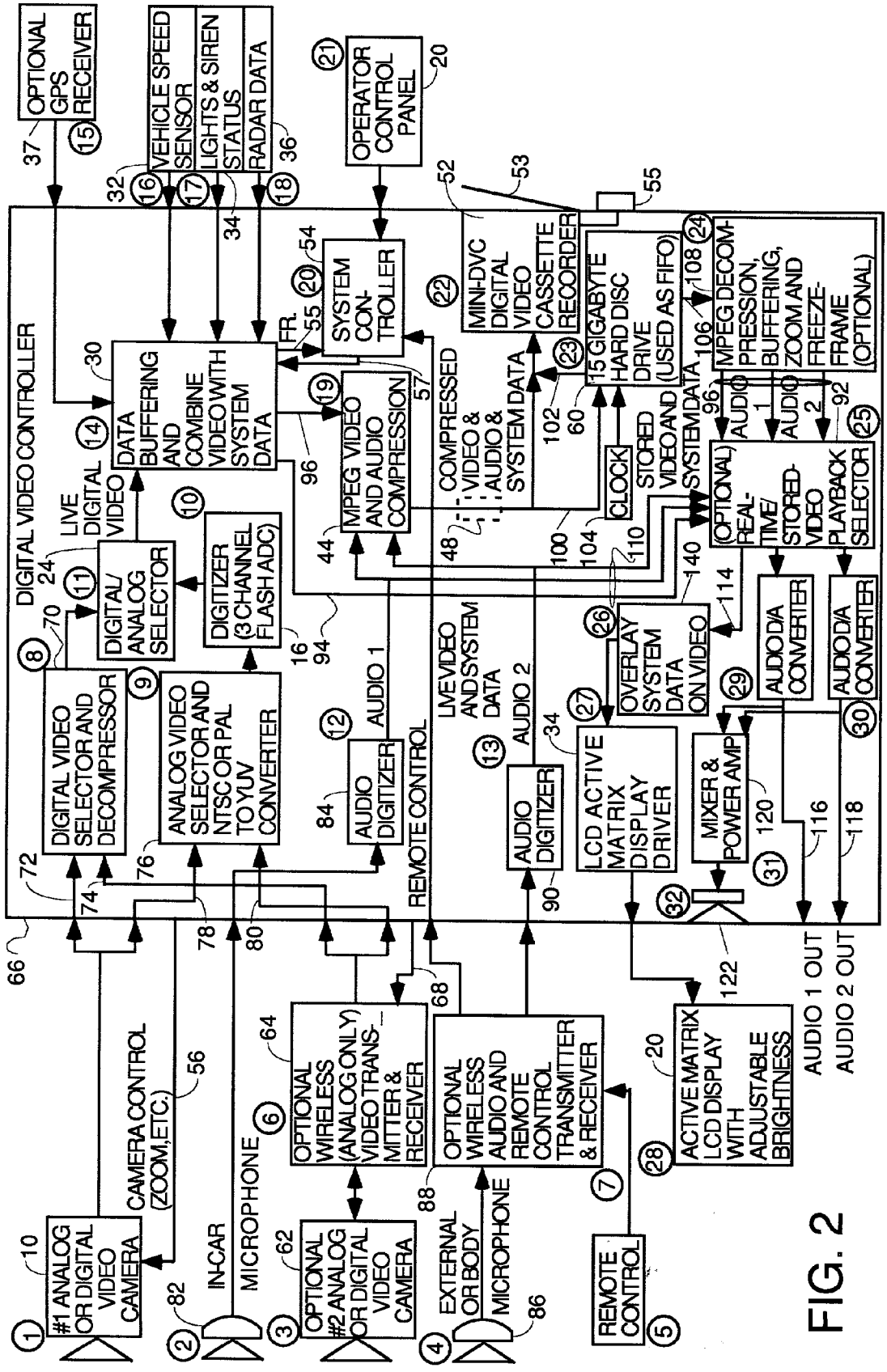

DIGITAL VIDEO CONTROLLER
OPTIONAL GPS RECEIVER
VEHICLE SPEED SENSOR
LIGHTS & SIREN STATUS
RADAR DATA
OPERATOR CONTROL PANEL
SYSTEM CONTROLLER
MINI-DVC DIGITAL VIDEO CASSETTE RECORDER
15 GIGABYTE HARD DISC DRIVE (USED AS FIFO)
MPEG DECOMPRESSION, BUFFERING, ZOOM AND FREEZE-FRAME (OPTIONAL)
DATA BUFFERING AND COMBINE VIDEO WITH SYSTEM DATA
MPEG VIDEO AND AUDIO COMPRESSION
COMPRESSED VIDEO & AUDIO & SYSTEM DATA
STORED VIDEO AND SYSTEM DATA
CLOCK
(OPTIONAL) REAL-TIME/ STORED-VIDEO PLAYBACK SELECTOR
LIVE DIGITAL VIDEO
DIGITAL/ ANALOG SELECTOR
DIGITIZER (3 CHANNEL FLASH ADC)
DIGITAL VIDEO SELECTOR AND DECOMPRESSOR
ANALOG VIDEO SELECTOR AND NTSC OR PAL TO YUV CONVERTER
AUDIO DIGITIZER
AUDIO 1
AUDIO 2
LIVE VIDEO AND SYSTEM DATA
REMOTE CONTROL
OVERLAY SYSTEM DATA ON VIDEO
LCD ACTIVE MATRIX DISPLAY DRIVER
MIXER & POWER AMP
AUDIO D/A CONVERTER
AUDIO D/A CONVERTER
AUDIO 1 OUT
AUDIO 2 OUT
#1 ANALOG OR DIGITAL VIDEO CAMERA
CAMERA CONTROL (ZOOM, ETC.)
IN-CAR MICROPHONE
OPTIONAL WIRELESS (ANALOG ONLY) VIDEO TRANSMITTER & RECEIVER
OPTIONAL #2 ANALOG OR DIGITAL VIDEO CAMERA
OPTIONAL WIRELESS AUDIO AND REMOTE CONTROL TRANSMITTER & RECEIVER
EXTERNAL OR BODY MICROPHONE
REMOTE CONTROL
ACTIVE MATRIX LCD DISPLAY WITH ADJUSTABLE BRIGHTNESS

FIG. 2

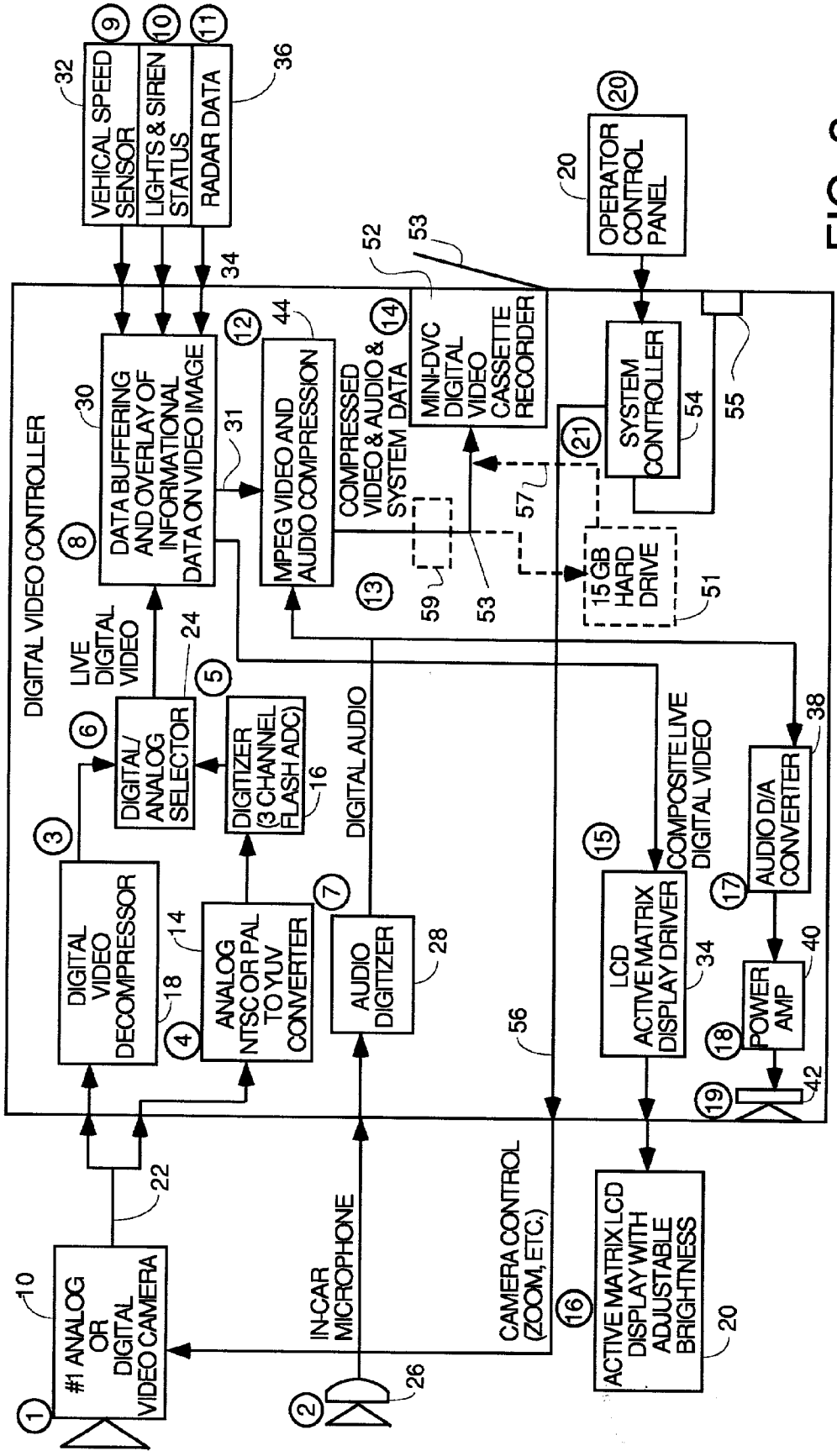

DIGITAL VIDEO CONTROLLER
#1 ANALOG OR DIGITAL VIDEO CAMERA
IN-CAR MICROPHONE
CAMERA CONTROL (ZOOM, ETC.)
ACTIVE MATRIX LCD DISPLAY WITH ADJUSTABLE BRIGHTNESS
DIGITAL VIDEO DECOMPRESSOR
ANALOG NTSC OR PAL TO YUV CONVERTER
AUDIO DIGITIZER
DIGITAL AUDIO
DIGITAL/ ANALOG SELECTOR
DIGITIZER (3 CHANNEL FLASH ADC)
LIVE DIGITAL VIDEO
DATA BUFFERING AND OVERLAY OF INFORMATIONAL DATA ON VIDEO IMAGE
MPEG VIDEO AND AUDIO COMPRESSION
COMPRESSED VIDEO & AUDIO & SYSTEM DATA
MINI-DVC DIGITAL VIDEO CASSETTE RECORDER
15 GB HARD DRIVE
SYSTEM CONTROLLER
OPERATOR CONTROL PANEL
VEHICAL SPEED SENSOR
LIGHTS & SIREN STATUS
RADAR DATA
LCD ACTIVE MATRIX DISPLAY DRIVER
COMPOSITE LIVE DIGITAL VIDEO
AUDIO D/A CONVERTER
POWER AMP

FIG. 3

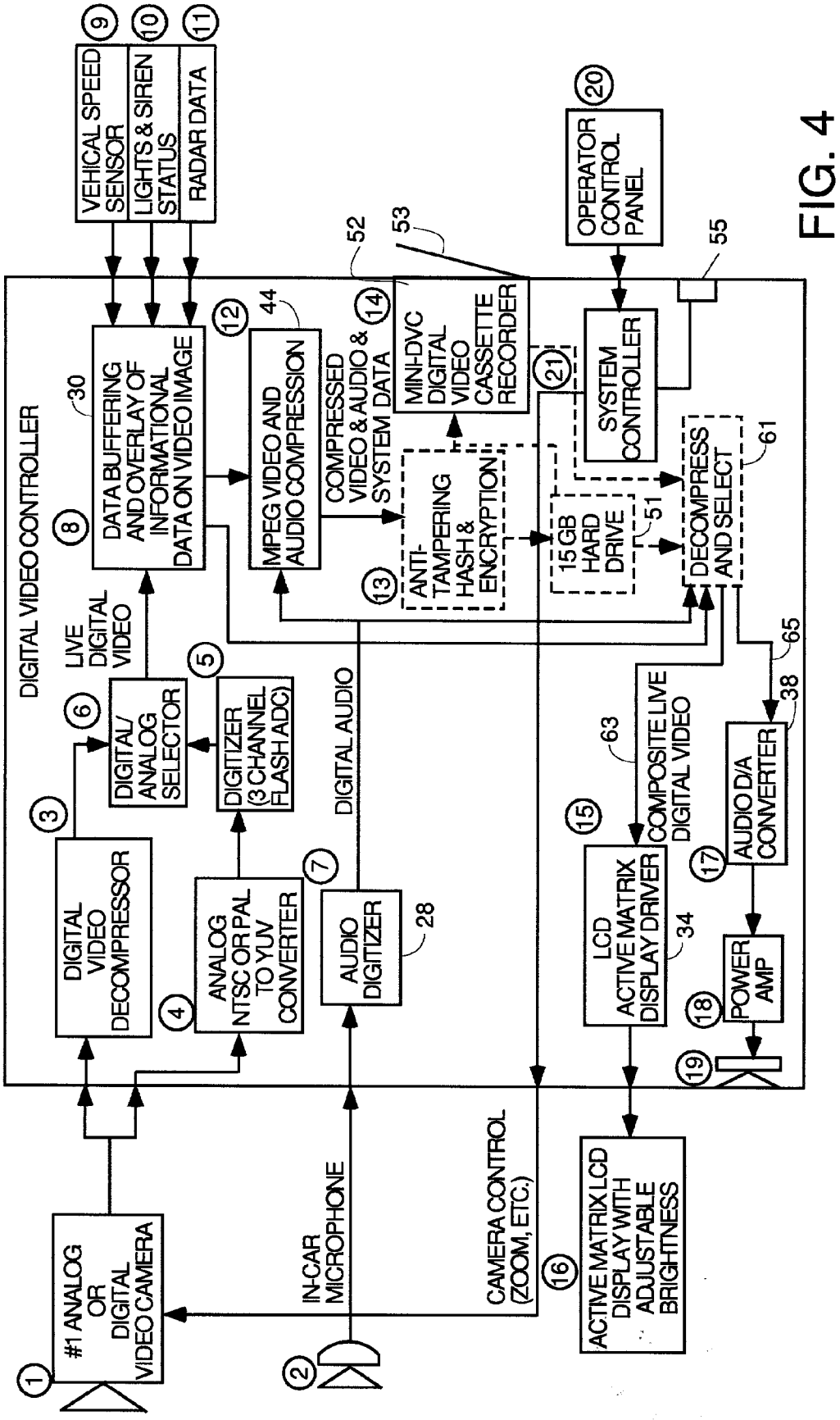

VEHICAL SPEED SENSOR
LIGHTS & SIREN STATUS
RADAR DATA
OPERATOR CONTROL PANEL
DIGITAL VIDEO CONTROLLER
DATA BUFFERING AND OVERLAY OF INFORMATIONAL DATA ON VIDEO IMAGE
MPEG VIDEO AND AUDIO COMPRESSION
COMPRESSED VIDEO & AUDIO & SYSTEM DATA
MINI-DVC DIGITAL VIDEO CASSETTE RECORDER
SYSTEM CONTROLLER
ANTI-TAMPERING HASH & ENCRYPTION
15GB HARD DRIVE
DECOMPRESS AND SELECT
LIVE DIGITAL VIDEO
DIGITAL/ ANALOG SELECTOR
DIGITIZER (3 CHANNEL FLASH ADC)
DIGITAL AUDIO
DIGITAL VIDEO DECOMPRESSOR
ANALOG NTSC OR PAL TO YUV CONVERTER
AUDIO DIGITIZER
COMPOSITE LIVE DIGITAL VIDEO
LCD ACTIVE MATRIX DISPLAY DRIVER
AUDIO D/A CONVERTER
POWER AMP
#1 ANALOG OR DIGITAL VIDEO CAMERA
IN-CAR MICROPHONE
CAMERA CONTROL (ZOOM, ETC.)
ACTIVE MATRIX LCD DISPLAY WITH ADJUSTABLE BRIGHTNESS
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
28
30
34
38
44
51
52
53
55
61
63
65

FIG. 4

DOUBLE ENCRYPTION OF SIGNATURES TO PREVENT TAMPERING

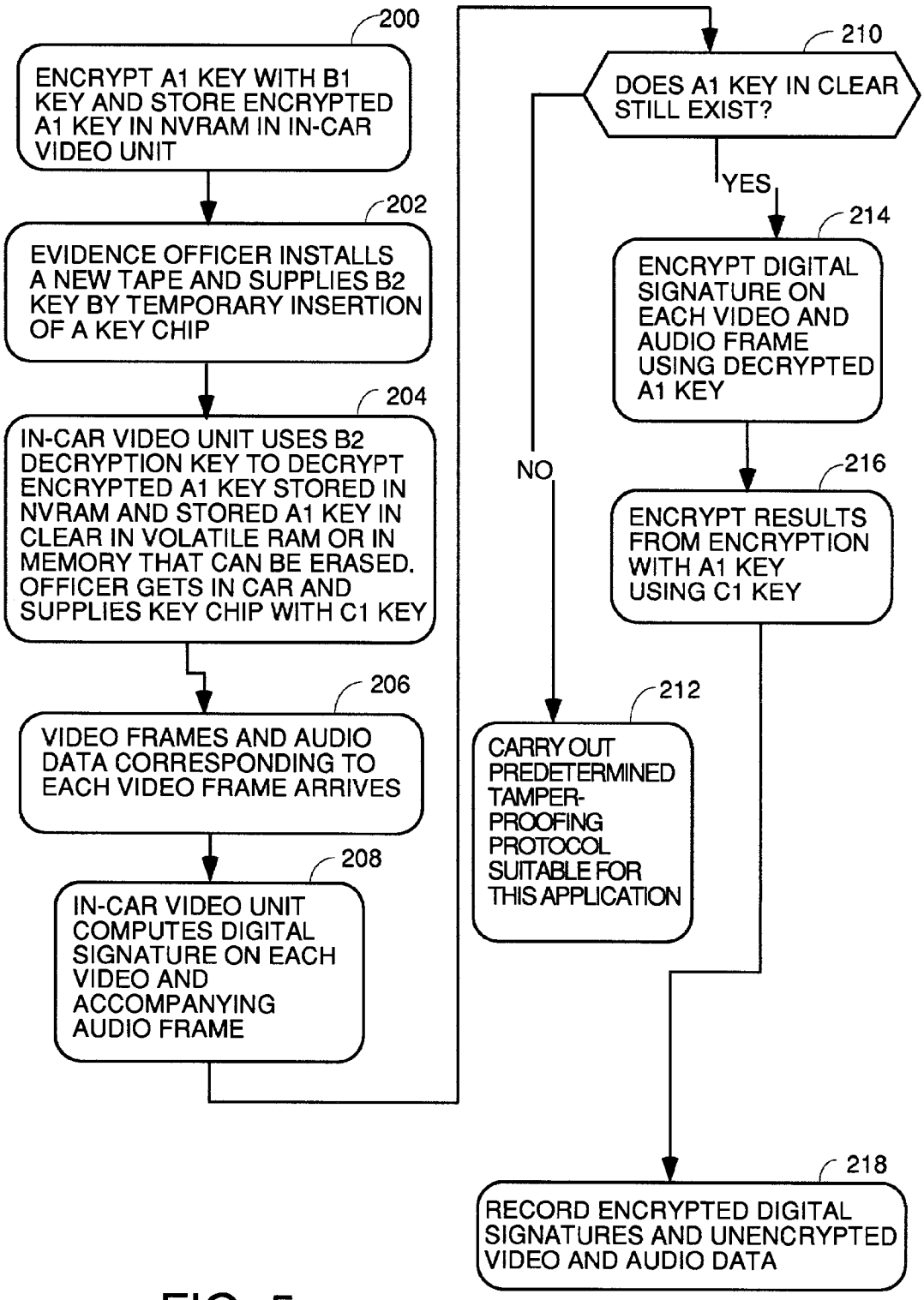


FIG. 5

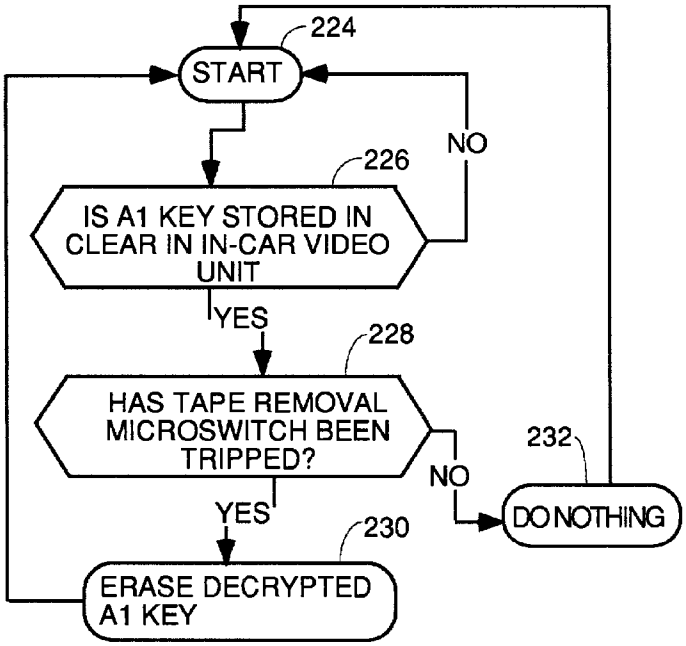

224
START
NO
226
IS A1 KEY STORED IN CLEAR IN IN-CAR VIDEO UNIT
YES
228
HAS TAPE REMOVAL MICROSWITCH BEEN TRIPPED?
NO
232
DO NOTHING
YES
230
ERASE DECRYPTED A1 KEY

FIG. 6

234
DECRYPT EACH RECORDED VIDEO AND AUDIO FRAME SIGNATURE WITH C2 KEY
236
DECRYPT RESULTS WITH A2 KEY
238
COMPUTE DIGITAL SIGNATURE FOR EACH RECORDED VIDEO FRAME AND THE ACCOMPANYING AUDIO USING SAME DIGITAL SIGNATURE ALGORITHM AS USED BY IN-CAR VIDEO UNIT TO COMPUTE DIGITAL SIGNATURES
240
COMPARE DIGITAL SIGNATURES JUST COMPUTED FOR EACH FRAME TO DECRYPTED DIGITAL SIGNATURES DERIVED FROM RECORDED DIGITAL SIGNATURES FOR THE CORRESPONDING FRAME
244
TAPE HAS NOT BEEN ALTERED
YES
242
MATCH?
246
TAPE HAS BEEN ALTERED

FIG. 7

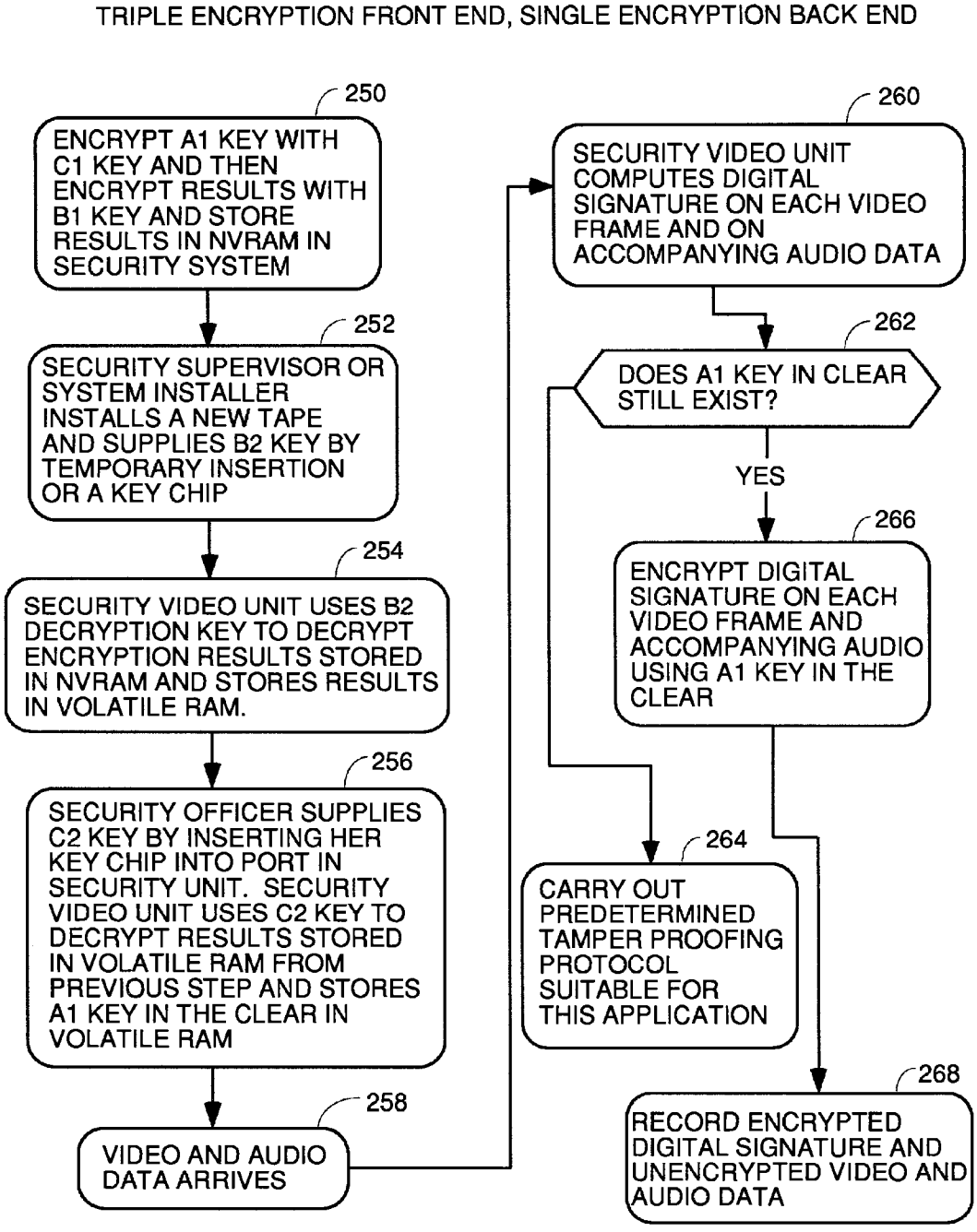

TRIPLE ENCRYPTION FRONT END, SINGLE ENCRYPTION BACK END
250
ENCRYPT A1 KEY WITH C1 KEY AND THEN ENCRYPT RESULTS WITH B1 KEY AND STORE RESULTS IN NVRAM IN SECURITY SYSTEM
252
SECURITY SUPERVISOR OR SYSTEM INSTALLER INSTALLS A NEW TAPE AND SUPPLIES B2 KEY BY TEMPORARY INSERTION OR A KEY CHIP
254
SECURITY VIDEO UNIT USES B2 DECRYPTION KEY TO DECRYPT ENCRYPTION RESULTS STORED IN NVRAM AND STORES RESULTS IN VOLATILE RAM.
256
SECURITY OFFICER SUPPLIES C2 KEY BY INSERTING HER KEY CHIP INTO PORT IN SECURITY UNIT. SECURITY VIDEO UNIT USES C2 KEY TO DECRYPT RESULTS STORED IN VOLATILE RAM FROM PREVIOUS STEP AND STORES A1 KEY IN THE CLEAR IN VOLATILE RAM
258
VIDEO AND AUDIO DATA ARRIVES
260
SECURITY VIDEO UNIT COMPUTES DIGITAL SIGNATURE ON EACH VIDEO FRAME AND ON ACCOMPANYING AUDIO DATA
262
DOES A1 KEY IN CLEAR STILL EXIST?
YES
266
ENCRYPT DIGITAL SIGNATURE ON EACH VIDEO FRAME AND ACCOMPANYING AUDIO USING A1 KEY IN THE CLEAR
264
CARRY OUT PREDETERMINED TAMPER PROOFING PROTOCOL SUITABLE FOR THIS APPLICATION
268
RECORD ENCRYPTED DIGITAL SIGNATURE AND UNENCRYPTED VIDEO AND AUDIO DATA

FIG. 8

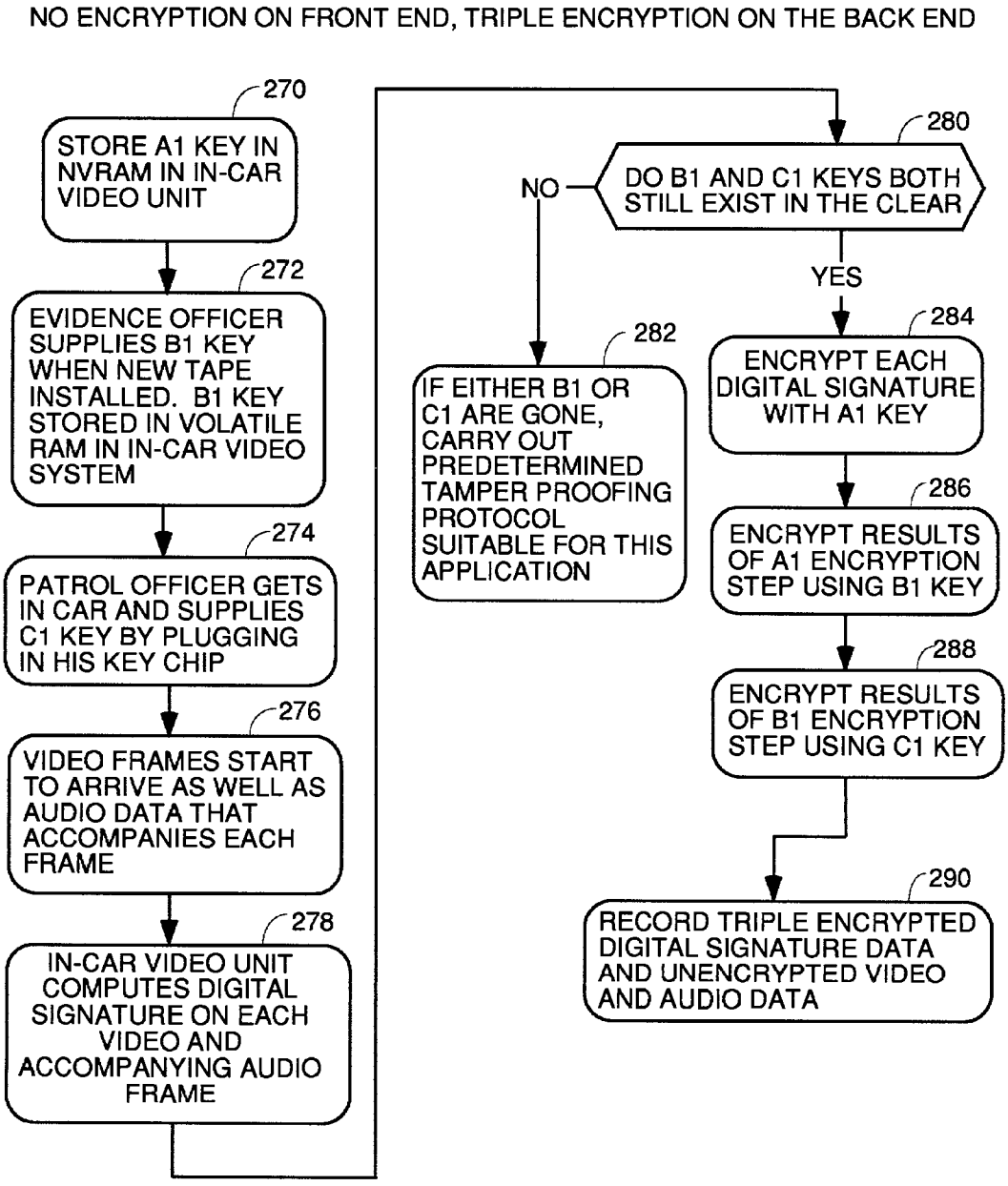

NO ENCRYPTION ON FRONT END, TRIPLE ENCRYPTION ON THE BACK END
270
STORE A1 KEY IN NVRAM IN IN-CAR VIDEO UNIT
272
EVIDENCE OFFICER SUPPLIES B1 KEY WHEN NEW TAPE INSTALLED. B1 KEY STORED IN VOLATILE RAM IN IN-CAR VIDEO SYSTEM
274
PATROL OFFICER GETS IN CAR AND SUPPLIES C1 KEY BY PLUGGING IN HIS KEY CHIP
276
VIDEO FRAMES START TO ARRIVE AS WELL AS AUDIO DATA THAT ACCOMPANIES EACH FRAME
278
IN-CAR VIDEO UNIT COMPUTES DIGITAL SIGNATURE ON EACH VIDEO AND ACCOMPANYING AUDIO FRAME
280
DO B1 AND C1 KEYS BOTH STILL EXIST IN THE CLEAR
NO
YES
282
IF EITHER B1 OR C1 ARE GONE, CARRY OUT PREDETERMINED TAMPER PROOFING PROTOCOL SUITABLE FOR THIS APPLICATION
284
ENCRYPT EACH DIGITAL SIGNATURE WITH A1 KEY
286
ENCRYPT RESULTS OF A1 ENCRYPTION STEP USING B1 KEY
288
ENCRYPT RESULTS OF B1 ENCRYPTION STEP USING C1 KEY
290
RECORD TRIPLE ENCRYPTED DIGITAL SIGNATURE DATA AND UNENCRYPTED VIDEO AND AUDIO DATA

FIG. 9

IN-CAR DIGITAL VIDEO RECORDING WITH MPEG-4 COMPRESSION FOR POLICE CRUISERS AND OTHER VEHICLES

BACKGROUND OF THE INVENTION

[0001] Police cruisers have begun recording the scene outside the cruiser for evidentiary purposes for drunk driving surveillance and arrests, traffic stops and arrests, etc. Many conventional police video systems use analog VHS video tape recorders and analog video cameras. An example of such systems is U.S. Pat. No. 4, 789,904 owned by Kustom Signal, Inc. This patent discloses a vehicle mounted camera and control head mounted within the police car and a video recorder housed in the trunk in a bulletproof, environmentally controlled vault. The surveillance system also includes a wireless microphone. The system is powered off the battery and may be manually or automatically activated such as when the siren and/or lights come on.

[0002] Another example of in-car video systems is U.S. Pat. No. 6,028,528 assigned to Mobile-Vision, Inc. This patent discloses an apparatus that can manage transfers of video recording media bearing machine readable registration codes. This media is adapted to record video from a vehicle-mounted camera. The management apparatus (and the methods) operate with a user identification key carrying at least one machine readable, identification code, as well as a supplemental code. The apparatus has a port for reading and writing to the key, a registration device, and a processor. The port can provide in response to the key, an identification signal and a supplemental signal corresponding to the identification and supplemental code. The registration device can read the registration codes borne by the video recording media and can provide in response thereto a registration signal. The processor is coupled to the port and the registration device for (a)producing in response to the identification signal, a selection signal signifying an instruction to transfer that one of the video recording media bearing a selected one of the registration codes without requiring an intervening user selection, (b) verifying and recording the registration signal, and (c) writing the supplemental code through the port to the identification key. The management apparatus also includes a mobile system and a station system.

[0003] The mobile system includes a video recorder, a remote port device, and a controller. The video recorder can record on the video recording media, video from the vehicle-mounted camera. The remote port device can (i) write the supplemental code to the key, and (ii) read the key and provide in response thereto, a remote identification signal corresponding to the identification code. The controller is coupled to the remote port device and the video recorder for controlling the video recorder in response to the remote identification signal.

[0004] Another example of prior art in-car video systems is U.S. Pat. No. 5,408,330 to Squicciarini , et al. and owned by CrimTec, Inc. This patent teaches a video incident capture system for law enforcement vehicles. The video incident capture system incorporates a video camera, a VHS analog video recorder, a radar unit, a real time clock, a monitor, a portable wireless microphone and its associated receiver and a system controller integrating the control of the various components to produce a comprehensive, unedited record of the incident. The system controller superimposes the target speed and patrol speed data generated by the radar unit over the video signals generated by the video camera prior to being recorded on the videotape. The portable wireless microphone permits the conversation between the law enforcement and a second party to be made part of the recorded incident. A radar interface will replace the target and/or patrol speed data with error data when an error in the operating parameters of the radar unit is detected. The system controller also provides a control function which prohibits the video recorder from recording over a previously recorded portion of the videotape when the videotape has been either rewound or fast-forwarded from the position where the prior recording was terminated. The system controller and video recorder are enclosed in a temperature controlled sealed vault mounted in the trunk of the law enforcement vehicle.

[0005] The main problem with all these prior art systems is that they do not have adequate recording time capacity to cover an entire 8-hour police shift on one tape much less a 24-hour period. There are numerous other deficiencies of these analog video tape recorder systems. For example, they are bulky and the video recorder components frequently have to be mounted in the trunk of the police car. This complicates getting the video and audio signals to them and complicates interfacing between the officer and the unit. Further, the prior art in-car video systems do not all have the ability to select from different video and audio sources such as digital video cameras, analog video cameras and in-car or wireless microphones. They do not have the ability to report the police car position, and they all do not have the ability to record the lights and siren status. They do not all have an antitampering encryption process, and they do not have the ability to copy events that have already occurred onto video tape or a mini-digital video cassette recorder from a hard disk recorder if the record mode has not been selected. They also do not have the ability to select between in-car monitoring of the live video being recorded or local playback of what has already been recorded while continuing to record live video. They also do not all have the ability to select between in-car monitoring of the live video being recorded or local playback of what has already been recorded. None of these prior art systems have the ability to play back what has already been recorded while continuing to record.

[0006] Thus, a need has arisen for an in-car video system that has higher recording capacity and is small enough to be mounted in a single unit which may be mounted in the cab of the police car. Solution of one or more of the other above noted problems would also be desirable.

SUMMARY OF THE INVENTION

[0007] The genus of the invention is characterized by the characteristic that all species will share the ability to digitize, and compress live audio signals and at least compress digital video camera output and record the compressed video and audio on a compact digital video tape recorder. In the preferred embodiment, the amount of compression and the medium size provide substantially larger amounts of record time than the prior art VHS based systems. Various species within this genus will also have hardware and/or software to solve one or more of the other problems identified above including the ability to record to tape events that have already happened and the ability to render the digital video

and audio recordings tamper proof. Other species allow either analog or digital video cameras to be used and/or allow real time video playback of recorded video.

[0008] Also disclosed is a separate invention that can be used in conjunction with the first invention to tamper proof the video and audio data, but which can also be used to tamper proof any digital data. This separate invention is a genus of multiple key, multiple encryption processes where multiple key pairs are assigned to multiple different people who are unlikely to conspire to supply all their keys. All species within the genus share the following characteristics:

[0009] (1) there will be digital data of some sort that needs to be rendered tamper proof such as video and audio evidence gathered by an in-car police patrol car video surveillance system, security camera images, digital crime scene files, message traffic, etc.

[0010] (2) there will be multiple key pairs, each key pair assigned to a different person, the group of people owning the keys being a group which is highly unlikely to enter into a conspiracy together to supply all their keys, often including a judge and an evidence officer;

[0011] (3) there will be monitoring for the occurrence of any physical or electrical phenomenon or event which indicates that the data to be protected has been improperly accessed or altered;

[0012] (4) there will be multiple encryptions or multiple encryption and decryption operations using different keys either on the front end (see definition below) of the process or the back end (see definition below) or both including a species with no encryptions on the front end and triple encryptions on the back end. These encryptions and decryptions are done using the encryption and decryption keys belonging to the different people. If the event indicating possible tampering or access has occurred, a suitable tamper proofing protocol such as blocking all recording or making a notation in the data that possible tampering has occurred will be performed on the back end. The "front end" is a process that occurs one time at the time the tape is inserted into the system or just prior to the start of generation of the digital frame or frames or file to be protected. The "back end" is an encryption process that is applied to every video frame and accompanying audio data in an in-car or security camera application or performed on one or more digital files to be protected in other applications.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] **FIG. 1** is a block diagram of a basic in-car video system according to the teachings of the invention.

[0014] **FIG. 2** is a block diagram of an in-car video system according to the invention which includes a hard drive that constantly records video and audio and which has two camera inputs and two microphone inputs and an anti-tampering option.

[0015] **FIG. 3** is a block diagram of the basic class of embodiments represented by **FIG. 1** enhanced by an optional hard drive which constantly records video and audio data and with an anti-tampering option.

[0016] **FIG. 4** is is a block diagram of the basic class of embodiments represented by **FIG. 1** enhanced by an optional hard drive which constantly records video and audio data and with an anti-tampering option and an option for local playback of stored video and audio.

[0017] **FIG. 5** is a flow diagram of a multiple key, multiple encryption species within the genus of the second invention with a single encryption and decryption of one of the back end encryption keys on the front end and double encryption using two different keys on the back end.

[0018] **FIG. 6** is a flowchart of a process indicating how the integrity of the backend encryption keys is monitored.

[0019] **FIG. 7** is a flowchart of a process of how the integrity of a double back-end encrypted file is verified.

[0020] **FIG. 8** is a flowchart of a process for protecting digital data using double encryption of the back end encryption key using two different encryption keys with single encryption on the back end.

[0021] **FIG. 9** is a flowchart of a process for protecting a digital file using no encryption of one of the back end encryption keys on the front end but triple encryption at the back end using three different encryption keys.

DETAILED DESCRIPTION OF THE PREFERRED AND ALTERNATIVE EMBODIMENTS

[0022] Referring to **FIG. 1**, there is shown a basic in-car video system according to one embodiment within the genus of the invention. Video camera **10**, in this embodiment, can be either an NTSC or PAL format analog video camera or a digital video camera. In this embodiment, circuitry is provided in the base unit **12** to allow either type camera to be used. If a digital video camera is used, a camera with an IEEE 1394 Firewire interface is preferred. The video camera may also be a night vision video camera. Typical video cameras provide 128:1 or greater zoom, operator adjustable or automatic focus from 3 feet to infinity, adjustable shutter speed and f8 or adjustable f2 to f16 lens aperture. Typically, the video camera is mounted to the rear view mirror boom facing forward to look out the windshield. However, the video camera **10** may also be a wireless body camera worn by the officer so that when he steps out of the car, the scene he sees may be recorded.

[0023] Alternatively, the video camera **10** may be a wireless camera mounted on a helicopter although this is typically found in embodiments where there are two camera inputs and the helicopter camera is the second of two video inputs. In wireless camera embodiments, link **22** between the video camera and the base unit **12** is a wireless link. Wireless video cameras are known and are in extensive use on umpires in the National Football League and the XFL, and, in such embodiments, the base unit includes a suitable receiver, decompression circuitry if the camera is digital and NTSC to YUV converter and A/D converter if the camera is analog. Zoom and focus for any of these cameras may be remotely controllable in some embodiments by issuing commands on an operator control panel **20**. The term "video camera" in the claims is intended to mean any one of these cameras.

[0024] The base unit includes circuitry to display the live video from the camera on a video display **20** so that zoom and focus setting and framing may be adjusted by the officer.

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Typically, the video display is an active matrix LCD display with adjustable brightness, but any type video display may be used.

[0025] In alternative embodiments, only one or the other type camera is allowed as opposed to either analog or digital hard wired types as shown in **FIG. 1**. In embodiments where only one type of camera is allowed, regardless of whether it is hard wired to the base unit **12** or coupled by a wireless link, the appropriate circuitry is present in the base unit for the type of camera selected. This appropriate circuitry is referred to in the claims as "means for receiving the output signal of said video camera". For example, if only an analog video camera **10** is in use, the base unit only needs an analog NTSC or PAL to YUV format converter **14** to convert the analog NTSC or PAL signal to a YUV format signal. The YUV signal is then digitized in an A/D converter **16** so as to output digital data in the same format output by decompressor **18** to put the image data into a format suitable for compression and overlay of status data. Preferably, the A/D converter is a **3** channel flash A/D. If a digital video camera is the only camera allowed, the base unit **12** includes only a digital video decompressor **18** that decompresses the lightly compressed AVI signals output by digital video cameras to output a digital format suitable for manipulation of the video image to mix in status data and suitable for compression. If a wireless camera is used, a receiver to convert the RF signals to baseband analog or compressed digital video is present along with the appropriate circuitry as described above to convert the baseband analog or digital video signal to a digital video signal suitable for compression.

[0026] If either an analog or a digital video camera may be coupled to the base unit, the base unit includes a digital/analog selector to pick the appropriate signal source of live video digital data to supply to the compression circuitry.

[0027] The embodiment of **FIG. 1** also includes a microphone **26**. In this embodiment, the microphone is mounted in the car so that radio traffic may be recorded as well as any sounds from outside the car which may be heard inside the car. In alternative embodiments, the microphone could be a wireless microphone worn on the body of the officer.

[0028] The base unit interfaces to the microphone via an audio digitizer **28** that functions to perform automatic gain control and digitize the audio signal of the microphone. In the case of a wireless microphone, a suitable receiver (not shown) precedes the A/D converter **28**.

[0029] The live digital video is supplied to a data buffering and overlay circuit **30**. Typically, this circuit is a programmed microprocessor. The function of this buffering and overlay circuit **30** is to buffer the video data for the compression process and overlay status data onto the image defined by the data stream carrying the video image data from the video camera. The status data is text and/or graphic information from other systems of interest in the arrest. For example, a speed sensor **32** provides data regarding the speed of the patrol car, lights and siren status data is provided from these systems, represented by block **34**, and radar data such as the speed of the fastest and/or strongest targets detected by the radar is supplied from a police traffic surveillance radar represented by block **36**. In some embodiments, a GPS receiver provides continuous position data in latitude and longitude that can also be overlaid on the image being recorded. In the embodiment of **FIG. 1**, overlay circuit **30** implements a process to merge this auxiliary or status data from auxiliary systems with the video image data so that, upon playback, selected items of the status data can be overlaid on the video image using known video technology. It also overlays certain items of status data onto the video image data output on line **32** for local monitoring of the video being recorded. Other types of status information that can be provided for overlay are: (1) video and audio input selections where more than one video camera and microphone are available to choose from; (2) video frame counter; (3) time of day clock; (4) vehicle ID; (5) operator ID; (6) Lidar or radar data such as locked vehicle speed, mode of operation, patrol vehicle speed as detected by radar, target distance; and (7) two-way radio status. In. some alternative embodiments, the video frame count is not carried as system status data and is simply overlaid on every frame by the buffer and overlay circuit **30**.

[0030] In alternative embodiments, the overlay process could also merge two video sources for recording in picture in picture or split frame format.

[0031] Another function of buffer and overlay circuit **30** is to output uncompressed video on line **32** for use by a display driver **34** in driving display **20** for real time monitoring of the video being recorded. The audio being recorded is supplied on line **36** to a D/A converter **38** for conversion back to an audio signal. This audio signal drives a power amplifier **40** which drives a speaker **42**.

[0032] The video with any status data merged therein is output to an MPEG video and audio compression circuit **44**. The digital audio data from A/D converter **28** is also supplied to the compression circuit. This compression circuit **44** is typically one or more digital signal processors programmed to carry out any video and audio compression process on the digital video and audio data. In the preferred embodiment, compression circuit **44** implements the MPEG-4 compression process detailed in the MPEG-4 standards which are publicly available. In fact, the complete source code for MPEG-4 compression version 1 is publicly available for 56 francs from the International Standards Organization Moving Pictures Experts Group. The MPEG-4 overview document is ISO/IECJTC1/SC29/WG11.

[0033] It is this compression along with the capacity of the digital data recording medium which gives the long recording capacity of the system. Other compression algorithms that will work to practice the invention are MPEG-2 or MPEG-1 and other lossless or lossy compression algorithms such as P×64 and JPEG.

[0034] The compressed audio and video data is output on line **46**. An optional anti-tampering circuit **48** can then make the data to be recorded tamper proof. If the data is to be made tamper proof, it is necessary to include overlaid frame counter data to make sure nobody is able to remove frames or add frames. Typically, the anti-tampering circuit is simply a program in the DSP that does the compression which computes a digital signature algorithm on each frame of compressed data and then encrypts the digital signatures but not the actual video or audio data. In other words, each digital signature is encrypted (or all the digital signatures are concatenated and then encrypted) and the encrypted digital signatures are recorded along with the unencrypted video and audio data. The preferred digital signature algorithms are the known MD5 and SHA-1 algorithms which compute

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a digital signature on the video data defining the content of each frame and the accompanying audio. The digital signature is unique to each frame, and if either the video or audio of the frame is altered, the resulting digital signature will be altered. This is how the fidelity of the recorded video and audio to what was truly seen by the camera and heard by the microphone is guaranteed.

[0035] When the video and audio is to be played back, another digital signature is calculated on each frame of video and audio using the same algorithm. If the recorded digital signature for that frame, after decryption, is not the same as the computed digital signature, somebody has altered either the video or audio of the frame or both.

[0036] By recording unencrypted video and audio data, local playback of the recorded data on display **20** is possible. Although local playback of already recorded data is not possible in the embodiment of **FIG. 1**, dashed line **50** represents an embodiment where unencrypted video and audio data from a digital video tape recorder **52** is supplied to an optional decompression circuit **51** for decompression and thence to the drivers **34** and **38** for local playback of previously recorded data. Driver **34** converts the digital, decompressed video data on said display **20**. D/A converter **38** converts the decompressed audio data on speaker **42** through power amplifier **40**.

[0037] A digital video data tape recorder **52** records the compressed video and audio data in embodiments where no anti-tamper circuit **48** is present. The tape recorder **52** provides storage of video, audio, and system data. In embodiments where an anti-tampering circuit is present, tape recorder **52** simply stores whatever data is output by the anti-tampering circuit. In one embodiment, that output data would be encrypted digital signature data and unencrypted, compressed video and audio data. In another embodiment, the data output by the anti-tampering circuit **48** would be just encrypted video and audio data. In the preferred embodiment, the recorder **52** is a mini-DVC digital video cassette recorder. In alternative embodiments, it can be any other type of digital video tape recorder. In other alternative embodiments, the DVC recorder includes a small, non-volatile memory which stores vehicle ID data, operator ID data and the date and time of each tape insertion. In an alternative embodiment, the system controller **54** or the DSP that performs the compression and encryption processes will encrypt the vehicle ID, operator ID and date and time of tape insertion data in the NVRAM in the DVC and store the encrypted version of the data in the non-volatile memory in the DVC. In the preferred embodiment, the recorder **52** will have capacity to store 24 hours of MPEG-4 compressed data.

[0038] Access to the tape compartment of the tape recorder is provided through a microswitch sensed door **53**. Each time this door is opened, a microswitch senses this fact. The system controller **54** monitors this microswitch either by polling it or through an interrupt generated by circuitry connected to the microswitch or by polling a flag or register bit which is set when the door is opened. When the door **53** has been opened, an unencrypted **A1** encryption key (described below) stored in the system controller **54** is erased and the anti-tamper circuit will thereafter be incapable of encrypting any data. As discussed below, other constraints may also be imposed when the **A1** key has been erased which are part of an anti-tamper protocol the varieties of which will be described below.

[0039] Where the anti-tamper circuit **48** is present, the digital video tape recorder **52** records the unencrypted data if any along with the encrypted digital signature data. Secure playback in court can be accomplished by computing a digital signature on each frame recorded on the tape using the same digital signature algorithm used by the anti-tampering circuit **48** and then reversing the compression, converting the decompressed data to NTSC or PAL video signals and an audio signal and playing the signals on a TV. The digital signatures recorded on the tape are then decrypted, and the decrypted, recorded digital signatures are compared with the digital signatures computed from the frames recorded on the tape. If there is any variance, the recorded data has been tampered with and can be disregarded.

[0040] In embodiments where local playback is not implemented, such as the embodiment of **FIG. 1** without the option represented by dashed line **50**, the anti-tampering process **48** can operate in the same way described above or it can omit the digital signature calculations. If the digital signature calculations are omitted, the anti-tampering circuit **48** simply encrypts each frame of video data and encrypts the audio data and records the resulting encrypted data on digital video cassette recorder **52**. This also renders it impossible to add, delete or alter any frame. Secure playback is accomplished by decrypting the encrypted data, decompressing it and converting it back to audio and NTSC or PAL signals for display on a TV.

[0041] However, with frame numbers overlaid and simply computing a digital signature on every frame and encrypting the digital signature, it is impossible to either add or remove frames without being detected. Further, because each frame has had a digital signature computed on it, it is also not possible to use video image manipulation software to morph any frame because this would cause the digital signature computed from the untampered frame to not match the digital signature of the morphed or altered frame thereby signalling that tampering had occurred.

[0042] In all of these tamper-proof embodiments, the decryption key is held only by the court so only the court can play back the recorded tape secure in the knowledge that no changes have been made.

[0043] The control panel **20** contains operator controls for whichever functions are implemented in the base unit. Typical operator interface mechanisms that may be included on the control panel are: push buttons; a keyboard; an LCD touchscreen; any sort of point and click device such as a trackball, mouse, joystick, touchpad, etc.; indicator lights, on-screen indicators overlaid on the video image; on-screen indicators in a virtual control panel in combination with an LCD touchscreen or point and click device.

[0044] The control panel is coupled to a system controller **54** which is coupled to every circuit in the base unit and includes a remote zoom control signal path to control zoom, focus, etc. of camera **10**. The system controller **54** may also receive inputs from a remote control (not shown), and serves to control all other circuits in the base unit **12**. The system controller also includes at least a frame counter and, optionally, a time of day clock. When the frames of video data are

digitized, the sync interval is encoded into the resulting digital video data as a special character which can be recognized by circuitry in the buffer and merge circuit **30**. Each sync interval that is recognized by the buffer and merge circuit is signalled to the system controller **54** by a frame signal on data path **55**. This causes a frame counter in the system controller to be incremented. The frame count and, optionally, the time of day data are supplied to the buffer and merge circuit **30** by a data path **57** for merger into the video data stream such that this data can be overlaid upon the video data upon playback.

[**0045**] In embodiments where the multikey, multiencryption anti-tamper process (described below) is used, a key chip port **55** is used to to receive a key chip which contains the encryption or decryption keys needed by the system for whatever anti-tamper process is in use.

[**0046**] Referring to **FIG. 2**, there is shown a block diagram of an alternative, buffered embodiment of the system of **FIG. 1** which has all the alternatives and optional capabilities of the embodiments described above with reference to **FIG. 1**. However, the embodiment of **FIG. 2** has the additional capability to record after-the-fact events which the officer may have missed because the record mode was not on when the event occurred. This is provided by the use of a hard disk **60** which stores all compressed video and audio data output by the compression process or the optional anti-tampering circuit at all times regardless of whether tape recording mode is on or off. This system also has the ability to record data from either of two-different video cameras, one of which may be wireless, and either of which may be selected and the ability to record audio from either of two different microphones, one of which may be wireless, and either of which may be selected.

[**0047**] Video camera #**1** is shown at **10** and may be either an analog or a digital video camera. Its zoom, focus and/or other features such as lens aperture, shutters speed, etc. may be controlled remotely via signals on line **56** as was the case for the embodiment of **FIG. 1**. Video camera #**2** is shown at **62**. It also may be either an analog or digital video camera, but it also may be a wireless analog or digital video camera as was the case for camera **10** in **FIG. 1**. The transceiver pair needed to send video data back to base unit **66** and remote control zoom, record on or off, focus, etc. commands is represented by block **64**. Remote control commands from system controller **54** are sent to the camera via line **68** and the transceiver pair **64**. One of the transceivers **64** is mounted on or in the base unit **66**. The other is mounted in camera **62**. The transceivers **64** and **88** are not restricted to receiving radio frequency carriers. They could receive any electromagnetic transmission such as modulated infrared, modulated light, microwave, ultraviolet, X-ray etc.

[**0048**] Digital video selector and decompressor **70** has an input from both cameras and both inputs will be active carrying digital video data if both cameras are digital. This circuit functions to receive a selection control signal from the system controller **54** and to select one of the digital video inputs **72** or **74**. The lightly compressed AVI format digital video is then decompressed to put it in condition for heavy compression by an MPEG-4 process or other compression algorithm.

[**0049**] An analog selector and converter circuit **76** functions to receive analog video signals from cameras #**1** and #**2** if both cameras are analog. Circuit **76** selects between one or the other of the two analog video signals on lines **78** or **80**. The selected analog signal is then converted from NTSC or PAL format to YUV format. Digitizer **16** then digitizes the YUV signal and outputs the samples to a digital or analog selector **24**. The other digital video data input to selector **24** comes from selector and decompressor **70**. Selector **24** selects the digital samples from A/D converter **16** or selector and decompressor **70** under control of system controller **54**. It is possible that one camera is analog and one is digital. In such an embodiment, the selectors **70** and **76** make no selection and the selection of which camera's video to compress is made by selector **24**.

[**0050**] There are also two microphones. Microphone **82** is an in-car microphone and has its signal digitized by an A/D converter **84**. Microphone **86** is an external or body microphone which can be hard wired to the base unit **66** or coupled by a wireless connection using a transmitter and receiver pair represented by block **88**. The audio signal from microphone **86** is digitized by A/D converter **90**.

[**0051**] The digital audio outputs from digitizers **84** and **90** are coupled to a compression circuit **44** which has the same structure and function as the compression circuit **44** in **FIG. 1**. Although block **44** is labelled MPEG compression, other compression algorithms can also be used. The preferred form of compression is MPEG-4.

[**0052**] The digital audio outputs from digitizers **84** and **90** are also coupled to the audio inputs of an optional real time stored video playback selector **92**. This circuit also has a video input **94** coupled to receive the combined, uncompressed video and merged status data from buffering and combining circuit **30**. The structure and function of the buffering and merge circuit **30** is similar to its counterpart in the embodiment of **FIG. 1** except in **FIG. 1** it overlays the status data and in **FIG. 2**, it merges the status data so that selected status data from the collection of all status data that has been recorded can be merged into the image by circuit **140** for local playback.

[**0053**] The buffering and merge circuit **30** merges vehicle speed data, lights and siren status and radar data from interfaces **32**, **34** and **36** along with GPS position data from a GPS receiver **37** with the video data selected by selector **24**, and buffers the resulting composite live video data and outputs it simultaneously on line **94** for real time monitoring of the selected video. The buffered data is also made available to the video and audio compression circuit **44** via line **96** for compression along with the audio data in the same manner as in the embodiment of **FIG. 1**.

[**0054**] An optional anti-tampering circuit **48** (shown in dashed lines) tamper proofs the compressed video and audio in any one of the alternative ways described for the same circuit in **FIG. 1**. It outputs either compressed, unencrypted video and audio data and encrypted digital signature data or compressed and encrypted video and audio data with no digital signature data on line **100**. If the anti-tampering circuit is not present, line **100** bears compressed, unencrypted video and audio data. The output data on line **100** is also coupled to the record data input of a digital video tape recorder **52** which has the same structure and alternative structures as in the embodiment of **FIG. 1**.

[**0055**] All the data on line **100** is continuously recorded on a **15** gigabyte hard drive **60** which is used as a FIFO

memory. Data can be archived off the hard disk **60** to the digital video tape recorder **52** via bus **102**. After the fact recording to tape can be accomplished using the system controller. If an officer wants to record to tape all the events that happened in the last **10** minutes or starting from some particular time of day he remembers to be before a significant event, he can give a command via control panel **20** to the system controller **54**. Part of the data continuously recorded on hard disk **60** is time of day data supplied by clock **104** and/or a frame count signal. Although a separate clock **104** is shown, in most embodiments, the clock and/or frame counter is actually in the system controller **54** and the frame counter is incremented by the frame signal on line **55** from the data buffer and merge circuit. The time of day and/or frame count data is then supplied back to the buffer and merge circuit on bus **57** (the same thing happens in other embodiments with after-the-fact recording capability or where the frame count and/or time of day are needed such as in most tamper-proof embodiments).

[**0056**] By recording the time of day and/or a frame count, the data stored on hard disk **60** can be searched using the time of day or some interval data entered by the officer via control panel **20** to find the first frame that corresponds to the requested start time. Data from that frame and subsequent frames are then output by the hard disk on lines **102** and **106**. The data on line **102** can be archived onto the digital tape recorder **52** when the system controller so orders. The data on line **106** can be viewed by the officer via the an optional MPEG decompression, buffering, zoom and freeze-frame circuit **108**. The optional real time stored video playback selector **92** also has video and audio inputs **96** from this optional MPEG decompression, buffering, zoom and freeze-frame circuit.

[**0057**] The functions of the optional MPEG decompression, buffering, zoom and freeze-frame circuit **108** are to decompress the compressed data coming off the hard disk and buffer it for playback. Additional functions such as zoom and freeze-frame can also be implemented in this circuit using conventional digital video signal processsing techniques. In embodiments where the MPEG decompression, buffering, zoom and freeze-frame circuit **108** is not present, local playback of video and audio data is only of live video and audio as it is happening. In such an embodiment, there is no need for selector **92**, so the live video and audio signals on bus **110** in **FIG. 2** will have the video data on bus **94** applied directly to the inputs of the overlay system data on video circuit **140**. The function of the overlay circuit **140** is to pick out the status data that is to be overlaid from all the status data supplied at the inputs and to overlay that status data on the video image for display. In some embodiments, the overlay circuit also receives commands from the system controller to move the overlaid data so that it does not obscure critical portions of the video image.

[**0058**] The function of the real-time/stored video playback selector is to select the stored video, status and audio data on lines **96** or the real time video and audio and status data on lines **110** for playback. This selection is made by the officer via control panel **20** and system controller **54**. The selected video data is output on line **114** and is displayed via an active matrix display driver **34** and an active matrix display **20**. The selected audio (which may contain audio from both microphones) is output on lines **116** and **118**. A mixer and power amplifier **120** mixes the audio on lines **116** and **118** if both have audio signals on them and amplifies the mix and applies it to a speaker **122**.

[**0059**] Referring to **FIG. 3**, there is shown an alternative embodiment which is basically the same as the embodiment of **FIG. 1** except that it includes an optional hard disk to continuously record the compressed composite live video and audio data output by the compression circuit **44**. In this embodiment, all other circuits with the same reference number as a counterpart circuit in **FIG. 1** have the same structure and function as the counterpart circuit in **FIG. 1**. Optionally, a hard disk **51** is included and coupled to receive and continuously record the compressed composite video, audio and system data on line **53**.

[**0060**] The hard disk can be controlled by the system controller **55** to replay any recorded data on output **57** for archiving on tape recorder **52**. As was the case for the embodiment of **FIG. 2** and the anti-tampering embodiment of **FIG. 1**, the system controller includes a frame counter which is incremented by a frame signal output by the buffer and merge circuit **30**. The frame count and, optionally, a time of data signal are supplied by the system controller **55** for merger as status data into the composite live digital video data output on line **31**. This frame counter data and time of day data are recorded on the hard disk **51** with the rest of the status data. The system controller **55** can be controlled in this embodiment by the officer via control panel **20** to send a command to the hard disk **51** to cause it to playback all recorded data starting from a specific frame number or a specific time of day or going back from the present time by a specified number of minutes on output **57** to be archived by tape recorder **52**. The hard disk then finds the appropriate data in any way and outputs it on line **57**. In some embodiments, the hard disk has a cache memory in which frame number and time of data data are recorded along with the track and sector or block number on the hard disk where the corresponding video, audio and status data for that frame number and/or time of day were recorded. This provides an after-the-fact recording capability in case the officer did not have the in-car video system in record mode when some significant event happened. In alternative embodiments, since the hard disk **51** is used as a FIFO and will be overwritten when it reaches its capacity, the system controller can be programmed to automatically cause the digital video tape recorder to record all data on line **53** when the hard disk reaches capacity.

[**0061**] In a further alternative embodiment, the embodiment of **FIG. 3** may include any of the anti-tampering circuits previously described, as symbolized by dashed block **59**.

[**0062**] In still another alternative embodiment represented by **FIG. 4**, any of the embodiments for **FIG. 3** previously described may be enhanced with an optional decompression and selection circuit **61**. This circuit received compressed video, status and audio data from all of three sources: live video and audio from the buffer and merge circuit **30** and the audio digitizer **28**; recorded video, status and audio data from the hard disk **51**; and recorded video, status and audio data from the tape recorder **52**. The decompression and selection circuit **61** selects one of these sources of data, decompresses it, and outputs the decompressed video data

on line **63** to the active matrix display driver **34** and outputs the decompressed audio data on line **65** to the audio digitizer **38**.

A Genus of Multiple Key, Multiple Encryption Process to Tamper-proof any Digital Data

[**0063**] The anti-tamper embodiments described above, except for the embodiments where the digital video and audio data itself are encrypted, have a vulnerability.

[**0064**] To render the recorded video and audio data completely tamper proof with no vulnerability, a process from a genus of multiple key, multiple encryption processes can be used. The crux of the problem this genus of multiple key, multiple encryption processes solves is that it renders it impossible for a single person, acting alone to generate tampered, encrypted data which will decrypt in the courtroom as if it had not been tampered with. Any process that can solve this problem, is within the genus of the invention, but all species within this genus are believed to share the following common characteristics:(1) there will be digital data of some sort that needs to be rendered tamper proof such as video and audio evidence gathered by an in-car police patrol car video surveillance system, security camera images, digital crime scene files, message traffic, etc.

[**0065**] (2) there will be multiple key pairs, each key pair assigned to a different person, the group of people owning the keys being a group which is highly unlikely to enter into a conspiracy together, often including a judge and an evidence officer;

[**0066**] (3) there will be monitoring for the occurrence of any physical or electrical phenomenon or event which indicates that the data to be protected has been accessed improperly or altered;

[**0067**] (4) there will be multiple encryptions or multiple encryption and decryption operations either on the front end of the process or the back end or both including a species with no encryptions on the front end and triple encryptions on the back end. These encryptions and decryptions are done using the encryption and decryption keys belonging to the different people. If the event indicating possible tampering or access has occurred, a suitable tamper proofing protocol such as blocking all recording or making a notation in the data that possible tampering has occurred will be performed on the back end.

[**0068**] **FIG. 5** is a flow chart showing one example of one species within this genus of processes used to protect video and audio data recorded by a police car in-car surveillance unit. In this particular example, there are three people and three key pairs. The first key pair is comprised of an encryption and decryption key pair designated A1 and A2 assigned to a judge. The second key pair is comprised of an encryption and decryption key pair designated B1 and B2 assigned to a police evidence officer. The third key pair is comprised of an encryption and decryption key pair designated C1 and C2 assigned to a particular patrolman.

[**0069**] The particular species represented by **FIG. 5** uses a double encryption/decryption on the front end and a double encryption on the back end. Step **200** represents the process of encrypting the A1 key with the B1 key and storing the encrypted A1 key in non volatile RAM or EEPROM in the in-car video unit. Step **202** represents the process of inserting a new tape in the digital video tape recorder and supplying of the B2 key. The B2 key is the decryption key of the evidence officer. It is supplied by inserting a key chip into the key port **55** in any of the embodiments of FIGS. **1-4**. The system controller can then read the B2 key from the chip. Step **204** represents the process carried out by the system controller **54** of using the B2 key to decrypt the encrypted A1 key stored in the system controller using the B2 key. The decrypted A1 key is then stored in the clear in some volatile RAM or in some memory that is automatically erased when power is disconnected to the unit or the microswitch sensed door **53** is opened for any reason. Finally, in step **204**, the particular officer assigned to the car for that shift gets in the car and supplies the C1 key by plugging his key chip into the unit.

[**0070**] Step **206** represents the arrival of video frames and the audio data that corresponds to each video frame. In step **208**, the in-car video unit anti-tamper circuit **48** computes a digital signature on each frame of video and the corresponding audio data. Test **210** represents the process of determining whether the A1 key still exists in the clear in the volatile RAM and has not been erased. If the A1 key in the clear is still present, step **214** is performed to encrypt the digital signature of each video frame and the digital signature of the audio data that corresponds to each frame using the decrypted A1 key. Step **216** represents the process of encrypting the resulting encrypted data from step **214** using the C1 encryption key of the particular officer that is driving the patrol car. This C1 key is supplied by the patrol officer at the beginning of each shift when the patrol officer inserts his key chip into the key port **55**. The anti-tamper circuit **48** encrypts the results of step **214** by reading the C1 key from the chip in port **55**. Step **218** represents the process of recording the double encrypted digital signature data and unencrypted video and audio data on the digital video tape recorder **52** and/or hard disk **60** if present and depending upon the particular mode of operation at the time.

[**0071**] Returning to test **210**, if it is determined that the A1 key in the clear is no longer present, step **212** is performed. Step **212** represents the process of carrying out whatever predetermined tamper-proofing protocol that is suitable for the particular application and which is acceptable to the police department. In some embodiments, multiple different tamper-proofing protocols are pre-programmed into the system controller, and whichever one has been selected by configuration data programmed into the system by the evidence officer is performed. The possibilities for this protocol are: (1) stop encrypting the digital signatures but continue recording and enter a notation in the recorded data at the point the A1 key disappeared that any recorded data from that point forward is to be viewed with suspicion as it may have been tampered with; (2) start encrypting the digital signatures with the C1 key and make a notation of the change such that all recorded data from that point forward should be viewed with suspicion; (3) stop encrypting digital signatures and block all further recording; or (4) any other suitable anti-tampering protocol.

[**0072**] **FIG. 6** is a flowchart of the process for controlling the integrity of the A1 key by monitoring the microswitch sensed door **53**. Step **224** represents the start of the process. Step **226** is a test to determine if the A1 key is stored in the clear in the in-car video unit. If not, processing returns to step **224**. If the A1 key is stored in the clear, test **228** is

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performed to determine if the tape removal microswitch has been tripped. If it has, step **230** is performed to erase the A1 key in the clear from the volatile memory in which it is stored or to remove the power from the volatile memory in which it is stored so that it will be automatically erased (the encrypted A1 key stored in NVRAM is not erased). The A1 in the clear key should be stored in such a way that when power to the in-car video unit is disconnected such as when the unit is removed, the A1 key in the clear will be lost, and there should be no external access such that the A1 key in the clear can be accessed from the outside without removing power to the unit. If step **228** determines that the tape removal microswitch has not been tripped, step **232** is performed to do nothing and processing returns to step **224**. If this tape removal microswitch is tripped, it should set a flag so that if it is not tripped when step **228** is performed, the flag will still be seen and step **230** will be performed.

[**0073**] **FIG. 7** is a flowchart of the process of determining the authenticity of the recorded data on a tape removed from the in-car video system if the tamper proofing processing of **FIGS. 5 and 6** have been used to safeguard the contents of the tape. Step **234** is the process of decrypting each recorded video frame digital signature and the accompanying audio digital signature using decryption key C2. This reverses the encryption with the C1 key performed in step **216** of **FIG. 5**. Step **236** decrypts the results generated in step **234** using the A2 key to reverse the encryption performed in step **214** in **FIG. 5**. Step **238** is the process of computing digital signatures for each recorded video frame and the accompanying audio data. This is done using the same digital signature algorithm used by the in-car video unit to compute the digital signatures that were encrypted and recorded on the tape being authenticated. Step **240** is the process of comparing the digital signatures computed in step **238** to the corresponding decrypted digital signatures computed in step **236**. Step **242** represents the test to determine whether the digital signatures match. If they do, each frame for which there is a match has not been tampered with, as represented by step **244**. If there is not a match for any frame, that frame has been tampered with, as represented by step **246**.

[**0074**] The tamper proofing system of **FIG. 5** is most useful in applications such as police departments where it is not clear which patrol officer will be driving any particular car on a particular day. This is the normal case since cars break, officers get sick etc. so car assignments can vary on a day to day basis. If the car assignments never vary or in other applications where there is no uncertainty as to whose C1 and C2 keys are going to be used, the process of **FIG. 8** can be used. In **FIG. 8**, there is a triple encryption on the front end and only a single encryption on the back end, the tamper proofing protection arises from the triple encryption on the front end. The tamper proofing process of **FIG. 8** is useful where there is no uncertainty as to the exact identities of the three people who will be creating, supervising or holding in evidence and using in court or for other uses a particular digital file to be protected from tampering. Such applications include securing security camera files or digital crime scene files.

[**0075**] Step **250** of **FIG. 8** represents encrypting the A1 key with the C1 key and then encrypting those results with the B1 key and storing the results in NVRAM in the security system used to generate the digital file to be protected. In step **252**, the security supervisor or system installer installs a new tape or other recording medium in the system such as ZIP drive or removable hard disk cartridge or rewritable CD (these other types of removable media may be substituted in the other embodiments disclosed herein also). When the new medium for recording is inserted, a key chip containing the B2 key of the security supervisor or system installer is inserted into the key port. This key chip will be removed when the supervisor or installer in done installing the new recording medium. Step **254** represents the process of the security video unit reading the B2 key from the chip and using it to decrypt the encryption results generated in step **250**. These intermediate results generated in step **254** are stored in volatile RAM. In step **256**, the security officer or other person who will be generating the digital file to be protected plugs her key chip containing the C2 key into the key port of the security video unit (the term security video unit is intended to mean any device that generates and/or records digital data of any kind, whether or not it includes video data, to be protected). The security video unit then uses the C2 key read from the key chip to decrypt the intermediate decryption results generated in step **254** to generate the A1 key in the clear. The A1 key is then stored in the clear in volatile RAM. In the embodiment of **FIG. 8**, the A1 key is first encrypted with the C1 key and then the results are encrypted with the B1 key. In alternative embodiments, this order can be changed so that the A1 key is encrypted with the B1 key first and then the results encrypted with the C1 key and appropriate changes are then made to to decrypt the results to arrive back at the A1 key in the clear. In the embodiment shown in **FIG. 8**, the decryption using the B2 and C2 keys are indicated as being done when the key chips are inserted. In alternative embodiments, the B2 and C2 keys can simply stored in memory when the key chips are inserted, and the decryptions can be done at a time when both keys are available. In this case, **FIG. 6** would erase both B2 and C2 if the microswitch sensed door switch had been tripped or if any other event being monitored for improper access or tampering has occurred.

[**0076**] Step **258** represents the arrival of video and audio data (or any other type of digital data to be protected) forming evidence that must be rendered tamper proof. Step **260** is the process the security video unit carries out to calculate one or more digital signatures on the incoming data. If the incoming data is video frames with audio data accompanying each frame, a digital signature is calculated on each frame of video and on the audio data that accompanies each frame. Step **262** is a test to determine if the A1 key still exists in volatile RAM in the clear. If not, step **264** is performed to carry out any suitable anti-tampering protocol for this particular application. The protocols identified above may be used as well as others to give an indication that tampering may have occurred, block recording, etc. The A1 key will be automatically erased by a process similar to that of **FIG. 6** if the microswitch sensed door **53** is opened. The only difference between this process and **FIG. 6** is that step **230** in **FIG. 6** is modified to erase not only the A1 key but also the intermediate decryption result generated in step **254** in **FIG. 8**.

[**0077**] If test **262** determines that the A1 key still exists in the clear, step **266** is performed to perform a single encryption of each digital signature computed in step **260** using the A1 key. Finally, step **268** is performed to record the

encrypted digital signature data and the unencrypted data of the video frames and accompanying audio data or other digital data to be protected.

[0078] To verify that the data protected by the process of **FIG. 8** has not been tampered with, a process similar to that shown in **FIG. 7** is used. The only difference between the process used to verify a file protected by the process of **FIG. 8** and the process of **FIG. 7** is that step **234** is omitted. Thus, a process to verify the integrity of a file protected by the process of **FIG. 8** comprises performing steps **236**, **238**, **240**, **242**, **244** and **246** of **FIG. 7**.

[0079] Referring to **FIG. 9**, there is shown a process using no encryption on the front end and triple encryption of the digital signature data on the back end. This process can be used in situations where there is uncertainty as to whose B1 and C1 keys will be used to encrypt. Step **270** represents the process of storing the A1 key in nonvolatile RAM in the in-car video unit or other security video system (again, any type system that generates and/or records digital data files to be protected can be used). Step **272** represents the process of the evidence officer supplying a new recordable medium to the in-car video unit and plugging his key chip into the key chip port. His key chip contains the B1 key, and this key is read by the in-car video unit and stored in volatile RAM. The evidence officer's key chip is then removed, and the patrol officer takes possession of the car. Step **274** represents the process of the patrol officer plugging his key chip into the key port to provide the C1 key. In step **276**, video frames and the accompanying audio data (or whatever other type of digital data that is to be protected) arrives. In step **278**, the in-car video unit computes a digital signature on each video frame and a signature on the accompanying audio (or computes a digital signature on whatever digital data is to be protected).

[0080] Test **280** determines if both the B1 and C1 keys still exist in the clear in volatile RAM. If either B1 or C1 is not still there, step **282** is performed to carry out whatever predetermined tamper proofing protocol is appropriate for this application. That can be stopping all recording, making a notation on the recording and continuing to record, etc. If both B1 and C1 still exist in the clear, step **284** is performed to encrypt each digital signature with the A1 key. Then step **286** is performed to encrypt the results of the encryption of step **284** using the B1 key. Then, step **288** is performed to encrypt the results generated by step **286** using the C1 key. Finally, step **290** is performed to record the triple encrypted digital signature data along with the unencrypted video and audio data (or other digital data to be protected).

[0081] A process similar to the process of **FIG. 6** is used to safeguard the B1 and C1 keys in the clear. Basically, this process is the process of **FIG. 6** except that step **230** erases the B1 and C1 keys if the microswitch sensed door **53** is opened.

[0082] A process similar to the process of **FIG. 7** is used to verify that the data protected by the process of **FIG. 9** has not been tampered with. This process is the process of **FIG. 7** modified by insertion of an additional decryption step between steps **234** and **236**. This additional decryption step decrypts the results obtained by step **234** using the B2 key. Step **236** in all the processes to verify the integrity of files protected with the processes of **FIGS. 5, 8** and **9** results in output of the digital signature data recorded on the recording medium.

[0083] The above multiple encryption processes can also be applied to single, double or triple encrypt the compressed video and audio data or other digital data to be protected itself without the additional steps to calculate digital signatures on the data and encrypt only the signatures.

[0084] The term tamper proof data used in the claims is intended to include all the forms of tamper proof data discussed herein including single, double or triple encrypted signature data along with the unencrypted compressed video and audio data or other digital data from the signature data was calculated as well as singe, double or triple encrypted digital video and audio or other digital data of the original file and upon which no signature data was calculated.

[0085] Although the invention has been disclosed in terms of the preferred and alternative embodiments disclosed herein, those skilled in the art will appreciate possible alternative embodiments and other modifications to the teachings disclosed herein which do not depart from the spirit and scope of the invention. All such alternative embodiments and other modifications are intended to be included within the scope of the claims appended hereto.

What is claimed is:

1. An apparatus comprising:

a video camera;

a microphone;

a display;

a speaker;

an input for receiving status data;

a base unit comprising:

means for receiving the output signal of said video camera and preparing said output signal for compression;

an analog-to-digital converter coupled to convert audio signals from said microphone to digital data;

a buffer and merge circuit functioning to merge said status data with the frames of video data output by said means for receiving to generate composite live digital video data, and for buffering the resulting composite live digital video data;

a compression circuit for compressing said composite live digital video data stored in said buffer using any compression algorithm, and for compressing said audio data output by said analog-to-digital converter using any compression algorithm;

a digital video tape recorder or other removable medium recording device for recording said frames of compressed video data and said audio data;

local playback means for receiving said composite live digital video from said buffer and merge circuit and for displaying at least said video frames from said video camera along with a selected number of items of said status data on said display and for playing audio captured by said microphone on said speaker; and

means for controlling said base unit.

2. The apparatus of claim 1 further comprising an anti-tampering circuit coupled to receive said compressed frames

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of video data and said compressed audio data and for computing a digital signature on every frame of compressed data and for encrypting each said digital signature and recording said encrypted digital signature data on said digital video tape recorder or other removable medium recording device.

3. The apparatus of claim 1 further comprising an anti-tampering means coupled to receive compressed data and for tamper proofing said data to generate tamper proof data and recording said tamper proof data on said digital video tape recorder or other removable medium recording device.

4. The apparatus of claim 1 wherein said video camera is an analog video camera.

5. The apparatus of claim 1 wherein said video camera is a digital video camera.

6. The apparatus of claim 1 wherein said video camera is a wireless video camera, and wherein said means for receiving a signal from said video camera includes a receiver for receiving and demodulating radio frequency signals from said video camera and circuitry to develop digital video data suitable for compression from the received radio frequency signals.

7. The apparatus of claim 1 wherein said microphone is a wireless microphone and said base unit includes a receiver to receive and demodulate radio frequency signals from said wireless microphone to develop an audio signal and apply the audio signal to said analog-to-digital converter

8. An apparatus comprising:

a video camera;

a microphone;

a display;

a speaker;

an input for receiving status data;

a base unit comprising:

means for receiving the output signal of said video camera and preparing said output signal for compression;

an analog-to-digital converter coupled to convert audio signals from said microphone to digital data;

a buffer and merge circuit functioning to merge said status data with the frames of video data output by said means for receiving to generate composite live digital video data, and for buffering the resulting composite live digital video data and for detecting sync intervals in said frames of video data output by said means for receiving and outputting a frame signal, and for receiving at least frame number data that increments with each received frame and merging said frame number data into said composite live digital video data stream;

a compression circuit for compressing said composite live digital video data stored in said buffer using any compression algorithm, and for compressing said audio data output by said analog-to-digital converter using any compression algorithm;

anti-tampering means for receiving said compressed video and audio data and rendering it tamper proof;

a digital video tape recorder or other removable medium recording device for recording whatever data is output by said anti-tampering means;

local playback means for receiving said composite live digital video from said buffer and merge circuit and for displaying at least said video frames from said video camera along with a selected number of items of said status data on said display and for playing audio captured by said microphone on said speaker; and

means for controlling said base unit including a frame counter for receiving said frame signal and for incrementing a frame count each time said frame signal is received and for supplying said frame count data as status data to said buffer and merge circuit.

9. The apparatus of claim 8 wherein said video camera is an analog video camera.

10. The apparatus of claim 8 wherein said video camera is a digital video camera.

11. The apparatus of claim 8 wherein said video camera is a wireless video camera, and wherein said means for receiving a signal from said video camera includes a receiver for receiving and demodulating radio frequency signals from said video camera and circuitry to develop digital video data suitable for compression from the received radio frequency signals.

12. The apparatus of claim 8 wherein said system controller also includes a clock and supplies time of day data to said buffer and merge circuit as status data, and wherein said buffer and merge circuit functions to merge said time of day data into said composite live video data stream.

13. The apparatus of claim 8 wherein means for local playback is controlled by said means for controlling as to which items of said status data are overlaid on the displayed video and wherein said means for local playback further comprises an input for receiving compressed video and audio data and said status data recorded on said digital video tape recorder and functions to decompress said video and audio data and display the decompressed video data along with zero or more items of selected status data on said display and convert said decompressed audio data to an audio signal and play it on said speaker.

14. The apparatus of claim 8 wherein means for local playback is controlled by said means for controlling as to which items of said status data are overlaid on the displayed video and wherein said means for local playback further comprises an input for receiving compressed video and audio data and said status data recorded on said digital video tape recorder and functions to decompress said video and audio data and display the decompressed video data along with zero or more items of selected status data on said display and convert said decompressed audio data to an audio signal and play it on said speaker.

15. The apparatus of claim 8 wherein said microphone is a wireless microphone and said base unit includes a receiver to receive and demodulate radio frequency signals from said wireless microphone to develop an audio signal and apply the audio signal to said analog-to-digital converter

16. An apparatus comprising:

a video camera;

a microphone;

a display;

a speaker;

an input for receiving status data;

a base unit comprising:

means for receiving the output signal of said video camera and preparing said output signal for compression;

an analog-to-digital converter coupled to convert audio signals from said microphone to digital data;

a buffer and merge circuit functioning to merge said status data with the frames of video data output by said means for receiving to generate composite live digital video data, and for buffering the resulting composite live digital video data, and for recognizing a sync signal in the incoming video data and outputting a frame signal, and for receiving a frame count signal and merging said frame count as status data in said composite live digital video data;

a compression circuit for compressing said composite live digital video data stored in said buffer using any compression algorithm to generate compressed composite live digital video data, and for compressing said audio data output by said analog-to-digital converter using any compression algorithm to generate compressed audio data;

a hard disk means for receiving and continuously recording said compressed composite live digital video data along with said compressed audio data, and for receiving an archive signal commanding playback of recorded data and specifying in any way at least the starting point in the stream recorded data where said playback is to begin;

a digital video tape recorder or other removable medium digital data recording device for recording compressed data output by said hard disk means when a record signal is received; and

control means for controlling said base unit and including at least a frame counter, said control means also coupled to receive said frame signal and for incrementing said frame counter each time said frame signal is received and for supplying said frame count to said buffer and merge circuit as status data.

17. The apparatus of claim 16 further comprising anti-tampering means coupled to receive said compressed data output by said compression means and rendering said compressed data tamper proof.

18. The apparatus of claim 16 further comprising local playback means for receiving said live digital video from said buffer and merge circuit and for displaying at least said video frames from said video camera along with a selected number of items of said status data on said display and for playing audio captured by said microphone on said speaker.

19. The apparatus of claim 16 further comprising local playback means for receiving said live digital video from said buffer and merge circuit and recorded, compressed video, status and audio data from said hard disk means or said digital video tape recorder and for selection of one source of video, status and audio data under control of said control means and for decompressing at least the selected compressed video and audio data and for displaying the decompressed video along with a selected number from zero to some larger number of items of said status data on said display and for playing audio captured by said microphone on said speaker.

20. An apparatus comprising:

one or more video inputs, each for receiving either an analog or a digital video signal and outputting a video signal;

zero or more wireless video input means for receiving either an analog or a digital video signal that is transmitted by electromagnetic transmission and for outputting a zero or more video signals;

means for selecting a video signal from any of said one or more video inputs or said zero or more wireless video inputs and appropriately preparing said video signal as digital data ready for compression, the type of preparation being dependent upon whether the video signal selected is digital or analog;

one or more audio inputs for receiving audio signals and outputting same;

zero or more wireless audio input means for receiving audio signals modulated onto an electromagnetic carrier and outputting zero or more audio signals;

means for digitizing the audio signals output by said one or more audio inputs and said zero or more wireless audio input means to generate one or more channels of digital audio data;

zero or more data paths for receiving one or more types of system status data including a time of day signal and/or a frame counter signal;

a buffer and merge circuit for receiving the digital data of the selected video signal and said status data and merging them into a live digital video stream of data which includes said status data;

compression means for receiving said live digital video stream of data and said one or more channels of digital audio data and for compressing all said data using any compression algorithm;

anti-tamper means for receiving compressed data output by said compression means and rendering it tamper proof;

a hard disk for continuously recording the compressed data output by said compression means;

a digital video cassette recorder or other removable medium digital data recording means for recording digital data, coupled to said anti-tamper means and said hard disk, for recording digital data;

controller means for receiving operator input and for controlling which video signal input is selected and which microphone input is selected and controlling said recorder means to record data directly from said anti-tamper means or data played back from said hard disk or to not record data at all and for controlling said hard disk to search for and playback data starting from a starting point designated by an operator, which can be a previously recorded time or frame, and for controlling said recorder means to record said played back data from said hard disk to provide an after-the-fact recording capability; and

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playback means for providing outputs from which a video image may be derived and sound waves may be generated, said playback means having as a video and audio input either said live digital video stream of data and live audio data or previously recorded compressed video and audio data, the source of video and audio data being under control of said controller means, and providing video data and audio signals for playback thereby providing the ability to display and hear live video and audio or previously recorded video and audio.

21. A process to tamper proof digital data absent a conspiracy between more than one person holding key pairs, comprising the steps:

(1) generating digital data of any type that is to be rendered tamper proof;

(2) assigning each of a plurality of multiple encryption/decryption key pairs to a different person;

(3) calculating one or more digital signatures on the data to be protected;

(4) encrypting the encryption key of a first key pair belonging to a first person to be used to encrypt said digital signature data using the encryption key of a second key pair;

(5) having a second person temporarily supply the decryption key of said second key pair and using it to decrypt said encryption key of said first key pair and store said encryption key of said first key pair in volatile memory in the clear;

(6) monitoring for the occurrence of any physical or electrical phenomenon or event which would indicate the possibility that said digital data to be protected has been accessed improperly or tampered with;

(7) determining if said phenomenon or event has occurred indicating improper access or possible tampering;

(8) if so, erasing said encryption key of said first key pair and performing any suitable anti-tampering protocol such as blocking all access to said data to be protected, blocking all recording of said data to be protected or placing a notation in said data that it may have been tampered with or accessed improperly;

(9) if said phenomenon or event indicating improper access or possible tampering has not occurred, encrypting said digital signature data using said encryption key of said first key pair which is stored in the clear in said volatile memory and then encrypting these results with the encryption key of a third key pair.

22. The process of claim 21 further comprising the steps of recording the encrypted signature data and said data to be protected and a step for verifying that said recorded data has not been tampered with by comparison of digital signatures.

23. The process of claim 21 wherein said encryption of step **9** is of the digital data to be protected itself and not encryption of digital signature data calculated from the data to be protected, and wherein step (3) is eliminated.

24. A process to tamper proof digital data absent a conspiracy between more than one person holding key pairs, comprising the steps:

(1) generating digital data of any type that is to be rendered tamper proof;

(2) assigning each of a plurality of multiple encryption/decryption key pairs to a different person;

(3) calculating one or more digital signatures on the data to be protected;

(4) encrypting the encryption key of a first key pair belonging to a first person to be used to encrypt said digital signature data using the encryption key of a third key pair assigned to a third person and then encrypting that result with the encryption key of a second key pair assigned to a second person and storing the double encrypted result in volatile RAM;

(5) having said second person temporarily supply the decryption key of said second key pair and using it to decrypt said double encrypted result to generate a single encrypted result and store said single encrypted result in volatile memory;

(6) having said third person temporarily supply the decryption key of said third key pair and using it to decrypt said single encrypted result to generate an in-the-clear version of the encryption key of said first key pair, and storing same in volatile RAM;

(7) monitoring for the occurrence of any physical or electrical phenomenon or event which would indicate the possibility that said digital data to be protected has been accessed improperly or tampered with;

(8) determining if said phenomenon or event has occurred indicating improper access or possible tampering;

(9) if so, erasing said encryption key of said first key pair from said volatile memory and performing any suitable anti-tampering protocol such as blocking all access to said data to be protected, blocking all recording of said data to be protected or placing a notation in said data that it may have been tampered with or accessed improperly;

(10) if said phenomenon or event indicating improper access or possible tampering has not occurred, encrypting said digital signature data using said encryption key of said first key pair which is stored in the clear in said volatile memory.

25. The process of claim 24 further comprising a step for verifying the integrity of said data to be protected by comparison of digital signatures.

26. The process of claim 24 wherein step (3) is eliminated and wherein step (10) comprises encrypting the data to be protected itself using the encryption key of said first key pair instead of digital signature data computed therefrom.

27. A process to tamper proof digital data absent a conspiracy between more than one person holding key pairs, comprising the steps:

(1) generating digital data of any type that is to be rendered tamper proof;

(2) assigning each of a plurality of multiple encryption/decryption key pairs to a different person;

(3) calculating one or more digital signatures on the data to be protected;

(4) storing the encryption key of a first key pair belonging to a first person to be used to encrypt said digital signature data in nonvolatile RAM;

(5) having said second person temporarily supply the encryption key of said second key pair and storing it in volatile memory;

(6) having a third person temporarily supply the encryption key of said third key pair;

(7) monitoring for the occurrence of any physical or electrical phenomenon or event which would indicate the possibility that said digital data to be protected has been accessed improperly or tampered with;

(8) determining if said phenomenon or event has occurred indicating improper access or possible tampering;

(9) if so, erasing said encryption key of said second key pair and/or said third key pair from said volatile memory and performing any suitable anti-tampering protocol such as blocking all access to said data to be protected, blocking all recording of said data to be protected or placing a notation in said data that it may have been tampered with or accessed improperly;

(10) if said phenomenon or event indicating improper access or possible tampering has not occurred, encrypting said digital signature data using said encryption key of said first key pair and then encrypting that result using said encryption key of said second key pair, and then encrypting that result using said encryption key of said third key pair.

28. The process of claim 27 further comprising a step for verifying the integrity of said data to be protected by comparing digital signature data.

29. The process of claim 27 wherein step (3) is eliminated and step (10 comprises encrypting the actual data to be protected instead of digital signature data calculated therefrom using the encryption keys of said first, second and third key pairs.

* * * * *

Appendix E

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Gammenthaler (43) **Pub. Date: Oct. 14, 2004**

(54) **IN-CAR DIGITAL VIDEO RECORDING WITH MPEG COMPRESSION**

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(21) Appl. No.: **10/056,537**

(22) Filed: **Jan. 23, 2002**

Related U.S. Application Data

(63) Continuation-in-part of application No. 09/812,412, filed on Mar. 19, 2001.

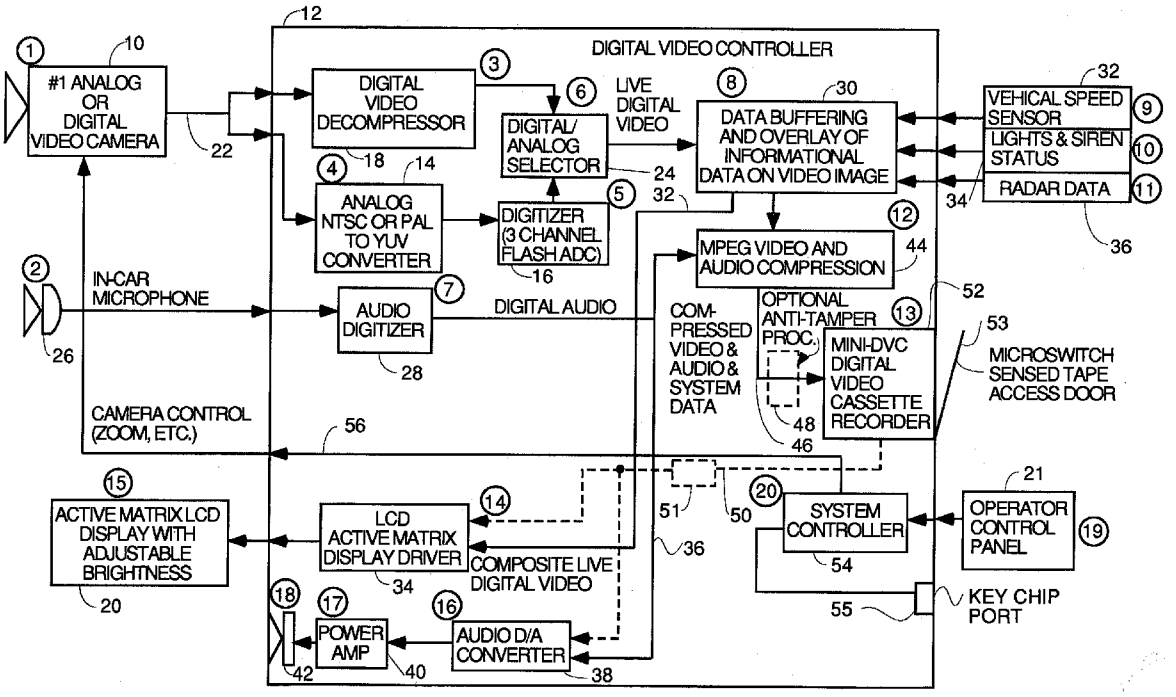
Publication Classification

(51) **Int. Cl.**[7] **H04N 5/225**; H04N 5/222

(52) **U.S. Cl.** **348/333.01**

(57) **ABSTRACT**

An in-car video system with inputs for one or more analog or digital video cameras, one or more of which may be wireless, and having inputs for one or more microphones, one or more of which may be wireless. The system includes circuitry to digitize the input signals, if necessary, merge the data with system status data and compress the resulting data with any algorithm, preferably MPEG-4. A hard disk and/or a digital video tape recorder records the compressed data, and a decompression circuit and active matrix video display and audio channel provide monitoring capability of live video and audio. In some embodiments, a hard disk continuously records all data and archives previously recorded data to tape when so ordered to provide after-the-fact recording capability. In some embodiments, anti-tampering circuitry renders the recorded data tamper-proof, and a local playback circuit allows local playback of either live or previously recorded video.



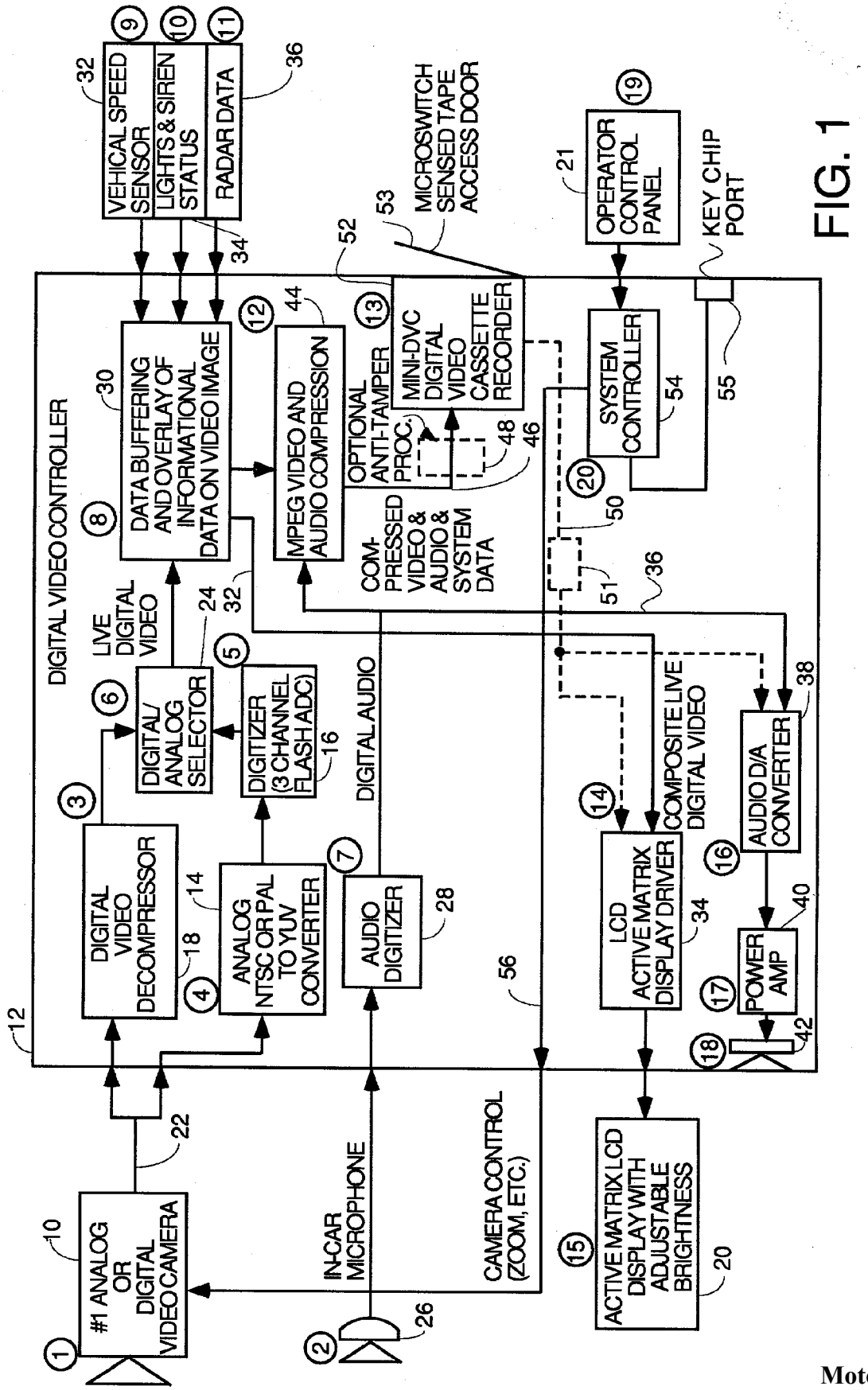

DIGITAL VIDEO CONTROLLER
#1 ANALOG OR DIGITAL VIDEO CAMERA
IN-CAR MICROPHONE
CAMERA CONTROL (ZOOM, ETC.)
ACTIVE MATRIX LCD DISPLAY WITH ADJUSTABLE BRIGHTNESS
DIGITAL VIDEO DECOMPRESSOR
ANALOG NTSC OR PAL TO YUV CONVERTER
AUDIO DIGITIZER
DIGITIZER (3 CHANNEL FLASH ADC)
DIGITAL/ ANALOG SELECTOR
LIVE DIGITAL VIDEO
DIGITAL AUDIO
DATA BUFFERING AND OVERLAY OF INFORMATIONAL DATA ON VIDEO IMAGE
MPEG VIDEO AND AUDIO COMPRESSION
OPTIONAL ANTI-TAMPER PROC.
COM-PRESSED VIDEO & AUDIO & SYSTEM DATA
MINI-DVC DIGITAL VIDEO CASSETTE RECORDER
MICROSWITCH SENSED TAPE ACCESS DOOR
VEHICAL SPEED SENSOR
LIGHTS & SIREN STATUS
RADAR DATA
OPERATOR CONTROL PANEL
KEY CHIP PORT
SYSTEM CONTROLLER
LCD ACTIVE MATRIX DISPLAY DRIVER
COMPOSITE LIVE DIGITAL VIDEO
AUDIO D/A CONVERTER
POWER AMP

FIG. 1

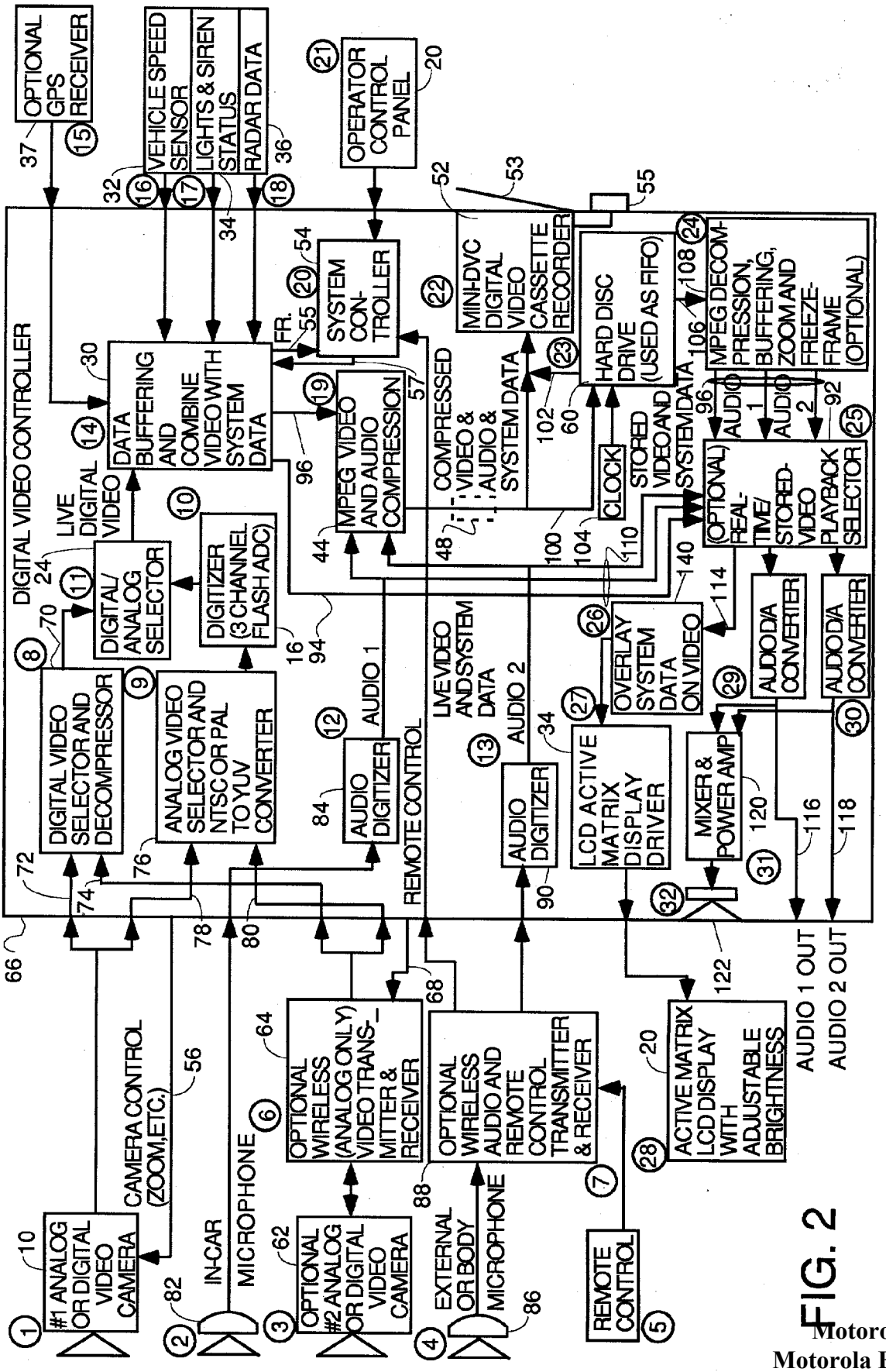


FIG. 2

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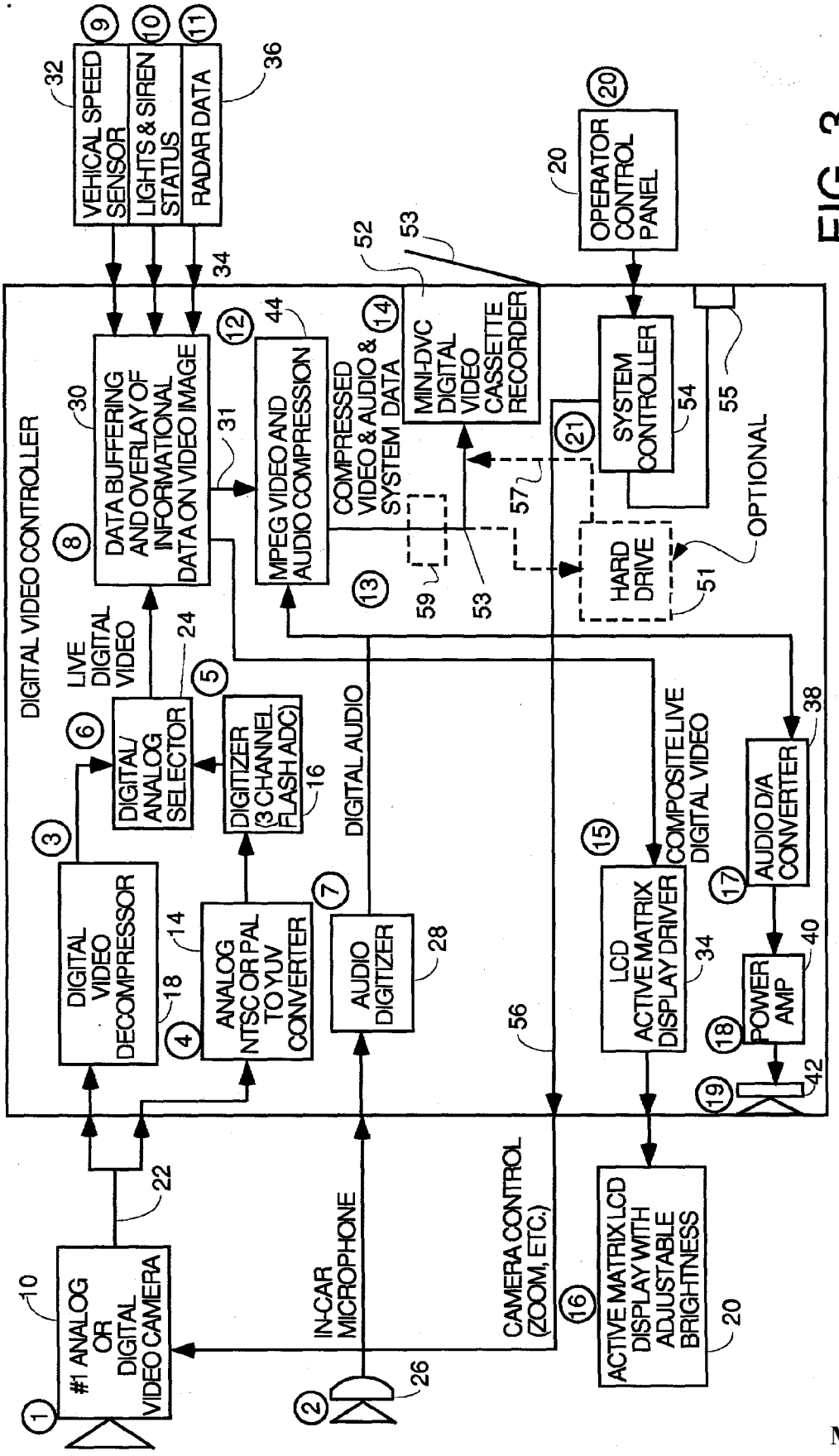

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LIVE DIGITAL VIDEO
DIGITAL AUDIO
DATA BUFFERING AND OVERLAY OF INFORMATIONAL DATA ON VIDEO IMAGE
MPEG VIDEO AND AUDIO COMPRESSION
COMPRESSED VIDEO & AUDIO & SYSTEM DATA
MINI-DVC DIGITAL VIDEO CASSETTE RECORDER
HARD DRIVE
SYSTEM CONTROLLER
OPERATOR CONTROL PANEL
VEHICAL SPEED SENSOR
LIGHTS & SIREN STATUS
RADAR DATA
LCD ACTIVE MATRIX DISPLAY DRIVER
COMPOSITE LIVE DIGITAL VIDEO
AUDIO D/A CONVERTER
POWER AMP
OPTIONAL

FIG. 3

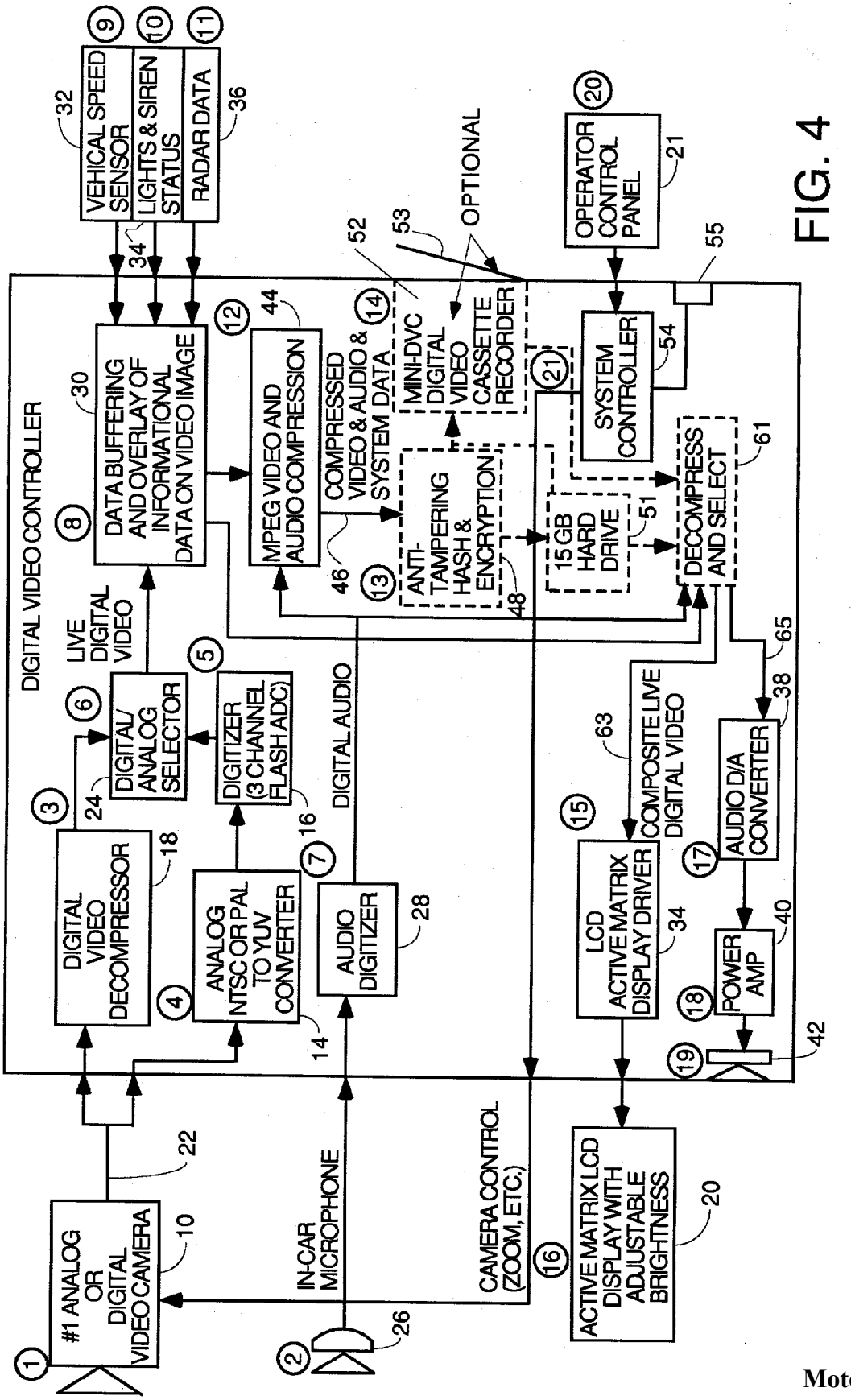

DIGITAL VIDEO CONTROLLER
VEHICAL SPEED SENSOR
LIGHTS & SIREN STATUS
RADAR DATA
OPTIONAL
OPERATOR CONTROL PANEL
DATA BUFFERING AND OVERLAY OF INFORMATIONAL DATA ON VIDEO IMAGE
MPEG VIDEO AND AUDIO COMPRESSION
COMPRESSED VIDEO & AUDIO & SYSTEM DATA
MINI-DVC DIGITAL VIDEO CASSETTE RECORDER
SYSTEM CONTROLLER
ANTI-TAMPERING HASH & ENCRYPTION
15 GB HARD DRIVE
DECOMPRESS AND SELECT
LIVE DIGITAL VIDEO
DIGITAL/ ANALOG SELECTOR
DIGITIZER (3 CHANNEL FLASH ADC)
DIGITAL AUDIO
DIGITAL VIDEO DECOMPRESSOR
ANALOG NTSC OR PAL TO YUV CONVERTER
AUDIO DIGITIZER
COMPOSITE LIVE DIGITAL VIDEO
AUDIO D/A CONVERTER
LCD ACTIVE MATRIX DISPLAY DRIVER
POWER AMP
#1 ANALOG OR DIGITAL VIDEO CAMERA
IN-CAR MICROPHONE
CAMERA CONTROL (ZOOM, ETC.)
ACTIVE MATRIX LCD DISPLAY WITH ADJUSTABLE BRIGHTNESS

FIG. 4

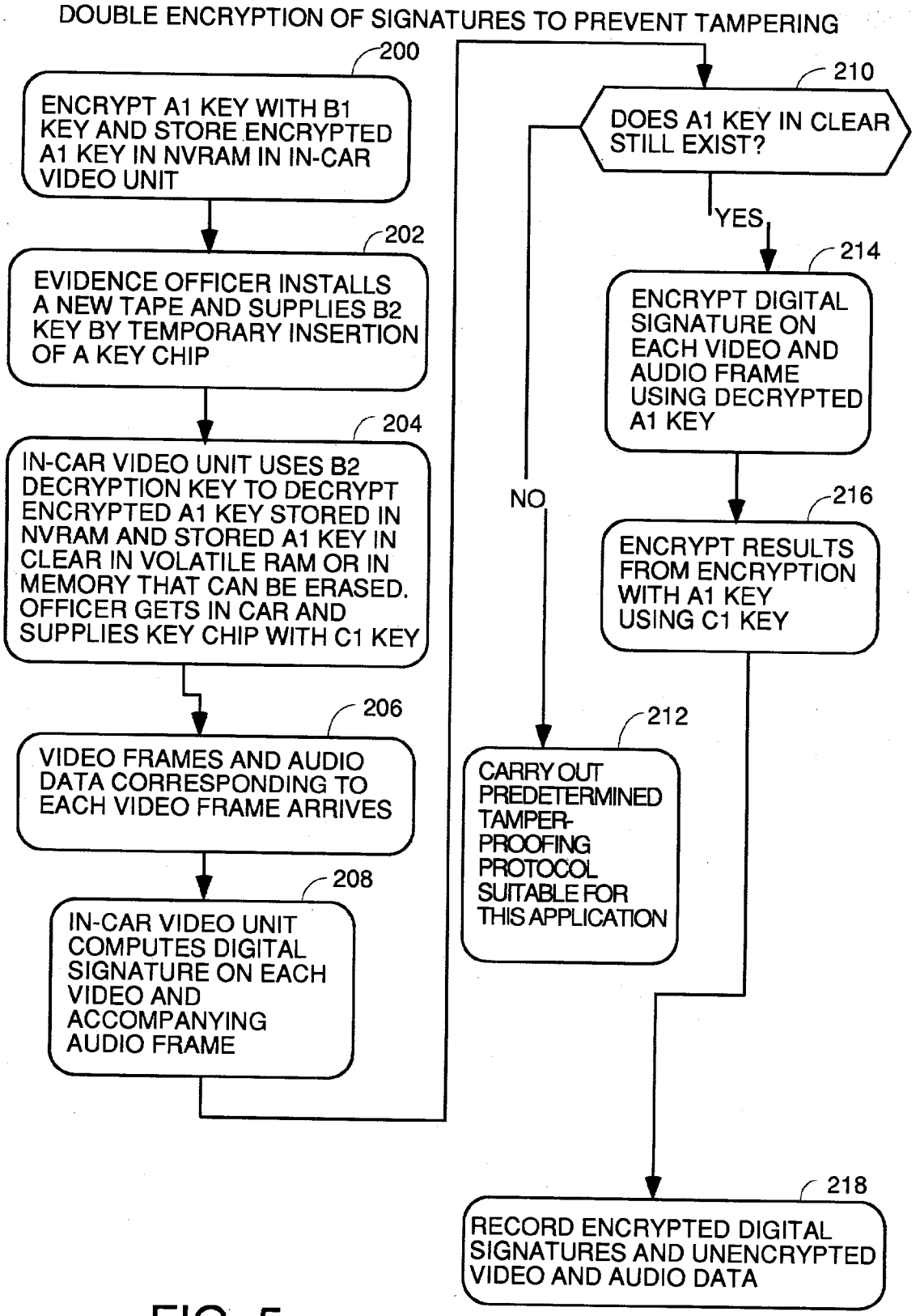

DOUBLE ENCRYPTION OF SIGNATURES TO PREVENT TAMPERING
200
ENCRYPT A1 KEY WITH B1 KEY AND STORE ENCRYPTED A1 KEY IN NVRAM IN IN-CAR VIDEO UNIT
202
EVIDENCE OFFICER INSTALLS A NEW TAPE AND SUPPLIES B2 KEY BY TEMPORARY INSERTION OF A KEY CHIP
204
IN-CAR VIDEO UNIT USES B2 DECRYPTION KEY TO DECRYPT ENCRYPTED A1 KEY STORED IN NVRAM AND STORED A1 KEY IN CLEAR IN VOLATILE RAM OR IN MEMORY THAT CAN BE ERASED. OFFICER GETS IN CAR AND SUPPLIES KEY CHIP WITH C1 KEY
206
VIDEO FRAMES AND AUDIO DATA CORRESPONDING TO EACH VIDEO FRAME ARRIVES
208
IN-CAR VIDEO UNIT COMPUTES DIGITAL SIGNATURE ON EACH VIDEO AND ACCOMPANYING AUDIO FRAME
210
DOES A1 KEY IN CLEAR STILL EXIST?
YES
214
ENCRYPT DIGITAL SIGNATURE ON EACH VIDEO AND AUDIO FRAME USING DECRYPTED A1 KEY
216
ENCRYPT RESULTS FROM ENCRYPTION WITH A1 KEY USING C1 KEY
NO
212
CARRY OUT PREDETERMINED TAMPER-PROOFING PROTOCOL SUITABLE FOR THIS APPLICATION
218
RECORD ENCRYPTED DIGITAL SIGNATURES AND UNENCRYPTED VIDEO AND AUDIO DATA

FIG. 5

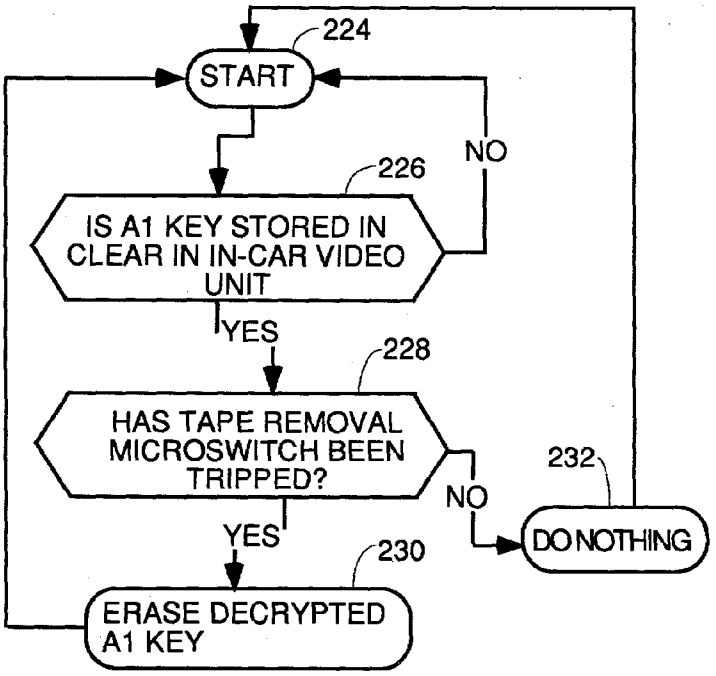

224
START
226
IS A1 KEY STORED IN CLEAR IN IN-CAR VIDEO UNIT
NO
YES
228
HAS TAPE REMOVAL MICROSWITCH BEEN TRIPPED?
NO
232
DO NOTHING
YES
230
ERASE DECRYPTED A1 KEY

FIG. 6

234
DECRYPT EACH RECORDED VIDEO AND AUDIO FRAME SIGNATURE WITH C2 KEY
236
DECRYPT RESULTS WITH A2 KEY
238
COMPUTE DIGITAL SIGNATURE FOR EACH RECORDED VIDEO FRAME AND THE ACCOMPANYING AUDIO USING SAME DIGITAL SIGNATURE ALGORITHM AS USED BY IN-CAR VIDEO UNIT TO COMPUTE DIGITAL SIGNATURES
240
COMPARE DIGITAL SIGNATURES JUST COMPUTED FOR EACH FRAME TO DECRYPTED DIGITAL SIGNATURES DERIVED FROM RECORDED DIGITAL SIGNATURES FOR THE CORRESPONDING FRAME
244
TAPE HAS NOT BEEN ALTERED
YES
242
MATCH?
246
TAPE HAS BEEN ALTERED

FIG. 7

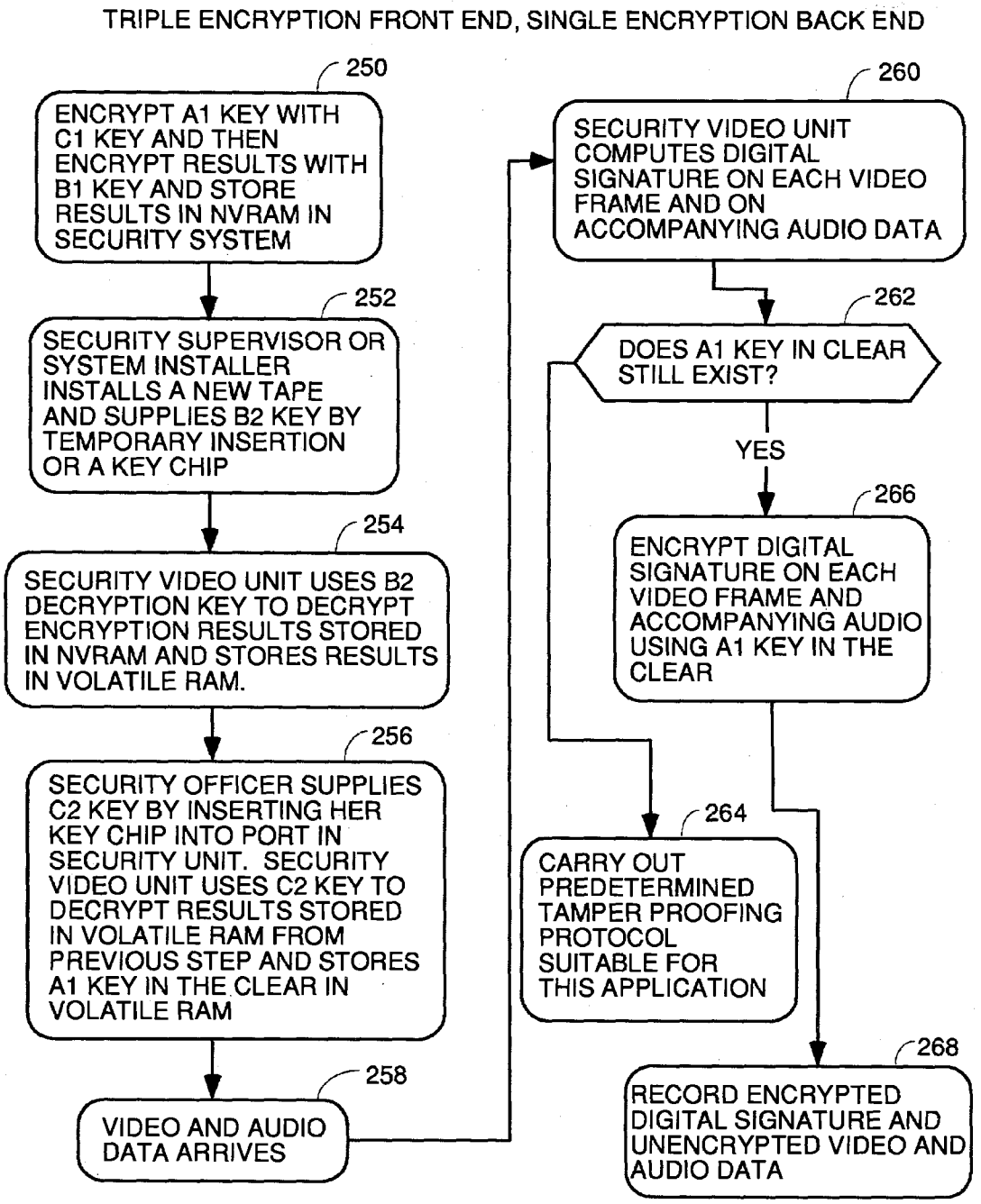

TRIPLE ENCRYPTION FRONT END, SINGLE ENCRYPTION BACK END
250
ENCRYPT A1 KEY WITH C1 KEY AND THEN ENCRYPT RESULTS WITH B1 KEY AND STORE RESULTS IN NVRAM IN SECURITY SYSTEM
252
SECURITY SUPERVISOR OR SYSTEM INSTALLER INSTALLS A NEW TAPE AND SUPPLIES B2 KEY BY TEMPORARY INSERTION OR A KEY CHIP
254
SECURITY VIDEO UNIT USES B2 DECRYPTION KEY TO DECRYPT ENCRYPTION RESULTS STORED IN NVRAM AND STORES RESULTS IN VOLATILE RAM.
256
SECURITY OFFICER SUPPLIES C2 KEY BY INSERTING HER KEY CHIP INTO PORT IN SECURITY UNIT. SECURITY VIDEO UNIT USES C2 KEY TO DECRYPT RESULTS STORED IN VOLATILE RAM FROM PREVIOUS STEP AND STORES A1 KEY IN THE CLEAR IN VOLATILE RAM
258
VIDEO AND AUDIO DATA ARRIVES
260
SECURITY VIDEO UNIT COMPUTES DIGITAL SIGNATURE ON EACH VIDEO FRAME AND ON ACCOMPANYING AUDIO DATA
262
DOES A1 KEY IN CLEAR STILL EXIST?
YES
266
ENCRYPT DIGITAL SIGNATURE ON EACH VIDEO FRAME AND ACCOMPANYING AUDIO USING A1 KEY IN THE CLEAR
264
CARRY OUT PREDETERMINED TAMPER PROOFING PROTOCOL SUITABLE FOR THIS APPLICATION
268
RECORD ENCRYPTED DIGITAL SIGNATURE AND UNENCRYPTED VIDEO AND AUDIO DATA

FIG. 8

NO ENCRYPTION ON FRONT END, TRIPLE ENCRYPTION ON THE BACK END

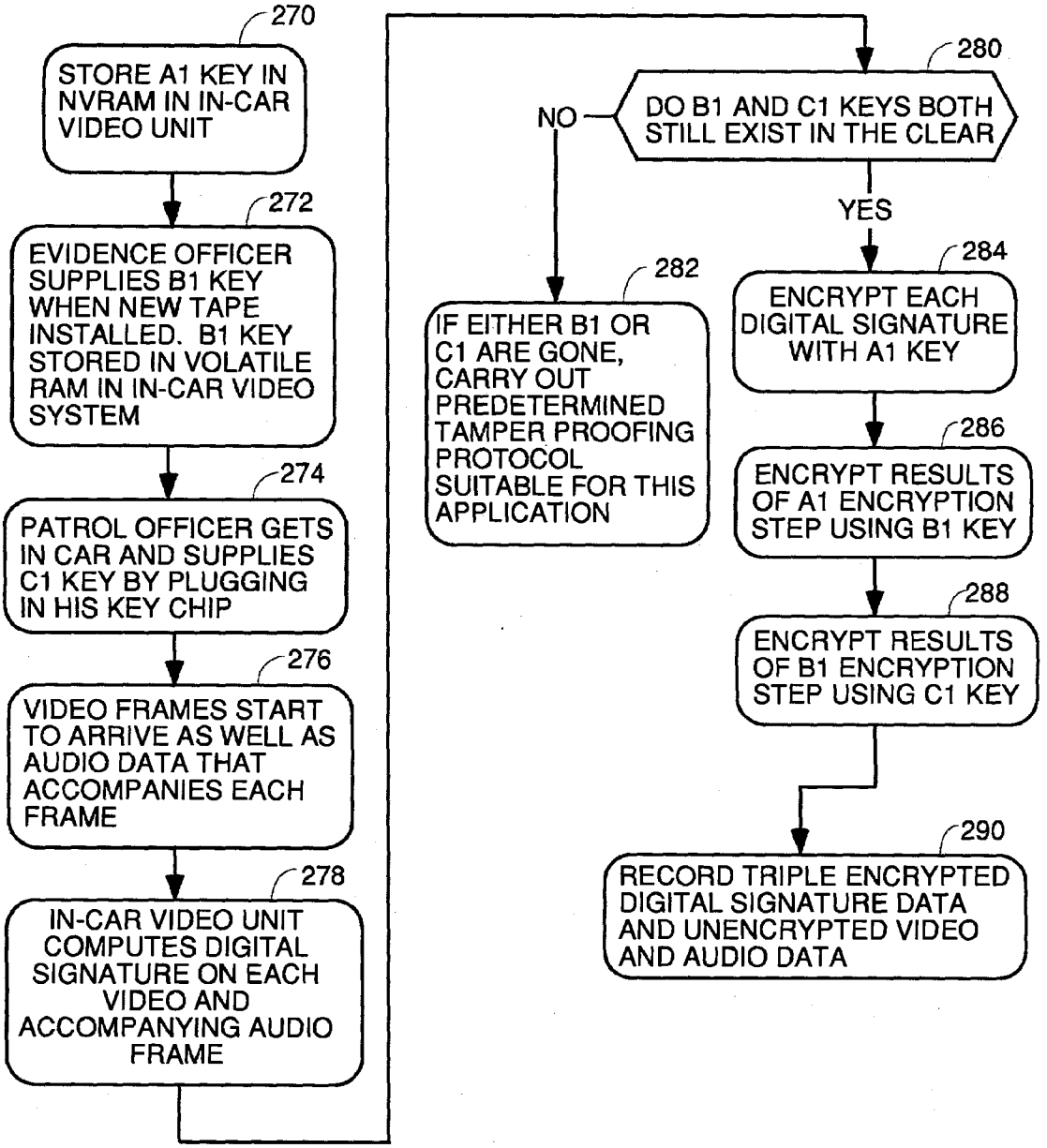


FIG. 9

IN-CAR DIGITAL VIDEO RECORDING WITH MPEG COMPRESSION

BACKGROUND OF THE INVENTION

[0001] Police cruisers have begun recording the scene outside the cruiser for evidentiary purposes for drunk driving surveillance and arrests, traffic stops and arrests, etc. Many conventional police video systems use analog VHS video tape recorders and analog video cameras. An example of such systems is U.S. Pat. No. 4,789,904 owned by Kustom Signal, Inc. This patent discloses a vehicle mounted camera and control head mounted within the police car and a video recorder housed in the trunk in a bulletproof, environmentally controlled vault. The surveillance system also includes a wireless microphone. The system is powered off the battery and may be manually or automatically activated such as when the siren and/or lights come on.

[0002] Another example of in-car video systems is U.S. Pat. No. 6,028,528 assigned to Mobile-Vision, Inc. This patent discloses an apparatus that can manage transfers of video recording media bearing machine readable registration codes. This media is adapted to record video from a vehicle-mounted camera. The management apparatus (and the methods) operate with a user identification key carrying at least one machine readable, identification code, as well as a supplemental code. The apparatus has a port for reading and writing to the key, a registration device, and a processor. The port can provide in response to the key, an identification signal and a supplemental signal corresponding to the identification and supplemental code. The registration device can read the registration codes borne by the video recording media and can provide in response thereto a registration signal. The processor is coupled to the port and the registration device for (a)producing in response to the identification signal, a selection signal signifying an instruction to transfer that one of the video recording media bearing a selected one of the registration codes without requiring an intervening user selection, (b) verifying and recording the registration signal, and (c) writing the supplemental code through the port to the identification key. The management apparatus also includes a mobile system and a station system.

[0003] The mobile system includes a video recorder, a remote port device, and a controller. The video recorder can record on the video recording media, video from the vehicle-mounted camera. The remote port device can (i) write the supplemental code to the key, and (ii) read the key and provide in response thereto, a remote identification signal corresponding to the identification code. The controller is coupled to the remote port device and the video recorder for controlling the video recorder in response to the remote identification signal.

[0004] Another example of prior art in-car video systems is U.S. Pat. No. 5,408,330 to Squicciarini, et al. and owned by CrimTec, Inc. This patent teaches a video incident capture system for law enforcement vehicles. The video incident capture system incorporates a video camera, a VHS analog video recorder, a radar unit, a real time clock, a monitor, a portable wireless microphone and its associated receiver and a system controller integrating the control of the various components to produce a comprehensive, unedited record of the incident. The system controller superimposes the target speed and patrol speed data generated by the radar unit over the video signals generated by the video camera prior to being recorded on the videotape. The portable wireless microphone permits the conversation between the law enforcement and a second party to be made part of the recorded incident. A radar interface will replace the target and/or patrol speed data with error data when an error in the operating parameters of the radar unit is detected. The system controller also provides a control function which prohibits the video recorder from recording over a previously recorded portion of the videotape when the videotape has been either rewound or fast-forwarded from the position where the prior recording was terminated. The system controller and video recorder are enclosed in a temperature controlled sealed vault mounted in the trunk of the law enforcement vehicle.

[0005] The main problem with all these prior art systems is that they do not have adequate recording time capacity to cover an entire 8-hour police shift on one tape much less a 24-hour period. There are numerous other deficiencies of these analog video tape recorder systems. For example, they are bulky and the video recorder components frequently have to be mounted in the trunk of the police car. This complicates getting the video and audio signals to them and complicates interfacing between the officer and the unit. Further, the prior art in-car video systems do not all have the ability to select from different video and audio sources such as digital video cameras, analog video cameras and in-car or wireless microphones. They do not have the ability to report the police car position, and they all do not have the ability to record the lights and siren status. They do not all have an antitampering encryption process. They also do not have the ability to select between in-car monitoring of the live video being recorded or local playback of what has already been recorded while continuing to record live video. They also do not all have the ability to select between in-car monitoring of the live video being recorded or local playback of what has already been recorded. None of these prior art systems have the ability to play back what has already been recorded while continuing to record.

[0006] Thus, a need has arisen for an in-car video system that has higher recording capacity and is small enough to be mounted in a single unit which may be mounted in the cab of the police car. Solution of one or more of the other above noted problems would also be desirable.

SUMMARY OF THE INVENTION

[0007] The genus of the invention is characterized by the characteristic that all species will share the ability to digitize, and compress live audio signals and at least compress digital video camera output and record the compressed video and audio on a digital data recording medium of some type. In the preferred embodiment, the digital data recording medium is a hard disk for real time storage and with the capability to archive data off the disk onto a digital video tape recorder. In other embodiments, the compressed video and audio data is recorded directly onto digital video tape without use of an intervening step of recording onto a hard disk. In the preferred embodiment, the amount of compression and the medium size of the hard disk or digital video taep provide substantially larger amounts of record time than the prior art VHS based systems. Various species within this genus will also have hardware and/or software to solve one

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or more of the other problems identified above including the ability to record to the videotape events that have already happened which have been recorded on the hard disk, and the ability to render the digital video and audio recordings tamper proof regardless of whether they have been recorded on the hard disk or on videotape. Other species allow either analog or digital video cameras to be used and/or allow real time video playback of recorded video. Other species will be totally passive monitoring systems that record audio and video signals continually without the need for the officer to turn the record mode on or off and without access by the officer to the control panel of the system so that record mode cannot be shut off by the officer if he is participating in illegal activity.

[0008] Also disclosed is a separate invention that can be used in conjunction with the first invention to tamper proof the video and audio data, but which can also be used to tamper proof any digital data. This separate invention is a genus of multiple key, multiple encryption processes where multiple key pairs are assigned to multiple different people who are unlikely to conspire to supply all their keys. All species within the genus share the following characteristics:

[0009] (1) there will be digital data of some sort that needs to be rendered tamper proof such as video and audio evidence gathered by an in-car police patrol car video surveillance system, security camera images, digital crime scene files, message traffic, etc.

[0010] (2) there will be multiple key pairs, each key pair assigned to a different person, the group of people owning the keys being a group which is highly unlikely to enter into a conspiracy together to supply all their keys, often including a judge and an evidence officer;

[0011] (3) there will be monitoring for the occurrence of any physical or electrical phenomenon or event which indicates that the data to be protected has been improperly accessed or altered;

[0012] (4) there will be multiple encryptions or multiple encryption and decryption operations using different keys either on the front end (see definition below) of the process or the back end (see definition below) or both including a species with no encryptions on the front end and triple encryptions on the back end.

[0013] These encryptions and decryptions are done using the encryption and decryption keys belonging to the different people. If the event indicating possible tampering or access has occurred, a suitable tamper proofing protocol such as blocking all recording or making a notation in the data that possible tampering has occurred will be performed on the back end. The "front end" is a process that occurs one time at the time the tape is inserted into the system or just prior to the start of generation of the digital frame or frames or file to be protected. The "back end" is an encryption process that is applied to every video frame and accompanying audio data in an in-car or security camera application or performed on one or more digital files to be protected in other applications.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] **FIG. 1** is a block diagram of a basic in-car video system according to the teachings of the invention.

[0015] **FIG. 2** is a block diagram of an in-car video system according to the invention which includes a hard drive that constantly records video and audio and which has two camera inputs and two microphone inputs and an anti-tampering option.

[0016] **FIG. 3** is a block diagram of the basic class of embodiments represented by **FIG. 1** enhanced by an optional hard drive which constantly records video and audio data and with an anti-tampering option.

[0017] **FIG. 4** is a block diagram of the basic class of embodiments defined by the genus of the invention with a hard drive which constantly records video and audio data, and enhanced by an optional digital video tape recorder drive and with an anti-tampering option and an option for local playback of stored video and audio.

[0018] **FIG. 5** is a flow diagram of a multiple key, multiple encryption species within the genus of the second invention with a single encryption and decryption of one of the back end encryption keys on the front end and double encryption using two different keys on the back end.

[0019] **FIG. 6** is a flowchart of a process indicating how the integrity of the backend encryption keys is monitored.

[0020] **FIG. 7** is a flowchart of a process of how the integrity of a double back-end encrypted file is verified.

[0021] **FIG. 8** is a flowchart of a process for protecting digital data using double encryption of the back end encryption key using two different encryption keys with single encryption on the back end.

[0022] **FIG. 9** is a flowchart of a process for protecting a digital file using no encryption of one of the back end encryption keys on the front end but triple encryption at the back end using three different encryption keys.

DETAILED DESCRIPTION OF THE PREFERRED AND ALTERNATIVE EMBODIMENTS

[0023] Referring to **FIG. 1**, there is shown a basic in-car video system according to one embodiment within the genus of the invention. Video camera **10**, in this embodiment, can be either an NTSC or PAL format analog video camera or a digital video camera. In this embodiment, circuitry is provided in the base unit **12** to allow either type camera to be used. If a digital video camera is used, a camera with an IEEE 1394 Firewire™ interface is preferred. The video camera may also be a night vision video camera. Typical video cameras provide 128:1 or greater zoom, operator adjustable or automatic focus from 3 feet to infinity, adjustable shutter speed and f8 or adjustable f2 to f16 lens aperture. Typically, the video camera is mounted to the rear view mirror boom facing forward to look out the windshield. However, the video camera **10** may also be a wireless body camera worn by the officer so that when he steps out of the car, the scene he sees may be recorded. Alternatively, the video camera **10** may be a wireless camera mounted on a helicopter although this is typically found in embodiments where there are two camera inputs and the helicopter camera is the second of two video inputs. In wireless camera embodiments, link **22** between the video camera and the base unit **12** is a wireless link. Wireless video cameras are known and are in extensive use on umpires in the National

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Football League and the XFL, and, in such embodiments, the base unit includes a suitable receiver, decompression circuitry if the camera is digital and NTSC to YUV converter and A/D converter if the camera is analog. Zoom and focus for any of these cameras may be remotely controllable in some embodiments by issuing commands on an operator control panel **20**. The term "video camera" in the claims is intended to mean any one of these cameras.

[**0024**] The base unit includes circuitry to display the live video from the camera on a video display **20** so that zoom and focus setting and framing may be adjusted by the officer. Typically, the video display is an active matrix LCD display with adjustable brightness, but any type video display may be used.

[**0025**] In alternative embodiments, only one or the other type camera is allowed as opposed to either analog or digital hard wired types as shown in **FIG. 1**. In embodiments where only one type of camera is allowed, regardless of whether it is hard wired to the base unit **12** or coupled by a wireless link, the appropriate circuitry is present in the base unit for the type of camera selected. This appropriate circuitry is referred to in the claims as "means for receiving the output signal of said video camera". For example, if only an analog video camera **10** is in use, the base unit only needs an analog NTSC or PAL to YUV format converter **14** to convert the analog NTSC or PAL signal to a YUV format signal. The YUV signal is then digitized in an A/D converter **16** so as to output digital data in the same format output by decompressor **18** to put the image data into a format suitable for compression and overlay of status data. Preferably, the A/D converter is a 3 channel flash A/D. If a digital video camera is the only camera allowed, the base unit **12** includes only a digital video decompressor **18** that decompresses the lightly compressed AVI signals output by digital video cameras to output a digital format suitable for manipulation of the video image to mix in status data and suitable for compression. If a wireless camera is used, a receiver to convert the RF signals to baseband analog or compressed digital video is present along with the appropriate circuitry as described above to convert the baseband analog or digital video signal to a digital video signal suitable for compression.

[**0026**] If either an analog or a digital video camera may be coupled to the base unit, the base unit includes a digital/analog selector to pick the appropriate signal source of live video digital data to supply to the compression circuitry.

[**0027**] The embodiment of **FIG. 1** also includes a microphone **26**. In this embodiment, the microphone is mounted in the car so that radio traffic may be recorded as well as any sounds from outside the car which may be heard inside the car. In alternative embodiments, the microphone could be a wireless microphone worn on the body of the officer.

[**0028**] The base unit interfaces to the microphone via an audio digitizer **28** that functions to perform automatic gain control and digitize the audio signal of the microphone. In the case of a wireless microphone, a suitable receiver (not shown) precedes the A/D converter **28**.

[**0029**] The live digital video is supplied to a data buffering and overlay circuit **30**. Typically, this circuit is a programmed microprocessor. The function of this buffering and overlay circuit **30** is to buffer the video data for the compression process and overlay status data onto the image defined by the data stream carrying the video image data from the video camera. The status data is text and/or graphic information from other systems of interest in the arrest. For example, a speed sensor **32** provides data regarding the speed of the patrol car, lights and siren status data is provided from these systems, represented by block **34**, and radar data such as the speed of the fastest and/or strongest targets detected by the radar is supplied from a police traffic surveillance radar represented by block **36**. In some embodiments, a GPS receiver provides continuous position data in latitude and longitude that can also be overlaid on the image being recorded. In the embodiment of **FIG. 1**, overlay circuit **30** implements a process to merge this auxiliary or status data from auxiliary systems with the video image data so that, upon playback, selected items of the status data can be overlaid on the video image using known video technology. It also overlays certain items of status data onto the video image data output on line **32** for local monitoring of the video being recorded. Other types of status information that can be provided for overlay are: (1) video and audio input selections where more than one video camera and microphone are available to choose from; (2) video frame counter; (3) time of day clock; (4) vehicle ID; (5) operator ID; (6) Lidar or radar data such as locked vehicle speed, mode of operation, patrol vehicle speed as detected by radar, target distance; and (7) two-way radio status. In some alternative embodiments, the video frame count is not carried as system status data and is simply overlaid on every frame by the buffer and overlay circuit **30**.

[**0030**] In alternative embodiments, the overlay process could also merge two video sources for recording in picture in picture or split frame format.

[**0031**] Another function of buffer and overlay circuit **30** is to output uncompressed video on line **32** for use by a display driver **34** in driving display **20** for real time monitoring of the video being recorded. The audio being recorded is suppled on line **36** to a D/A converter **38** for conversion back to an audio signal. This audio signal drives a power amplifier **40** which drives a speaker **42**.

[**0032**] The video with any status data merged therein is output to an MPEG video and audio compression circuit **44**. The digital audio data from A/D converter **28** is also supplied to the compression circuit. This compression circuit **44** is typically one or more digital signal processors programmed to carry out any video and audio compression process on the digital video and audio data. In the preferred embodiment, compression circuit **44** implements the MPEG-4 compression process detailed in the MPEG-4 standards which are publicly available. In fact, the complete source code for MPEG-4 compression version 1 is publicly available for 56 francs from the International Standards Organization Moving Pictures Experts Group. The MPEG-4 overview document is ISO/IECJTC1/SC29/WG11.

[**0033**] It is this compression along with the capacity of the digital data recording medium which gives the long recording capacity of the system. Other compression algorithms that will work to practice the invention are MPEG-2 or MPEG-1 and other lossless or lossy compression algorithms such as Px64 and JPEG.

[**0034**] The compressed audio and video data is output on line **46**. An optional anti-tampering circuit **48** can then make the data to be recorded tamper proof. If the data is to be made

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tamper proof, it is necessary to include overlaid frame counter data to make sure nobody is able to remove frames or add frames. Typically, the anti-tampering circuit is simply a program in the DSP that does the compression which computes a digital signature algorithm on each frame of compressed data and then encrypts the digital signatures but not the actual video or audio data. In other words, each digital signature is encrypted (or all the digital signatures are concatenated and then encrypted) and the encrypted digital signatures are recorded along with the unencrypted video and audio data. The preferred digital signature algorithms are the known MD5 and SHA-1 algorithms which compute a digital signature on the video data defining the content of each frame and the accompanying audio. The digital signature is unique to each frame, and if either the video or audio of the frame is altered, the resulting digital signature will be altered. This is how the fidelity of the recorded video and audio to what was truly seen by the camera and heard by the microphone is guaranteed. When the video and audio is to be played back, another digital signature is calculated on each frame of video and audio using the same algorithm. If the recorded digital signature for that frame, after decryption, is not the same as the computed digital signature, somebody has altered either the video or audio of the frame or both.

[**0035**] By recording unencrypted video and audio data, local playback of the recorded data on display **20** is possible. Although local playback of already recorded data is not possible in the embodiment of **FIG. 1**, dashed line **50** represents an embodiment where unencrypted video and audio data from a digital video tape recorder **52** is supplied to an optional decompression circuit **51** for decompression and thence to the drivers **34** and **38** for local playback of previously recorded data. Driver **34** converts the digital, decompressed video data to a signal suitable for display on said display **20**. D/A converter **38** converts the decompressed audio data to a signal suitable for play on speaker **42** through power amplifier **40**.

[**0036**] A digital video data tape recorder **52** records the compressed video and audio data in embodiments where no anti-tamper circuit **48** is present. The tape recorder **52** provides storage of video, audio, and system data. In embodiments where an anti-tampering circuit is present, tape recorder **52** simply stores whatever data is output by the anti-tampering circuit. In one embodiment, that output data would be encrypted digital signature data and unencrypted, compressed video and audio data. In another embodiment, the data output by the anti-tampering circuit **48** would be just encrypted video and audio data. In the preferred embodiment, the recorder **52** is a mini-DVC digital video cassette recorder. In alternative embodiments, it can be any other type of digital video tape recorder. In other alternative embodiments, the DVC recorder includes a small, non-volatile memory which stores vehicle ID data, operator ID data and the date and time of each tape insertion. In an alternative embodiment, the system controller **54** or the DSP that performs the compression and encryption processes will encrypt the vehicle ID, operator ID and date and time of tape insertion data in the NVRAM in the DVC and store the encrypted version of the data in the non-volatile memory in the DVC. In the preferred embodiment, the recorder **52** will have capacity to store 24 hours of MPEG-4 compressed data.

[**0037**] Access to the tape compartment of the tape recorder is provided through a microswitch sensed door **53**. Each time this door is opened, a microswitch senses this fact. The system controller **54** monitors this microswitch either by polling it or through an interrupt generated by circuitry connected to the microswitch or by polling a flag or register bit which is set when the door is opened. When the door **53** has been opened, an unencrypted **A1** encryption key (described below) stored in the system controller **54** is erased and the anti-tamper circuit will thereafter be incapable of encrypting any data. As discussed below, other constraints may also be imposed when the **A1** key has been erased which are part of an anti-tamper protocol the varieties of which will be described below.

[**0038**] Where the anti-tamper circuit **48** is present, the digital video tape recorder **52** records the unencrypted data if any along with the encrypted digital signature data. Secure playback in court can be accomplished by computing a digital signature on each frame recorded on the tape using the same digital signature algorithm used by the anti-tampering circuit **48** and then reversing the compression, converting the decompressed data to NTSC or PAL video signals and an audio signal and playing the signals on a TV. The digital signatures recorded on the tape are then decrypted, and the decrypted, recorded digital signatures are compared with the digital signatures computed from the frames recorded on the tape. If there is any variance, the recorded data has been tampered with and can be disregarded.

[**0039**] In embodiments where local playback is not implemented, such as the embodiment of **FIG. 1** without the option represented by dashed line **50** or the embodiment of **FIG. 4** without the optional circuit **61**, the anti-tampering process **48** can operate in the same way described above or it can omit the digital signature calculations. If the digital signature calculations are omitted, the anti-tampering circuit **48** simply encrypts each frame of video data and encrypts the audio data and records the resulting encrypted data on digital video cassette recorder **52**. This also renders it impossible to add, delete or alter any frame. Secure playback is accomplished by decrypting the encrypted data, decompressing it and converting it back to audio and NTSC or PAL signals for display on a TV.

[**0040**] However, with frame numbers overlaid and simply computing a digital signature on every frame and encrypting the digital signature, it is impossible to either add or remove frames without being detected. Further, because each frame has had a digital signature computed on it, it is also not possible to use video image manipulation software to morph any frame because this would cause the digital signature computed from the untampered frame to not match the digital signature of the morphed or altered frame thereby signalling that tampering had occurred.

[**0041**] In all of these tamper-proof embodiments, the decryption key is held only by the court so only the court can play back the recorded tape secure in the knowledge that no changes have been made.

[**0042**] The control panel **21** contains operator controls for whichever functions are implemented in the base unit. Typical operator interface mechanisms that may be included on the control panel are: push buttons; a keyboard; an LCD touchscreen display; any sort of point and click device such

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as a trackball, mouse, joystick, touchpad, etc.; indicator lights, on-screen indicators overlaid on the video image; on-screen indicators in a virtual control panel in combination with an LCD touchscreen or point and click device.

[0043] The control panel is coupled to a system controller **54** which is coupled to every circuit in the base unit and includes a remote zoom control signal path to control zoom, focus, etc. of camera **10**. The system controller **54** may also receive inputs from a remote control (not shown), and serves to control all other circuits in the base unit **12**. The system controller also includes at least a frame counter and, optionally, a time of day clock. When the frames of video data are digitized, the sync interval is encoded into the resulting digital video data as a special character which can be recognized by circuitry in the buffer and merge circuit **30**. Each sync interval that is recognized by the buffer and merge circuit is signalled to the system controller **54** by a frame signal on data path **55**. This causes a frame counter in the system controller to be incremented. The frame count and, optionally, the time of day data are supplied to the buffer and merge circuit **30** by a data path **57** for merger into the video data stream such that this data can be overlaid upon the video data upon playback.

[0044] In embodiments where the multikey, multiencryption anti-tamper process (described below) is used, a key chip port **55** is used to to receive a key chip which contains the encryption or decryption keys needed by the system for whatever anti-tamper process is in use.

[0045] Referring to **FIG. 2**, there is shown a block diagram of an alternative, buffered embodiment of the system of **FIG. 1** which has all the alternatives and optional capabilities of the embodiments described above with reference to **FIG. 1**. However, the embodiment of **FIG. 2** has the additional capability to record after-the-fact events which the officer may have missed because the record mode was not on when the event occurred. This is provided by the use of a hard disk **60** which stores all compressed video and audio data output by the compression process or the optional anti-tampering circuit at all times regardless of whether tape recording mode is on or off. This system also has the ability to record data from either of two-different video cameras, one of which may be wireless, and either of which may be selected and the ability to record audio from either of two different microphones, one of which may be wireless, and either of which may be selected.

[0046] Video camera #1 is shown at **10** and may be either an analog or a digital video camera. Its zoom, focus and/or other features such as lens aperture, shutters speed, etc. may be controlled remotely via signals on line **56** as was the case for the embodiment of **FIG. 1**. Video camera #2 is shown at **62**. It also may be either an analog or digital video camera, but it also may be a wireless analog or digital video camera as was the case for camera **10** in **FIG. 1**. The transceiver pair needed to send video data back to base unit **66** and remote control zoom, record on or off, focus, etc. commands is represented by block **64**. Remote control commands from system controller **54** are sent to the camera via line **68** and the transceiver pair **64**. One of the transceivers **64** is mounted on or in the base unit **66**. The other is mounted in camera **62**. The transceivers **64** and **88** are not restricted to receiving radio frequency carriers. They could receive any electromagnetic transmission such as modulated infrared, modulated light, microwave, ultraviolet, X-ray etc.

[0047] Digital video selector and decompressor **70** has an input from both cameras and both inputs will be active carrying digital video data if both cameras are digital. This circuit functions to receive a selection control signal from the system controller **54** and to select one of the digital video inputs **72** or **74**. The lightly compressed AVI format digital video is then decompressed to put it in condition for heavy compression by an MPEG-4 process or other compression algorithm.

[0048] An analog selector and converter circuit **76** functions to receive analog video signals from cameras #1 and #2 if both cameras are analog. Circuit **76** selects between one or the other of the two analog video signals on lines **78** or **80**. The selected analog signal is then converted from NTSC or PAL format to YUV format. Digitizer **16** then digitizes the YUV signal and outputs the samples to a digital or analog selector **24**. The other digital video data input to selector **24** comes from selector and decompressor **70**. Selector **24** selects the digital samples from A/D converter **16** or selector and decompressor **70** under control of system controller **54**. It is possible that one camera is analog and one is digital. In such an embodiment, the selectors **70** and **76** make no selection and the selection of which camera's video to compress is made by selector **24**.

[0049] There are also two microphones. Microphone **82** is an in-car microphone and has its signal digitized by an A/D converter **84**. Microphone **86** is an external or body microphone which can be hard wired to the base unit **66** or coupled by a wireless connection using a transmitter and receiver pair represented by block **88**. The audio signal from microphone **86** is digitized by A/D converter **90**.

[0050] The digital audio outputs from digitizers **84** and **90** are coupled to a compression circuit **44** which has the same structure and function as the compression circuit **44** in **FIG. 1**. Although block **44** is labelled MPEG compression, other compression algorithms can also be used. The preferred form of compression is MPEG-4.

[0051] The digital audio outputs from digitizers **84** and **90** are also coupled to the audio inputs of an optional real time stored video playback selector **92**. This circuit also has a video input **94** coupled to receive the combined, uncompressed video and merged status data from buffering and combining circuit **30**. The structure and function of the buffering and merge circuit **30** is similar to its counterpart in the embodiment of **FIG. 1** except in **FIG. 1** it overlays the status data and in **FIG. 2**, it merges the status data so that selected status data from the collection of all status data that has been recorded can be merged into the image by circuit **140** for local playback.

[0052] The buffering and merge circuit **30** merges vehicle speed data, lights and siren status and radar data from interfaces **32**, **34** and **36** along with GPS position data from a GPS receiver **37** with the video data selected by selector **24**, and buffers the resulting composite live video data and outputs it simultaneously on line **94** for real time monitoring of the selected video. The buffered data is also made available to the video and audio compression circuit **44** via line **96** for compression along with the audio data in the same manner as in the embodiment of **FIG. 1**.

[0053] An optional anti-tampering circuit **48** (shown in dashed lines) tamper proofs the compressed video and audio

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in any one of the alternative ways described for the same circuit in **FIG. 1**. It outputs either compressed, unencrypted video and audio data and encrypted digital signature data or compressed and encrypted video and audio data with no digital signature data on line **100**. If the anti-tampering circuit is not present, line **100** bears compressed, unencrypted video and audio data. The output data on line **100** is also coupled to the record data input of a digital video tape recorder **52** which has the same structure and alternative structures as in the embodiment of **FIG. 1**.

[**0054**] All the data on line **100** is continuously recorded on a hard drive **60** which is used as a FIFO memory. Data can be archived off the hard disk **60** to the digital video tape recorder **52** via bus **102**. After the fact recording to tape can be accomplished using the system controller. If an officer wants to record to tape all the events that happened in the last **10** minutes or starting from some particular time of day he remembers to be before a significant event, he can give a command via control panel **20** to the system controller **54**. Part of the data continuously recorded on hard disk **60** is time of day data supplied by clock **104** and/or a frame count signal. Although a separate clock **104** is shown, in most embodiments, the clock and/or frame counter is actually in the system controller **54** and the frame counter is incremented by the frame signal on line **55** from the data buffer and merge circuit. The time of day and/or frame count data is then supplied back to the buffer and merge circuit on bus **57** (the same thing happens in other embodiments with after-the-fact recording capability or where the frame count and/or time of day are needed such as in most tamper-proof embodiments).

[**0055**] By recording the time of day and/or a frame count, the data stored on hard disk **60** can be searched using the time of day or some interval data entered by the officer via control panel **20** to find the first frame that corresponds to the requested start time. Data from that frame and subsequent frames are then output by the hard disk on lines **102** and **106**. The data on line **102** can be archived onto the digital tape recorder **52** when the system controller so orders. The data on line **106** can be viewed by the officer via the an optional MPEG decompression, buffering, zoom and freeze-frame circuit **108**. The optional real time stored video playback selector **92** also has video and audio inputs **96** from this optional MPEG decompression, buffering, zoom and freeze-frame circuit.

[**0056**] The functions of the optional MPEG decompression, buffering, zoom and freeze-frame circuit **108** are to decompress the compressed data coming off the hard disk and buffer it for playback. Additional functions such as zoom and freeze-frame can also be implemented in this circuit using conventional digital video signal processsing techniques. In embodiments where the MPEG decompression, buffering, zoom and freeze-frame circuit **108** is not present, local playback of video and audio data is only of live video and audio as it is happening. In such an embodiment, there is no need for selector **92**, so the live video and audio signals on bus **110** in **FIG. 2** will have the video data on bus **94** applied directly to the inputs of the overlay system data on video circuit **140**. The function of the overlay circuit **140** is to pick out the status data that is to be overlaid from all the status data supplied at the inputs and to overlay that status data on the video image for display. In some embodiments, the overlay circuit also receives commands from the system controller to move the overlaid data so that it does not obscure critical portions of the video image.

[**0057**] The function of the real-time/stored video playback selector is to select the stored video, status and audio data on lines **96** or the real time video and audio and status data on lines **110** for playback. This selection is made by the officer via control panel **20** and system controller **54**. The selected video data is output on line **114** and is displayed via an active matrix display driver **34** and an active matrix display **20**. The selected audio (which may contain audio from both microphones) is output on lines **116** and **118**. A mixer and power amplifier **120** mixes the audio on lines **116** and **118** if both have audio signals on them and amplifies the mix and applies it to a speaker **122**.

[**0058**] Referring to **FIG. 3**, there is shown an alternative embodiment which is basically the same as the embodiment of **FIG. 1** except that it includes an optional hard disk to continuously record the compressed composite live video and audio data output by the compression circuit **44**. In this embodiment, all other circuits with the same reference number as a counterpart circuit in **FIG. 1** have the same structure and function as the counterpart circuit in **FIG. 1**. Optionally, a hard disk **51** is included and coupled to receive and continuously record the compressed composite video, audio and system data on line **53**.

[**0059**] The hard disk can be controlled by the system controller **55** to replay any recorded data on output **57** for archiving on tape recorder **52**. As was the case for the embodiment of **FIG. 2** and the anti-tampering embodiment of **FIG. 1**, the system controller includes a frame counter which is incremented by a frame signal output by the buffer and merge circuit **30**. The frame count and, optionally, a time of data signal are supplied by the system controller **55** for merger as status data into the composite live digital video data output on line **31**. This frame counter data and time of day data are recorded on the hard disk **51** with the rest of the status data. The system controller **55** can be controlled in this embodiment by the officer via control panel **20** to send a command to the hard disk **51** to cause it to playback all recorded data starting from a specific frame number or a specific time of day or going back from the present time by a specified number of minutes on output **57** to be archived by tape recorder **52**. The hard disk then finds the appropriate data in any way and outputs it on line **57**. In some embodiments, the hard disk has a cache memory in which frame number and time of data data are recorded along with the track and sector or block number on the hard disk where the corresponding video, audio and status data for that frame number and/or time of day were recorded. This provides an after-the-fact recording capability in case the officer did not have the in-car video system in record mode when some significant event happened. In alternative embodiments, since the hard disk **51** is used as a FIFO and will be overwritten when it reaches its capacity, the system controller can be programmed to automatically cause the digital video tape recorder to record all data on line **53** when the hard disk reaches capacity.

[**0060**] In a further alternative embodiment, the embodiment of **FIG. 3** may include any of the anti-tampering circuits previously described, as symbolized by dashed block **59**.

[**0061**] **FIG. 4** is a block diagram of the basic class of embodiments defined by the genus of the invention with a

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hard drive which constantly records video and audio data. Alternative embodiments to the basic **FIG. 4** embodiment are enhanced by addition of an optional digital video tape recorder drive and/or an anti-tampering option and/or an option for local playback of stored video and audio. In this embodiment, all other circuits with the same reference number as a counterpart circuit in **FIG. 1** have the same structure and function as the counterpart circuit in **FIG. 1**. The difference over the embodiments of **FIGS. 1-3** is that a hard drive **51** is used as the main recording medium, and the digital video tape recorder **52** is optional and may not be present at all or may be present only for archiving of data off the hard drive. The hard drive **51** is used to record either all compressed data output by compression circuit **44** (optionally after tamper proofing) or selectively record only when placed in record mode by the operator. Where the digital VTR **52** is not present, the system has output audio and video jacks on decompression and selection circuit **61** (which is not optional if VTR **52** is not present) to allow archiving of decompressed video and audio signals off the hard drive **51** at the police station. Alternatively, neither digital VTR **52** nor decompression and selection circuit **61** is not present, and the system has a bus, Firewire or USB connection (not shown) to allow digital data on hard disk **51** to be offloaded at the police station onto an archival medium. Data can be archived from hard drive **51** onto digital VTR **52** (when present) in the same manner as described above for the **FIG. 3** embodiment.

[**0062**] With the advent of ever bigger hard drives, the capacity of the system of **FIG. 4** should increase. With current TIVO technology, two 80 megabyte drives are used which gives a 60 hour recording capacity. Hard drive **51** in **FIG. 4** can be an array of drives.

[**0063**] In some embodiments such as passive monitoring systems, the hard drive **51** is used to record all events and the officer has no access to control panel **21** to turn recording off. This passive record everything embodiment may record the data on only hard disk **51** or only a digital video tape recorder **52**. In the **FIG. 4** embodiment, an optional decompression and selection circuit **61** may be used to decompress data stored on the hard disk and play it back real time in the patrol car. Any of the embodiments of FIGS. **1** or **3** previously described may also be enhanced with this optional decompression and selection circuit **61**. This circuit received compressed video, status and audio data from all of three sources: live video and audio from the buffer and merge circuit **30** and the audio digitizer **28**; recorded video, status and audio data from the hard disk **51**; and recorded video, status and audio data from the tape recorder **52**. The decompression and selection circuit **61** selects one of these sources of data, decompresses it, and outputs the decompressed video data on line **63** to the active matrix display driver **34** and outputs the decompressed audio data on line **65** to the audio digital to analog converter **38**. In alternative embodiments, circuit **108** in **FIG. 2** may be substituted for circuit **61** to provide additional capabilities such as freeze-frame.

[**0064**] A Genus of Multiple Key, Multiple Encryption Processes to Tamper-Proof any Digital Data

[**0065**] The anti-tamper embodiments described above, except for the embodiments where the digital video and audio data itself are encrypted, have a vulnerability.

[**0066**] To render the recorded video and audio data completely tamper proof with no vulnerability, a process from a genus of multiple key, multiple encryption processes can be used. The crux of the problem this genus of multiple key, multiple encryption processes solves is that it renders it impossible for a single person, acting alone to generate tampered, encrypted data which will decrypt in the courtroom as if it had not been tampered with. Any process that can solve this problem, is within the genus of the invention, but all species within this genus are believed to share the following common characteristics:

[**0067**] (1) there will be digital data of some sort that needs to be rendered tamper proof such as video and audio evidence gathered by an in-car police patrol car video surveillance system, security camera images, digital crime scene files, message traffic, etc.

[**0068**] (2) there will be multiple key pairs, each key pair assigned to a different person, the group of people owning the keys being a group which is highly unlikely to enter into a conspiracy together, often including a judge and an evidence officer;

[**0069**] (3) there will be monitoring for the occurrence of any physical or electrical phenomenon or event which indicates that the data to be protected has been accessed improperly or altered;

[**0070**] (4) there will be multiple encryptions or multiple encryption and decryption operations either on the front end of the process or the back end or both including a species with no encryptions on the front end and triple encryptions on the back end. These encryptions and decryptions are done using the encryption and decryption keys belonging to the different people. If the event indicating possible tampering or access has occurred, a suitable tamper proofing protocol such as blocking all recording or making a notation in the data that possible tampering has occurred will be performed on the back end.

[**0071**] **FIG. 5** is a flow chart showing one example of one species within this genus of processes used to protect video and audio data recorded by a police car in-car surveillance unit. In this particular example, there are three people and three key pairs. The first key pair is comprised of an encryption and decryption key pair designated A**1** and A**2** assigned to a judge. The second key pair is comprised of an encryption and decryption key pair designated B**1** and B**2** assigned to a police evidence officer. The third key pair is comprised of an encryption and decryption key pair designated C**1** and C**2** assigned to a particular patrolman. The particular species represented by **FIG. 5** uses a double encryption/decryption on the front end and a double encryption on the back end. Step **200** represents the process of encrypting the A**1** key with the B**1** key and storing the encrypted A**1** key in non volatile RAM or EEPROM in the in-car video unit. Step **202** represents the process of inserting a new tape in the digital video tape recorder and supplying of the B**2** key. The B**2** key is the decryption key of the evidence officer. It is supplied by inserting a key chip into the key port **55** in any of the embodiments of **FIGS. 1-4**. The system controller can then read the B**2** key from the chip. Step **204** represents the process carried out by the system controller **54** of using the B**2** key to decrypt the encrypted A**1** key stored in the system controller using the B**2** key. The decrypted A**1** key is then stored in the clear in some volatile RAM or in some memory that is automatically

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erased when power is disconnected to the unit or the microswitch sensed door **53** is opened for any reason. Finally, in step **204**, the particular officer assigned to the car for that shift gets in the car and supplies the C1 key by plugging his key chip into the unit.

[**0072**] Step **206** represents the arrival of video frames and the audio data that corresponds to each video frame. In step **208**, the in-car video unit anti-tamper circuit **48** computes a digital signature on each frame of video and the corresponding audio data. Test **210** represents the process of determining whether the A1 key still exists in the clear in the volatile RAM and has not been erased. If the A1 key in the clear is still present, step **214** is performed to encrypt the digital signature of each video frame and the digital signature of the audio data that corresponds to each frame using the decrypted A1 key. Step **216** represents the process of encrypting the resulting encrypted data from step **214** using the C1 encryption key of the particular officer that is driving the patrol car. This C1 key is supplied by the patrol officer at the beginning of each shift when the patrol officer inserts his key chip into the key port **55**. The anti-tamper circuit **48** encrypts the results of step **214** by reading the C1 key from the chip in port **55**. Step **218** represents the process of recording the double encrypted digital signature data and unencrypted video and audio data on the digital video tape recorder **52** and/or hard disk **60** if present and depending upon the particular mode of operation at the time.

[**0073**] Returning to test **210**, if it is determined that the A1 key in the clear is no longer present, step **212** is performed. Step **212** represents the process of carrying out whatever predetermined tamper-proofing protocol that is suitable for the particular application and which is acceptable to the police department. In some embodiments, multiple different tamper-proofing protocols are pre-programmed into the system controller, and whichever one has been selected by configuration data programmed into the system by the evidence officer is performed. The possibilities for this protocol are: (1) stop encrypting the digital signatures but continue recording and enter a notation in the recorded data at the point the A1 key disappeared that any recorded data from that point forward is to be viewed with suspicion as it may have been tampered with; (2) start encrypting the digital signatures with the C1 key and make a notation of the change such that all recorded data from that point forward should be viewed with suspicion; (3) stop encrypting digital signatures and block all further recording; or (4) any other suitable anti-tampering protocol.

[**0074**] **FIG. 6** is a flowchart of the process for controlling the integrity of the A1 key by monitoring the microswitch sensed door **53**. Step **224** represents the start of the process.

[**0075**] Step **226** is a test to determine if the A1 key is stored in the clear in the in-car video unit. If not, processing returns to step **224**. If the A1 key is stored in the clear, test **228** is performed to determine if the tape removal microswitch has been tripped. If it has, step **230** is performed to erase the A1 key in the clear from the volatile memory in which it is stored or to remove the power from the volatile memory in which it is stored so that it will be automatically erased (the encrypted A1 key stored in NVRAM is not erased). The A1 in the clear key should be stored in such a way that when power to the in-car video unit is disconnected such as when the unit is removed, the A1 key in the clear will be lost, and there should be no external access such that the A1 key in the clear can be accessed from the outside without removing power to the unit. If step **228** determines that the tape removal microswitch has not been tripped, step **232** is performed to do nothing and processing returns to step **224**. If this tape removal microswitch is tripped, it should set a flag so that if it is not tripped when step **228** is performed, the flag will still be seen and step **230** will be performed.

[**0076**] **FIG. 7** is a flowchart of the process of determining the authenticity of the recorded data on a tape removed from the in-car video system if the tamper proofing processing of **FIGS. 5 and 6** have been used to safeguard the contents of the tape. Step **234** is the process of decrypting each recorded video frame digital signature and the accompanying audio digital signature using decryption key C2. This reverses the encryption with the C1 key performed in step **216** of **FIG. 5**. Step **236** decrypts the results generated in step **234** using the A2 key to reverse the encryption performed in step **214** in **FIG. 5**. Step **238** is the process of computing digital signatures for each recorded video frame and the accompanying audio data. This is done using the same digital signature algorithm used by the in-car video unit to compute the digital signatures that were encrypted and recorded on the tape being authenticated. Step **240** is the process of comparing the digital signatures computed in step **238** to the corresponding decrypted digital signatures computed in step **236**. Step **242** represents the test to determine whether the digital signatures match. If they do, each frame for which there is a match has not been tampered with, as represented by step **244**. If there is not a match for any frame, that frame has been tampered with, as represented by step **246**.

[**0077**] The tamper proofing system of **FIG. 5** is most useful in applications such as police departments where it is not clear which patrol officer will be driving any particular car on a particular day. This is the normal case since cars break, officers get sick etc. so car assignments can vary on a day to day basis. If the car assignments never vary or in other applications where there is no uncertainty as to whose C1 and C2 keys are going to be used, the process of **FIG. 8** can be used. In **FIG. 8**, there is a triple encryption on the front end and only a single encryption on the back end, the tamper proofing protection arises from the triple encryption on the front end. The tamper proofing process of **FIG. 8** is useful where there is no uncertainty as to the exact identities of the three people who will be creating, supervising or holding in evidence and using in court or for other uses a particular digital file to be protected from tampering. Such applications include securing security camera files or digital crime scene files.

[**0078**] Step **250** of **FIG. 8** represents encrypting the A1 key with the C1 key and then encrypting those results with the B1 key and storing the results in NVRAM in the security system used to generate the digital file to be protected. In step **252**, the security supervisor or system installer installs a new tape or other recording medium in the system such as ZIP drive or removable hard disk cartridge or rewritable CD (these other types of removable media may be substituted in the other embodiments disclosed herein also). When the new medium for recording is inserted, a key chip containing the B2 key of the security supervisor or system installer is inserted into the key port. This key chip will be removed when the supervisor or installer in done installing the new recording medium. Step **254** represents the process of the

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security video unit reading the B2 key from the chip and using it to decrypt the encryption results generated in step **250**. These intermediate results generated in step **254** are stored in volatile RAM. In step **256**, the security officer or other person who will be generating the digital file to be protected plugs her key chip containing the C2 key into the key port of the security video unit (the term security video unit is intended to mean any device that generates and/or records digital data of any kind, whether or not it includes video data, to be protected). The security video unit then uses the C2 key read from the key chip to decrypt the intermediate decryption results generated in step **254** to generate the A1 key in the clear. The A1 key is then stored in the clear in volatile RAM. In the embodiment of **FIG. 8**, the A1 key is first encrypted with the C1 key and then the results are encrypted with the B1 key. In alternative embodiments, this order can be changed so that the A1 key is encrypted with the B1 key first and then the results encrypted with the C1 key and appropriate changes are then made to to decrypt the results to arrive back at the A1 key in the clear. In the embodiment shown in **FIG. 8**, the decryption using the B2 and C2 keys are indicated as being done when the key chips are inserted. In alternative embodiments, the B2 and C2 keys can simply stored in memory when the key chips are inserted, and the decryptions can be done at a time when both keys are available. In this case, **FIG. 6** would erase both B2 and C2 if the microswitch sensed door switch had been tripped or if any other event being monitored for improper access or tampering has occurred.

[**0079**] Step **258** represents the arrival of video and audio data (or any other type of digital data to be protected) forming evidence that must be rendered tamper proof. Step **260** is the process the security video unit carries out to calculate one or more digital signatures on the incoming data. If the incoming data is video frames with audio data accompanying each frame, a digital signature is calculated on each frame of video and on the audio data that accompanies each frame. Step **262** is a test to determine if the A1 key still exists in volatile RAM in the clear. If not, step **264** is performed to carry out any suitable anti-tampering protocol for this particular application. The protocols identified above may be used as well as others to give an indication that tampering may have occurred, block recording, etc. The A1 key will be automatically erased by a process similar to that of **FIG. 6** if the microswitch sensed door **53** is opened. The only difference between this process and **FIG. 6** is that step **230** in **FIG. 6** is modified to erase not only the A1 key but also the intermediate decryption result generated in step **254** in **FIG. 8**.

[**0080**] If test **262** determines that the A1 key still exists in the clear, step **266** is performed to perform a single encryption of each digital signature computed in step **260** using the A1 key.

[**0081**] Finally, step **268** is performed to record the encrypted digital signature data and the unencrypted data of the video frames and accompanying audio data or other digital data to be protected.

[**0082**] To verify that the data protected by the process of **FIG. 8** has not been tampered with, a process similar to that shown in **FIG. 7** is used. The only difference between the process used to verify a file protected by the process of **FIG. 8** and the process of **FIG. 7** is that step **234** is omitted. Thus, a process to verify the integrity of a file protected by the process of **FIG. 8** comprises performing steps **236**, **238**, **240**, **242**, **244** and **246** of **FIG. 7**.

[**0083**] Referring to **FIG. 9**, there is shown a process using no encryption on the front end and triple encryption of the digital signature data on the back end. This process can be used in situations where there is uncertainty as to whose B1 and C1 keys will be used to encrypt.

[**0084**] Step **270** represents the process of storing the A1 key in nonvolatile RAM in the in-car video unit or other security video system (again, any type system that generates and/or records digital data files to be protected can be used). Step **272** represents the process of the evidence officer supplying a new recordable medium to the in-car video unit and plugging his key chip into the key chip port. His key chip contains the B1 key, and this key is read by the in-car video unit and stored in volatile RAM. The evidence officer's key chip is then removed, and the patrol officer takes possession of the car. Step **274** represents the process of the patrol officer plugging his key chip into the key port to provide the C1 key. In step **276**, video frames and the accompanying audio data (or whatever other type of digital data that is to be protected) arrives. In step **278**, the in-car video unit computes a digital signature on each video frame and a signature on the accompanying audio (or computes a digital signature on whatever digital data is to be protected).

[**0085**] Test **280** determines if both the B1 and C1 keys still exist in the clear in volatile RAM. If either B1 or C1 is not still there, step **282** is performed to carry out whatever predetermined tamper proofing protocol is appropriate for this application. That can be stopping all recording, making a notation on the recording and continuing to record, etc. If both B1 and C1 still exist in the clear, step **284** is performed to encrypt each digital signature with the A1 key. Then step **286** is performed to encrypt the results of the encryption of step **284** using the B1 key. Then, step **288** is performed to encrypt the results generated by step **286** using the C1 key. Finally, step **290** is performed to record the triple encrypted digital signature data along with the unencrypted video and audio data (or other digital data to be protected).

[**0086**] A process similar to the process of **FIG. 6** is used to safeguard the B1 and C1 keys in the clear. Basically, this process is the process of **FIG. 6** except that step **230** erases the B1 and C1 keys if the microswitch sensed door **53** is opened.

[**0087**] A process similar to the process of **FIG. 7** is used to verify that the data protected by the process of **FIG. 9** has not been tampered with. This process is the process of **FIG. 7** modified by insertion of an additional decryption step between steps **234** and **236**. This additional decryption step decrypts the results obtained by step **234** using the B2 key. Step **236** in all the processes to verify the integrity of files protected with the processes of **FIGS. 5, 8** and **9** results in output of the digital signature data recorded on the recording medium.

[**0088**] The above multiple encryption processes can also be applied to single, double or triple encrypt the compressed video and auido data or other digital data to be protected itself without the additional steps to calculate digital signatures on the data and enrypt only the signatures.

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[0089] The term tamper proof data used in the claims is intended to include all the forms of tamper proof data discussed herein including single, double or triple encrypted signature data along with the unencrypted compressed video and audio data or other digital data from the signature data was calculated as well as singe, double or triple encrypted digital video and audio or other digital data of the original file and upon which no signature data was calculated.

[0090] Although the invention has been disclosed in terms of the preferred and alternative embodiments disclosed herein, those skilled in the art will appreciate possible alternative embodiments and other modifications to the teachings disclosed herein which do not depart from the spirit and scope of the invention. All such alternative embodiments and other modifications are intended to be included within the scope of the claims appended hereto.

What is claimed is:

1. An in-car video recording apparatus comprising:

a video camera;

a microphone;

a display means for displaying status and control information;

a speaker;

an input for receiving status data;

a base unit comprising:

means for receiving the output signal of said video camera and preparing said output signal for compression;

an analog-to-digital converter coupled to convert audio signals from said microphone to digital data;

a buffer and merge circuit functioning to merge said status data with the frames of video data output by said means for receiving to generate composite live digital video data, and for buffering the resulting composite live digital video data;

a compression circuit for compressing said composite live digital video data stored in said buffer using any compression algorithm, and for compressing said audio data output by said analog-to-digital converter using any compression algorithm;

a means for recording said frames of compressed video data and said audio data; and

means for controlling said base unit coupled to said display means and said speaker.

2. The apparatus of claim 1 further comprising local playback means for receiving said composite live digital video from said buffer and merge circuit and for displaying at least said video frames from said video camera along with a selected number of items of said status data on a video display and for playing audio captured by said microphone on said speaker.

3. The apparatus of claim 1 further comprising an anti-tampering means coupled to receive compressed data and for tamper proofing said data to generate tamper proof data and recording said tamper proof data on said means for recording.

4. The apparatus of claim 1 wherein said means for recording comprises a hard disk and a digital video cassette recorder coupled to said hard disk and functioning to archive compressed digital and audio data from said hard disk so as to make more capacity on said hard disk.

5. The apparatus of claim 2 wherein said means for recording comprises a hard disk and a digital video cassette recorder coupled to said hard disk and functioning to archive compressed digital and audio data from said hard disk so as to make more capacity on said hard disk, and wherein said local playback means includes a decompression and selection circuit coupled to receive selected data at least from said hard disk, decompress said data and play the decompressed video and audio.

6. The apparatus of claim 1 wherein said video camera is a wireless video camera, and wherein said means for receiving a signal from said video camera includes a receiver for receiving and demodulating radio frequency signals from said video camera and circuitry to develop digital video data suitable for compression from the received radio frequency signals.

7. The apparatus of claim 1 wherein said microphone is a wireless microphone and said base unit includes a receiver to receive and demodulate radio frequency signals from said wireless microphone to develop an audio signal and apply the audio signal to said analog-to-digital converter

8. An apparatus comprising:

a video camera;

a microphone;

a display means for displaying status and control information;

a speaker;

an input for receiving status data;

a base unit comprising:

means for receiving the output signal of said video camera and preparing said output signal for compression;

an analog-to-digital converter coupled to convert audio signals from said microphone to digital data;

a buffer and merge circuit functioning to merge said status data with the frames of video data output by said means for receiving to generate composite live digital video data, and for buffering the resulting composite live digital video data and for detecting sync intervals in said frames of video data output by said means for receiving and outputting a frame signal, and for receiving at least frame number data that increments with each received frame and merging said frame number data into said composite live digital video data stream;

a compression circuit for compressing said composite live digital video data stored in said buffer using any compression algorithm, and for compressing said audio data output by said analog-to-digital converter using any compression algorithm;

anti-tampering means for receiving said compressed video and audio data and rendering it tamper proof;

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a hard disk for recording whatever data is output by said anti-tampering means; and

means for controlling said base unit coupled to said display means and including a frame counter for receiving said frame signal and for incrementing a frame count each time said frame signal is received and for supplying said frame count data as status data to said buffer and merge circuit.

9. The apparatus of claim 8 further comprising local playback means for receiving said composite live digital video from said buffer and merge circuit and for displaying at least said video frames from said video camera along with a selected number of items of said status data on a video display and for playing audio captured by said microphone on said speaker, or for receiving compressed digital and audio data recorded on said hard disk and for decompressing said video and audio data and playing video images on said video display and sound from said decompressed data on said speaker.

10. The apparatus of claim 9 further comprising means for displaying in real time images and sound captured by video camera and microphone as well as status data.

11. The apparatus of claim 8 wherein said video camera is a wireless video camera, and wherein said means for receiving a signal from said video camera includes a receiver for receiving and demodulating radio frequency signals from said video camera and circuitry to develop digital video data suitable for compression from the received radio frequency signals.

12. The apparatus of claim 8 wherein said system controller also includes a clock and supplies time of day data to said buffer and merge circuit as status data, and wherein said buffer and merge circuit functions to merge said time of day data into said composite live video data stream.

13. The apparatus of claim 9 wherein local playback means is controlled by said means for controlling as to which items of said status data are overlaid on the displayed video and wherein said local playback means includes an input for receiving compressed video and audio data and said status data recorded on said digital video tape recorder and functions to decompress said video and audio data and display the decompressed video data along with zero or more items of selected status data on said display and convert said decompressed audio data to an audio signal and play it on said speaker.

14. The apparatus of claim 8 wherein means for local playback is controlled by said means for controlling as to which items of said status data are overlaid on the displayed video and wherein said means for local playback further comprises an input for receiving compressed video and audio data and said status data recorded on said hard disk and functions to decompress said video and audio data to generate video and audio signals and display said video and audio signals along with zero or more items of selected status data on said display.

15. The apparatus of claim 8 wherein said microphone is a wireless microphone and said base unit includes a receiver to receive and demodulate radio frequency signals from said wireless microphone to develop an audio signal and apply the audio signal to said analog-to-digital converter

16. An in-car video recording apparatus comprising:

one or more video cameras;

one or more microphones;

a display means for displaying status and control information;

a speaker;

a GPS receiver;

an input for receiving status data;

a base unit comprising:

means for receiving the output signals of said one or more video cameras, selecting one output signal therefrom and preparing said selected output signal for compression;

an analog-to-digital converter means coupled to select one or more outputs from said one or more microphones and convert the selected audio signal(s) from said one or more microphones to generate digital audio data;

a buffer and merge circuit functioning to merge said status data including position data from said GPS receiver and vehicle speed data and lights and siren status data and traffic surveillance radar data with the frames of video data output by said means for receiving and said digital audio data to generate composite live digital video data, and for buffering the resulting composite live digital video data, and for recognizing a sync signal in the incoming video data and outputting a frame signal, and for receiving a frame count signal and merging said frame count as status data in said composite live digital video data;

a compression circuit for compressing said composite live digital video data stored in said buffer using any compression algorithm to generate compressed composite live digital video data, and for compressing said audio data output by said analog-to-digital converter using any compression algorithm to generate compressed audio data;

a hard disk means for receiving and continuously recording said compressed composite live digital video data along with said compressed audio data, and for receiving an archive signal commanding playback of recorded data and specifying in any way at least the starting point in the stream recorded data where said playback is to begin;

a digital video tape recorder or other removable medium digital data recording device for recording compressed data output by said hard disk means when a record signal is received; and

control means coupled to said display means for controlling said base unit and including at least a frame counter, said control means also coupled to receive said frame signal and for incrementing said frame counter each time said frame signal is received and for supplying said frame count to said buffer and merge circuit as status data.

17. The apparatus of claim 16 further comprising anti-tampering means coupled to receive said compressed data output by said compression means and rendering said compressed data tamper proof prior to recording on said hard disk means.

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18. The apparatus of claim 16 further comprising local playback means for receiving said live digital video from said buffer and merge circuit and for displaying at least said video frames from said video camera along with a selected number of items of said status data on a video display and for playing audio captured by said microphone on said speaker.

19. The apparatus of claim 16 further comprising local playback means for receiving said live digital video from said buffer and merge circuit and recorded, compressed video, status and audio data from said hard disk means or said digital video tape recorder and for selection of one source of video, status and audio data under control of said control means and for decompressing at least the selected compressed video and audio data and for displaying the decompressed video along with a selected number from zero to some larger number of items of said status data on a video display and for playing audio captured by said microphone on said speaker.

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Appendix I

US006389340B1

(12) **United States Patent**
Rayner

(10) **Patent No.: US 6,389,340 B1**
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(54) **VEHICLE DATA RECORDER**

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(52) **U.S. Cl.** **701/35**; 340/438; 348/148
(58) **Field of Search** 701/29, 33, 35; 340/438, 439, 937; 348/143, 148, 155; 396/429, 502

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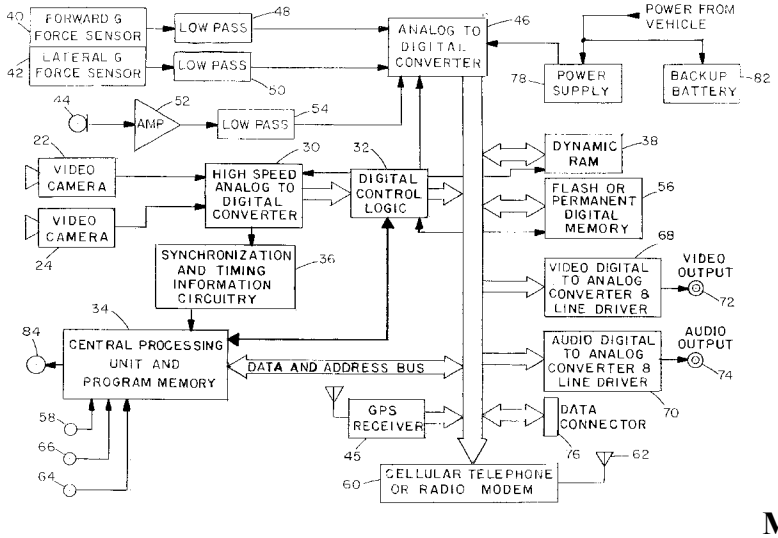
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(57) **ABSTRACT**

A self-contained device for capturing video imagery in response to a triggering event may include a mirror and be mounted to a vehicle windshield in place of a conventional rear-view mirror. The device includes a housing in which the electronics and related elements of the invention are contained. These elements include one or more data sensors, at least one of which is an image sensor,. Also included are a data sensor circuit and a capture circuit. The data sensor circuit responds to the triggering event, and may include data sensors coupled to vehicle systems such as a speedometer, tachometer, brake, turn signals or the like, or other data sensors such as an accelerometer or a vehicle position sensor. The triggering event may be, for example, a sudden change in acceleration indicative of an impending collision, or it may be a change in the signal provided by any such data sensor, including the image sensor. The capture circuit is coupled to the image sensor and captures a signal representing the video imagery by recording it in a digital memory, by transmitting it to a remote location, or by other suitable means. The capture circuit terminates capture of the signal in response to the data sensor circuit sensing a triggering event. The captured data thus describe circumstances leading up to the time of the triggering event. The data can be analyzed to help police, insurance or other investigative personnel understand those circumstances.

41 Claims, 2 Drawing Sheets



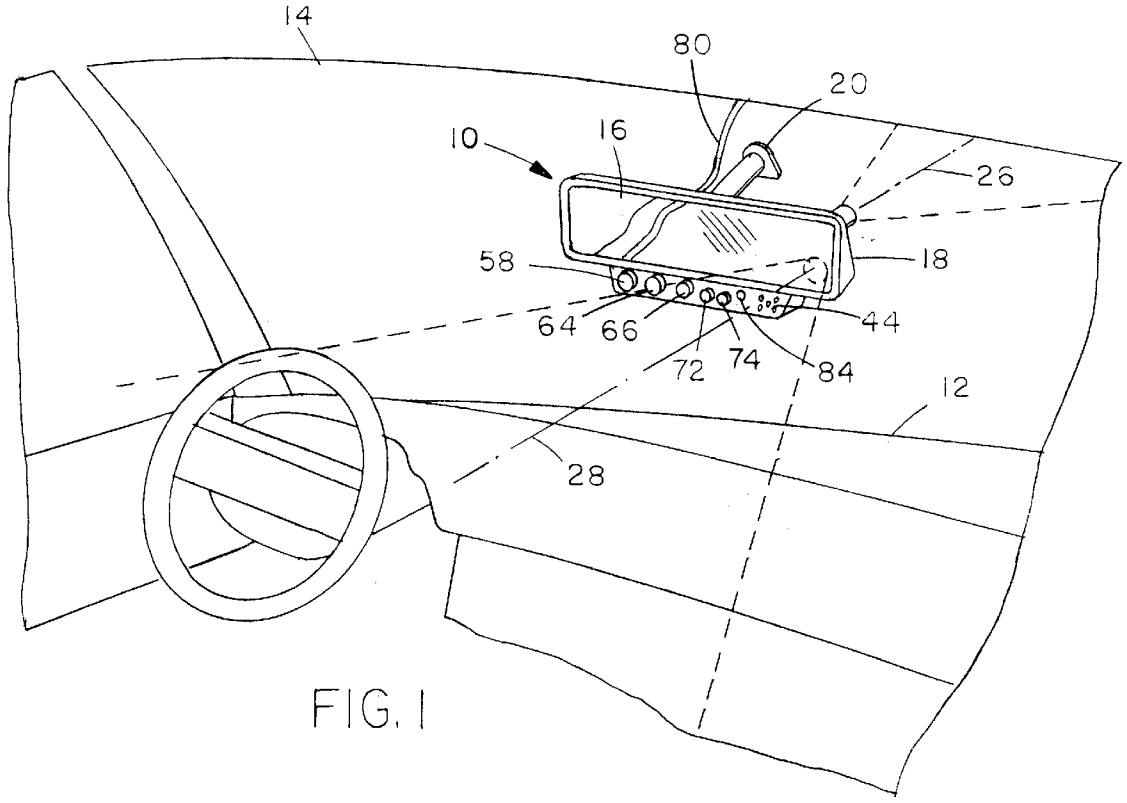


FIG. 1

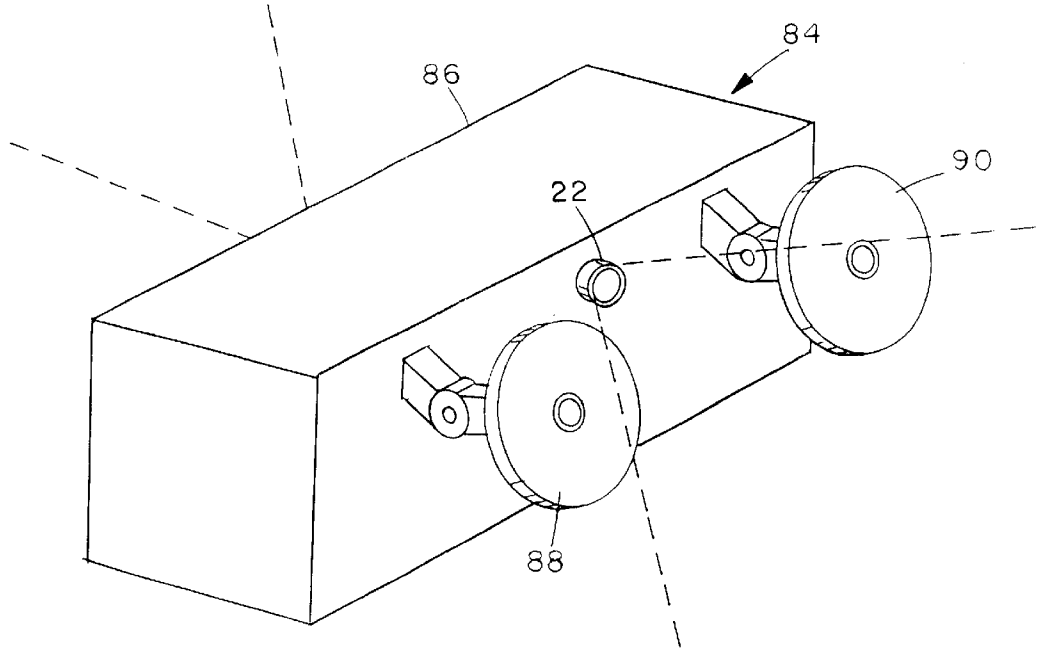


FIG. 2

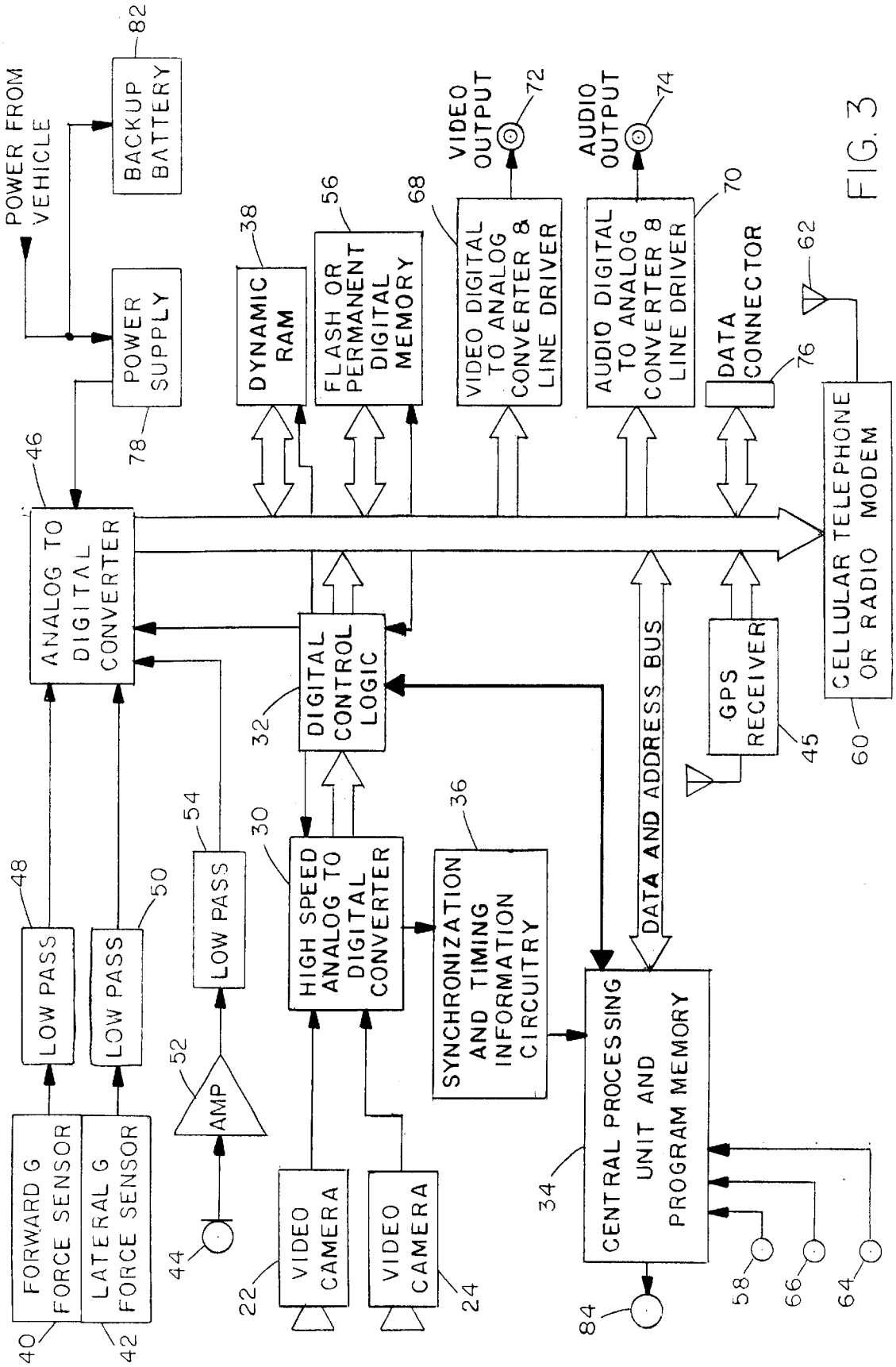

POWER FROM VEHICLE
BACKUP BATTERY
82
POWER SUPPLY
78
DYNAMIC RAM
38
FLASH OR PERMANENT DIGITAL MEMORY
56
VIDEO DIGITAL TO ANALOG CONVERTER & LINE DRIVER
68
VIDEO OUTPUT
72
AUDIO DIGITAL TO ANALOG CONVERTER & LINE DRIVER
70
AUDIO OUTPUT
74
DATA CONNECTOR
76
62
CELLULAR TELEPHONE OR RADIO MODEM
60
ANALOG TO DIGITAL CONVERTER
46
DIGITAL CONTROL LOGIC
32
GPS RECEIVER
45
DATA AND ADDRESS BUS
HIGH SPEED ANALOG TO DIGITAL CONVERTER
30
SYNCHRONIZATION AND TIMING INFORMATION CIRCUITRY
36
CENTRAL PROCESSING UNIT AND PROGRAM MEMORY
34
LOW PASS
48
LOW PASS
50
LOW PASS
54
AMP
52
FORWARD G FORCE SENSOR
40
LATERAL G FORCE SENSOR
42
44
VIDEO CAMERA
22
VIDEO CAMERA
24
58
66
64
84

FIG. 3

VEHICLE DATA RECORDER

CROSS-REFERENCE TO RELATED APPLICATION

This is a continuation-in-part of application Ser. No. 09/020,700, filed Feb 9,1998, titled "SEQUENTIAL IMAGE STORAGE SYSTEM WITH PREEVENT HISTORY" now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to devices for recording imagery and other data during operation of a vehicle and, more specifically, to a device that stores such data during the time interval surrounding a triggering event such as detection of an impending vehicle collision.

2. Description of the Related Art

Various recorders have been used to gather and retain data obtained from vehicle sensors. One well-known such recorder is the in-flight data recorder and cockpit voice recorder, sometimes referred to as the "black box" recorder, typically carried by commercial and military aircraft. These devices record certain operating parameters of the aircraft, as well as the voices of the operators, and have found use in setting maintenance schedules, or to assist in determining the cause of an accident. Data recorders have been known to use magnetic tape or solid-state storage devices.

The ever-increasing use of motor vehicles has created a complex and expensive system of determining liability for the damages which result from accidents. Inevitably, it is difficult to reconstruct the events leading up to, and resulting from, the accident impact, as witness testimony is often unreliable and contradictory, and the physical remains generally do not contain sufficient evidence of the actual incident. A device to gather and record data from a wide range of operating parameters would be of great use, provided that the data covered the time leading up to the accident, as well as the accident itself, and that the data was secure so that it could be admitted in proceedings to determine liability.

Efforts have been made to construct recording devices which are lighter, more versatile, and more secure in their data storage. For example, U.S. Pat. No. 5,497,419 to Hill discloses a device for recording sensor data which included provisions to compress and decompress data, as well as to encrypt the stored data to enhance the integrity of the data. U.S. Pat. No. 5,056,056 to Gustin discloses a device to record various analog signal inputs occurring before and after a triggering event. U.S. Pat. No. 5,581,464 to Woll et al. discloses an event recording apparatus to monitor the operational parameters of a vehicle. U.S. Pat. No. 5,262,813 to Scharton discloses a device to trigger the operation of a camera mounted in a vehicle upon the occurrence of an impact. U.S. Pat. No. 5,499,182 to Ousborne also discloses an recording apparatus to monitor the operational parameters of a vehicle. U.S. Pat. No. 5,311,197 to Sorden et al. discloses a device to trigger the operation of a location reporting device in a vehicle upon the occurrence of an event such as an impact. Each of these devices has certain limitations which reduce its applicability as a secure storage device for recording numerous sensor inputs occurring before and after a triggering event.

A disadvantage of some prior vehicle data recording devices is that they are not fully integrated or self-contained. Rather, they include a data recorder located remotely from and coupled by electrical cables to the video camera or other sensor that obtains the data to be recorded. Another disadvantage of some prior vehicle data recording devices is that they are not located in the vehicle cabin at a position that is both efficient for data-gathering and convenient to use. It would be desirable to provide a self-contained, compact, conveniently and efficiently located recording device that records video or other types of data during a time interval preceding a triggering event, such as a detection of an impending accident. These problems and deficiencies are clearly felt in the art and are solved by the present invention in the manner described below.

SUMMARY OF THE INVENTION

The present invention relates to a self-contained vehicle-mounted device for capturing video imagery in response to a triggering event. The device includes a housing in which the electronics and related elements of the invention are contained. These elements include one or more data sensors, at least one of which is an image sensor, such as a charge-coupled device, that senses visible light, infrared radiation or other optical phenomena representing video imagery. Also included are a data sensor circuit and a capture circuit. The data sensor circuit responds to the triggering event, and may include data sensors coupled to vehicle systems such as a speedometer, tachometer, brake, turn signals or the like, or other data sensors such as an accelerometer or a vehicle position sensor. The triggering event may be, for example, a sudden change in acceleration indicative of an impending collision, or it may be a change in the signal provided by any such data sensor, including the image sensor. The capture circuit is coupled to the image sensor and captures a signal representing the video imagery by recording it in a digital memory, by transmitting it to a remote location, or by other suitable means. The capture circuit terminates capture of the signal in response to the data sensor circuit sensing a triggering event. Note that data describing circumstances leading up to the time capture was terminated will have been captured. The data can be analyzed to help police, insurance or other investigative personnel understand those circumstances. In some embodiments of the present invention the device may continue to capture data for a predetermined time interval after the triggering event.

The device is mounted in the vehicle cabin a manner that provides a clear field-of-view for the image sensor. For example, it can be mounted on the windshield or on the dashboard of the vehicle, with the image sensor directed either forwardly toward action occurring on the other side of the windshield or rearwardly toward action occurring in the vehicle cabin. In some embodiments of the present invention, the device may include two such image sensors, one directed forwardly and the other rearwardly.

In a particularly advantageous embodiment of the invention the device is integrated with a rear-view mirror. In other words, the housing is similar in size and shape to that of a conventional automotive rear-view mirror assembly and includes, in addition to the elements described above, a mirror and other features commonly included in conventional automotive rear-view mirrors. In such embodiments, the device is mounted to the windshield or a surrounding area of the vehicle in the manner of a conventional rear-view mirror.

The foregoing, together with other features and advantages of the present invention, will become more apparent when referring to the following specification, claims, and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, reference is now made to the following detailed

description of the embodiments illustrated in the accompanying drawings, wherein:

FIG. **1** is a perspective view of a rear-view mirror vehicle data recorder device of the present invention mounted on an automobile windshield;

FIG. **2** is a perspective view of a vehicle data recorder device of the present invention with suction-cup mounts for mounting to an automobile windshield; and

FIG. **3** is schematic block diagram of the vehicle data recorder device.

DESCRIPTION OF PREFERRED EMBODIMENTS

As illustrated in FIG. **1**, a rear-view mirror data recorder device **10** is mounted in the cabin of an automobile **12**. Specifically, in this embodiment of the invention it is mounted to the windshield **14** of automobile **12** in the manner of a conventional rear-view mirror. Like a conventional rear-view mirror, it includes a generally elongated mirror **16** that is mounted to windshield **14** with mirror **16** and its axis of elongation generally parallel to windshield **14**. (They are generally parallel, but not precisely parallel, because windshield **14** has some curvature, and because recorder device **10** is pivotally mounted to provide limited two-axis adjustability, as in a conventional rear-view mirror.) Device **10** has a housing **18** with a mounting bracket **20**. Mounting bracket **20** is adhesively mounted to windshield **14** in the manner of a conventional rear-view mirror. Although in the illustrated embodiment device **10** is mounted in this manner, other embodiments of the device can alternatively be mounted to the cabin roof immediately above windshield **14** in the same manner in which other types of rear-view mirrors are conventionally mounted. Similarly, as discussed further below, other embodiments of the device can be mounted to windshield **14** in any other suitable manner and, indeed, can be mounted in other suitable locations inside the vehicle cabin.

The electronics and associated elements of device **10** that are contained within housing **18** are illustrated in FIG. **3**. Two video cameras **22** and **24**, which are preferably charge-coupled device (CCD) or CMOS silicon sensor arrays, generate signals corresponding to video imagery. Referring briefly again to FIG. **1**, camera **22** is mounted in housing **18** with its optical axis **26** directed forwardly with respect to vehicle **12**, and camera **24** is mounted in housing **18** with its optical axis **26** directed rearwardly with respect to vehicle **12**. Both axes **24** and **26** are thus generally aligned with the direction of travel of vehicle **12** and perpendicular to windshield **14**. The fields-of-view of cameras **22** and **24** are indicated by dashed lines bounding the angles bisected by axes **24** and **26**, but the dashed lines are for purposes of illustration only and are not intended to accurately depict the true fields-of-view, which would preferably cover the entire area ahead of vehicle **12** and the entire cabin area. The small circular aperture portion of mirror **16** through which axis **28** extends, indicated in dashed line, is preferably half-mirrored so that it appears to be mirrored to an observer, yet transmits light to camera **24**. Nevertheless, in other embodiments of the device this portion may be transparent and unmirrored.

Returning to FIG. **3**, a high-speed analog-to-digital (A/D) converter **30** digitizes the signals produced by cameras **22** and **24** and multiplexes them onto a digital data bus via digital control logic **32**. Device **10** operates under the control of a central processing unit **34**. Central processing unit (CPU) **34** may include a microprocessor, microcontroller or similar device and associated program memory. CPU **34** is programmed to perform the functions described in this specification. Because the descriptions of these functions below are sufficient to enable any person skilled in the art to which this invention relates to program CPU **34**, program code and the manner in which it is programmed are not described in this specification. CPU **34** is synchronized to A/D converter **30** via synchronization and timing information circuitry **36**.

Under control of CPU **34**, digital signals representing the video imagery are stored in dynamic random-access memory (DRAM) **38** that is configured as a continuous-loop buffer. CPU **34** or associated address counter circuitry defines the continuous-loop scheme by employing wrap-around memory addressing, in which the highest memory location in a predetermined addressing sequence is adjacent or next to the lowest. Incoming digitized data signals are written to memory locations in DRAM **38** in accordance with the addressing sequence until all allocated locations have been written to, at which time the data signals stored at the next location in the sequence are overwritten with further incoming data signals.

Device **10** includes sensors in addition to cameras **22** and **24**, including a forward accelerometer or G-force sensor **40**, a lateral accelerometer or G-force sensor **42**, a microphone **44**, and a global positioning system (GPS) receiver **45**. G-force sensors **40** and **42** are coupled to another A/D converter **46** via low-pass filters **48** and **50**, respectively. Microphone **44** is coupled to A/D converter **46** via an amplifier **52** and another low-pass filter **54**. G-force sensor **40** is mounted with respect to vehicle **12** in an orientation in which it is sensitive to changes in acceleration in a direction parallel to the direction of travel of the vehicle. Such changes may be indicative, for example, of a collision or sudden braking before a collision with a vehicle in front of or to the rear of vehicle **12**. G-force sensor **42** is mounted with respect to vehicle **12** in an orientation in which it is sensitive to changes in acceleration in a direction perpendicular or lateral to the direction of travel of the vehicle. Such changes may be indicative, for example, of a vehicle colliding with the side of vehicle **12**. Microphone **44**, being integrated within enclosure **18** (see FIG. **1**), is particularly sensitive to sounds occurring inside the cabin of vehicle **12**, such as the voices of the driver and any passengers. GPS receiver **45** receives GPS satellite signals and determines from them the geographical position of vehicle **12**. GPS receiver **45** and its antenna **47** are, like all other electronics and associated elements described above, disposed inconspicuously and securely inside housing **18**. This location harmonizes with the location of device **10** on windshield **14** or nearby because radio frequency energy emanating from satellites above vehicle **12** penetrate windshield **14** more readily than metallic portions of vehicle **12**. Under control of CPU **34**, A/D converter **46** multiplexes and digitizes the signals produced by these sensors. The digitized sensor data are stored in DRAM **38** along with the digital signals representing the video imagery.

CPU **34** monitors the digitized signals representing the acceleration data to which G-force sensors **40** and **42** are responsive. If CPU **34** determines that the acceleration data exceed a predetermined threshold that is believed to be indicative of a collision or other event that would warrant investigation, it copies data from the buffer memory to a more permanent non-volatile memory **56**, such as Flash memory. Memories **38** and **56** thus together define a two-tier system, in which the first tier records data in a continuous-loop fashion, and the second tier provides more permanent storage for data in the first tier in response to a triggering

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event. Data stored in memory **56** in accordance with this scheme are not overwritten unless the entire system is reset by an operator. Preferably, device **10** includes security measures to prevent inadvertent or unauthorized resetting, such as placing the button (not shown) or other sole means for resetting device **10** inside enclosure **18** or in another relatively inaccessible location.

Although in the illustrated embodiment a change in acceleration data that exceeds a predetermined threshold is defined as the triggering event that causes CPU **34** to terminate data acquisition and copy the contents of DRAM **38** to memory **56**, in other embodiments a change in any other monitored sensor signal can similarly be defined as the triggering event. Also, although data acquisition can be terminated upon occurrence of the triggering event, in other embodiments data acquisition may continue after occurrence of the triggering event for some predetermined time interval. Thus, so long as a sufficient amount of pre-event data are retained and not overwritten, additional frames of video data or other sensor data can be gathered during and after the collision and stored in memory **56** following the pre-event data.

Multiple data acquisition rates are accommodated by sampling and recording the data streams at different rates. For example, the data stream from microphone **44** can be sampled at 15.625KHz or 15,625 samples per second. G-force sensors **40** and **42** can be sampled at 100 to 700 samples per second. The actual recording rate for such data could simply record the maximum G-force experienced, e.g. four times per second. The image data stream will generally be sampled at the slowest rate, typically ranging from one to 60 samples per second, although four times per second is believed to provide sufficiently useful information for accident investigators.

The data acquisition rate will also affect the amount of time data can be recorded before the previously-entered data are overwritten. At the rates disclosed above, the device of the present invention will typically store 80 frames of video data, together with the associated audio and acceleration data, for a total of 20 seconds of event history. Nevertheless, these numbers are only exemplary, as it is anticipated that improvements in high-density, low-cost memory will enable substantial increases in capacity at minimal additional cost.

In addition to acceleration data exceeding a predetermined threshold, the triggering event can be defined as activation of a so-called "panic button" **58** by an operator such as the vehicle driver. Thus, if the driver presses button **58**, CPU **34** terminates data acquisition and copies the contents of the circular data buffer defined by DRAM **38** into memory **56**. Panic button **58** may be particularly useful in taxicabs, buses and similar commercial vehicles in which the driver may wish to record the actions of a passenger. In other embodiments, the triggering event can be defined in still other ways, such as by activation of a security system protecting the vehicle against theft or vandalism.

Data capture can include not only storage of signals representing acquired data in memory but also, in addition or alternatively, transmittal of such signals to a remote location. Preferably, the signals are transmitted in real-time, i.e., immediately following the triggering event. A cellular telephone and modem **60** can transmit the digital signals to a suitable receiver (not shown) that is coupled to the telephone network. Cellular telephone and modem **60** and its antenna **62** are, like all other electronics and associated elements of device **10** described above, disposed inconspicuously and securely inside housing **18**. The complete integration of these elements within housing **18** deters theft and tampering and does not inhibit surreptitious recording of passengers or would-be thieves. Furthermore, this location harmonizes with the location of device **10** on windshield **14** or nearby because windshield **14** is more transparent to radio frequency energy than areas of automobile **12** enclosed by metal. Although in the illustrated embodiment the transmitter is cellular, in other embodiments that include a transmitter it may be any suitable type of radio transmitter or even an infrared link or similar short-range transmitter. An infrared link is contemplated in embodiments in which the acquired data are not transmitted in real-time as described above, but rather are transmitted after the triggering event. For example, personnel investigating a collision may be provided with suitable receivers (not shown) that interrogate the vehicle data recording device via such an infrared link to retrieve the contents of its memory. Also, a programming unit (not shown) coupled by an infrared link to the recording device could be used to reset it or reprogram it.

Two other buttons **64** and **66** can be used by an operator to initiate and control the retrieval of stored data. In response to activation of buttons **64** and **66** in a predetermined manner, CPU **34** causes memory **56** to be addressed in sequence and provide the stored data on the data bus. CPU **34** also controls a video digital-to-analog (D/A) converter **68** and an audio D/A converter **70**, causing them to convert the data signals read from memory **56** to analog format. A video signal representing the stored video imagery data is provided at a video output connector **72**. By connecting a video monitor (not shown) to connector **72**, one can view the recorded imagery. An audio signal representing the stored audio data is provided at an audio output connector **74**. By connecting a speaker (not shown) to connector **74**, one can listen to the recorded sound. A data connector **76** is also included that provides access to the data on the data bus, either directly or via suitable input/output interface circuitry (not shown). Device **10** can be programmed via connector **76** as well. Although these connectors are included in the illustrated embodiment, as described above, in other embodiments the device may not have such readily accessible outputs and may provide access to the recorded data only by means of a transmitter and receiver.

The recorded data streams are preferably output in "correlated packets" of data that are associated with the sample time for a single image frame. For example, if the memory playback is advanced by a single frame, then in the four-frames-per-second example 0.25 seconds of audio data and the related G-force data will also be retrieved. For the other rates disclosed above, different sized packets will be obtained and played. When the device retrieves data at a "normal" playback mode, the data display will present a substantially continuous, substantially "real time" stream.

The active electronic elements of device **10** receive power from a power supply circuit **78**. Power supply circuit **78** can receive power from the electrical system of vehicle **12** via a suitable cable **80** (see FIG. **1**) or from a backup battery **82**. Cable **80** can have multiple conductors, some of which carry this power signal and others of which carry signals from other vehicle systems and sensors that provide data to device **10** for recording as described above.

CPU **34** can control a light-emitting diode (LED) **84** to provide status information, such as whether device **10** is powered-up and otherwise operational or, alternatively, whether a triggering event has occurred. The convenient location of LED **84** and buttons **58**, **64** and **66** where the rear-view mirror is normally situated in an automobile promotes ease of operation of device **10** by a driver of vehicle **12**.

As illustrated in FIG. **2**, in an alternative embodiment a data recorder device **84** of the present invention has an enclosure **86** that contains all of the electronics and associated elements described above with respect to FIG. **3**. In this embodiment, device **84** does not include a mirror or function as a rear-view mirror. Nevertheless, it can be mounted to windshield **14** by means of elastomeric suction cups **88** and **90**. In still other embodiments, it can be mounted to windshield **14** by means of a suitable adhesive, double-sided adhesive tape, or VELCRO-type hook and pile fasteners (not shown). Cameras **22** and **24** have fields-of-view, indicated generally by the dashed lines, that extend forwardly and rearwardly of vehicle **12** when attached to windshield **14**.

The present invention provides a vehicle data recorder device that is fully integrated in a single enclosure and does not require cabling to connect cameras with remotely located recording devices. In some embodiments the device may provide a rear-view mirror function and can be used in place of a conventional rear-view mirror. In such embodiments, the recording nature of the device is advantageously not immediately conveyed to taxicab passengers, would-be thieves or others whose actions the device may be intended to monitor. Furthermore, the convenient location of the device on or near the windshield promotes ease of operation and facilitates radio and other remote transmission of data through the windshield. It also deters tampering because removal of the device, particularly in rear-view mirror embodiments, will be immediately apparent to any driver as well as persons outside the vehicle.

Obviously, other embodiments and modifications of the present invention will occur readily to those of ordinary skill in the art in view of these teachings. For example, alternative methods of mounting the device to a windshield or the surrounding area will occur to such persons as natural extensions and variations of the described methods of adhering a rear-view mirror device to the windshield and mounting a device by means of suction cups. Therefore, this invention is to be limited only by the following claims, which include all such other embodiments and modifications when viewed in conjunction with the above specification and accompanying drawings.

What is claimed is:

1. A vehicle-mounted device for capturing video imagery in response to a triggering event, comprising:

a housing;

an image sensor mounted to said housing, said image sensor sensing optical phenomena representing said video imagery;

a data sensor circuit within said housing and in part responsive to said triggering event; and

a capture circuit within said housing; said capture circuit comprising:

a non-volatile memory;

a volatile, random-access memory configured as a continuous-loop buffer, said volatile memory coupled to said non-volatile memory and coupled to said image sensor; said volatile memory capturing a signal representing said video imagery from said image sensor in a first-in, first-overwritten manner, and, responsive to said data sensor circuit sensing a triggering event, terminating capture of said signal and copying the captured signal representing said a video imagery to said non-volatile memory.

2. The vehicle-mounted device claimed in claim **1**, wherein said capture circuit terminates capture of said signal a predetermined time interval after occurrence of said triggering event.

3. The vehicle-mounted device claimed in claim **1**, wherein said capture circuit comprises a digital recording circuit having a digital memory and records said signal representing said video imagery.

4. The vehicle-mounted device claimed in claim **3**, wherein said capture circuit further records a signal representing data produced by said data sensor circuit.

5. The vehicle-mounted device claimed in claim **1**, wherein said capture circuit comprises a transmitter transmitting a signal representing said video imagery to a remote location.

6. The vehicle-mounted device claimed in claim **5**, wherein said transmitter transmits said signal in real-time.

7. The vehicle-mounted device claimed in claim **1**, wherein said data sensor circuit comprises a sensor responsive to a change in force experienced by said device.

8. The vehicle-mounted device claimed in claim **7**, wherein said data sensor circuit comprises a forward sensor responsive to a change in force experienced by said device in a direction substantially perpendicular to a direction of elongation of said housing and a lateral sensor responsive to a change in force experienced by said device in a direction substantially parallel to said direction of elongation of said housing.

9. The vehicle-mounted device claimed in claim **1**, wherein said image sensor is disposed behind a mirror and senses said optical phenomena transmitted through a portion of said mirror.

10. The vehicle-mounted device claimed in claim **9**, wherein said portion of said mirror is half-silvered and partially transmits and partially reflects said optical phenomena to provide said mirror with a uniformly mirrored appearance.

11. The vehicle-mounted device claimed in claim **9**, wherein said portion of said mirror is transparent.

12. The vehicle-mounted device claimed in claim **1**, wherein said image sensor is oriented to sense the optical phenomena impinging upon it from a direction substantially perpendicular to a direction of elongation of said housing.

13. The vehicle-mounted device claimed in claim **12**, wherein said image sensor comprises first and second portions, said first portion oriented to sense the optical phenomena impinging upon it from a direction substantially perpendicular to a direction of elongation of said housing, said second portion oriented to sense the optical phenomena impinging upon it from a direction substantially perpendicular to a direction of elongation of said housing and axially opposite said direction from which said optical phenomena impinges upon said first portion.

14. The vehicle-mounted device claimed in claim **13**, wherein said first portion of said image sensor is disposed behind a mirror and senses said optical phenomena transmitted through a portion of said mirror.

15. The vehicle-mounted device claimed in claim **1**, wherein:

said data sensor circuit further comprises a global positioning system (GPS) receiver identifying a geographic position of said vehicle-mounted device; and

said capture circuit further records a signal representing said geographic position.

16. The vehicle-mounted device claimed in claim **1**, wherein:

said data sensor circuit further comprises a microphone; and

said capture circuit further records a signal representing a sound impinging upon said microphone.

17. A vehicle-mounted device for capturing video imagery in response to a triggering event, comprising:

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a housing having a generally elongated shape;

a rear-view mirror mounted to said housing and having a generally elongated shape;

an image sensor mounted to said housing, said image sensor sensing optical phenomena representing said video imagery;

a data sensor circuit within said housing and in part responsive to said triggering event; and

a capture circuit within said housing; said capture circuit comprising:

a non-volatile memory; and

a volatile, random-access memory configured as a continuous-loop buffer; said volatile memory coupled to said non-volatile memory and coupled to said image sensor; said volatile memory capturing a signal representing said video imagery from said image sensor in a first-in, first-overwritten manner, and, responsive to said data sensor circuit sensing a triggering event, terminating capture of said signal and copying the captured signal representing said video imagery to said non-volatile memory.

18. The vehicle-mounted device claimed in claim **17**, wherein said capture circuit terminates capture of said signal a predetermined time interval after occurrence of said triggering event.

19. The vehicle-mounted device claimed in claim **17**, wherein said capture circuit comprises a digital recording circuit having a digital memory and records said signal representing said video imagery.

20. The vehicle-mounted device claimed in claim **19**, wherein said capture circuit further records a signal representing data produced by said data sensor circuit.

21. The vehicle-mounted device claimed in claim **17**, wherein said capture circuit comprises a transmitter transmitting a signal representing said video imagery to a remote location.

22. The vehicle-mounted device claimed in claim **21**, wherein said transmitter transmits said signal in real-time.

23. The vehicle-mounted device claimed in claim **17**, wherein said data sensor circuit comprises a sensor responsive to a change in force experienced by said device.

24. The vehicle-mounted device claimed in claim **23**, wherein said data sensor circuit comprises a forward sensor responsive to a change in force experienced by said device in a direction substantially perpendicular to a direction of elongation of said housing and a lateral sensor responsive to a change in force experienced by said device in a direction substantially parallel to said direction of elongation of said housing.

25. The vehicle-mounted device claimed in claim **17**, wherein said image sensor is disposed behind said mirror and senses said optical phenomena transmitted through a portion of said mirror.

26. The vehicle-mounted device claimed in claim **25**, wherein said portion of said mirror is half-silvered and partially transmits and partially reflects said optical phenomena to provide said mirror with a uniformly mirrored appearance.

27. The vehicle-mounted device claimed in claim **25**, wherein said portion of said mirror is transparent.

28. The vehicle-mounted device claimed in claim **17**, wherein said image sensor is oriented to sense the optical phenomena impinging upon it from a direction substantially perpendicular to a direction of elongation of said housing.

29. The vehicle-mounted device claimed in claim **18**, wherein said image sensor comprises first and second portions, said first portion oriented to sense the optical phenomena impinging upon it from a direction substantially perpendicular to a direction of elongation of said housing, said second portion oriented to sense the optical phenomena impinging upon it from a direction substantially perpendicular to a direction of elongation of said housing and axially opposite said direction from which said optical phenomena impinge upon said first portion.

30. The vehicle-mounted device claimed in claim **29**, wherein said first portion of said image sensor is disposed behind said mirror and senses said optical phenomena transmitted through a portion of said mirror.

31. The vehicle-mounted device claimed in claim **17**, wherein:

said data sensor circuit further comprises a global positioning system (GPS) receiver identifying a geographic position of said vehicle-mounted device; and

said capture circuit further records a signal representing said geographic position.

32. The vehicle-mounted device claimed in claim **17**, wherein:

said data sensor circuit further comprises a microphone; and

said capture circuit further records a signal representing a sound impinging upon said microphone.

33. A method for capturing video imagery in a vehicle-mounted system in response to a triggering event, said system comprising a rear-view mirror device mounted upon a windshield of a vehicle, said rear-view mirror device having a housing with a generally elongated shape, a mirror assembly mounted to said housing and having a generally elongated shape, an image sensor mounted to said housing and sensing optical phenomena representing said video imagery, a data sensor circuit within said housing, and a capture circuit within said housing; said capture circuit comprising: a non-volatile memory; and a volatile, random-access memory configured as a continuous-loop buffer, said volatile memory coupled to said non-volatile memory, the method comprising the steps of:

using said image sensor sensing optical phenomena transmitted through a portion of said mirror assembly and representing said video imagery; using said capture circuit capturing said video imagery in said volatile, random-access memory in a first-in, first-overwritten manner, and, responsive to said data sensor circuit sensing a triggering event, terminating capture of a signal representing said video imagery and copying the captured signal representing video imagery to said non-volatile memory.

34. The method claimed in claim **33**, further comprising the step of transmitting said signal representing said video imagery to a remote location.

35. The method claimed in claim **33**, wherein said step of terminating capture of said signal representing said video imagery comprises terminating capture of said signal in response to a change in force experienced by said device.

36. A method for capturing video imagery in a vehicle-mounted system in response to a triggering event, said system comprising a rear-view mirror device mounted upon a windshield of a vehicle, said rear-view mirror device having a housing with a generally elongated shape, a mirror assembly mounted to said housing and having a generally elongated shape, an image sensor mounted to said housing and sensing optical phenomena representing said video imagery, a data sensor circuit within said housing, and a capture circuit within said housing; said capture circuit

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comprising: a non-volatile memory; and a volatile, random-access memory configured as a continuous-loop buffer; said volatile memory coupled to said non-volatile memory, the method comprising the steps of:

using said image sensor sensing optical phenomena representing said video imagery impinging upon it from a direction substantially perpendicular to a direction of elongation of said housing and forwardly through said windshield of said vehicle and said video imagery impinging upon it from a direction substantially perpendicular to a direction of elongation of said housing and rearwardly with respect to said vehicle; using said capture circuit capturing said video imagery in said volatile, random-access memory in a first-in, first-overwritten manner, and, responsive to said data sensor circuit sensing a triggering event, terminating capture of a signal representing said video imagery and copying the captured signal representing video imagery to said non-volatile memory.

37. The method claimed in claim **36**, further comprising the step of transmitting said signal representing said video imagery to a remote location.

38. The method claimed in claim **36**, wherein said step of terminating capture of said signal representing said video imagery comprises terminating capture of said signal in response to a change in force experienced by said device.

39. A method for mounting a system for capturing video imagery in response to a triggering event, comprising the steps of mounting upon a vehicle windshield a device comprising a housing, an image sensor mounted to said housing to sensing optical phenomena representing said video imagery, a data sensor circuit within said housing responsive to said triggering event, and a capture circuit within said housing; said capture circuit comprising: a non-volatile memory; and a volatile, random-access memory configured as a continuous-loop buffer; said volatile memory coupled to said non-volatile memory and coupled to said image sensor using; using said volatile memory capturing a signal representing said video imagery from said image sensor in a first-in, first-overwritten manner, and, responsive to said data sensor circuit sensing a triggering event, terminating capture of said signal and copying the captured signal representing said video imagery to said non-volatile memory.

40. The method claimed in claim **39**, wherein said housing has a generally elongated shape, said device further comprises a suction-cup attached to said housing and a mirror having a generally elongated shape mounted to said housing, and said mounting step comprises the step of adhering said device to said windshield.

41. The method claimed in claim **39**, wherein said mounting step comprises the step of engaging said suction-cup upon said windshield.

* * * * *

US006389340C1

(12) EX PARTE REEXAMINATION CERTIFICATE (9887th)

United States Patent
Rayner

(10) Number: US 6,389,340 C1
(45) Certificate Issued: Oct. 21, 2013

(54) **VEHICLE DATA RECORDER**

(75) Inventor: **Gary A. Rayner**, San Diego, CA (US)

(73) Assignee: **Leader Ventures, LLC**, San Francisco, CA (US)

Reexamination Request:
No. 90/011,951, Oct. 11, 2011

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Filed: **Sep. 24, 1999**

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(51) **Int. Cl.**
G07C 5/00 (2006.01)
G07C 5/08 (2006.01)

(52) **U.S. Cl.**
USPC **701/32.4**; 340/438; 348/148; 701/32.2; 701/33.4

(58) **Field of Classification Search**
None
See application file for complete search history.

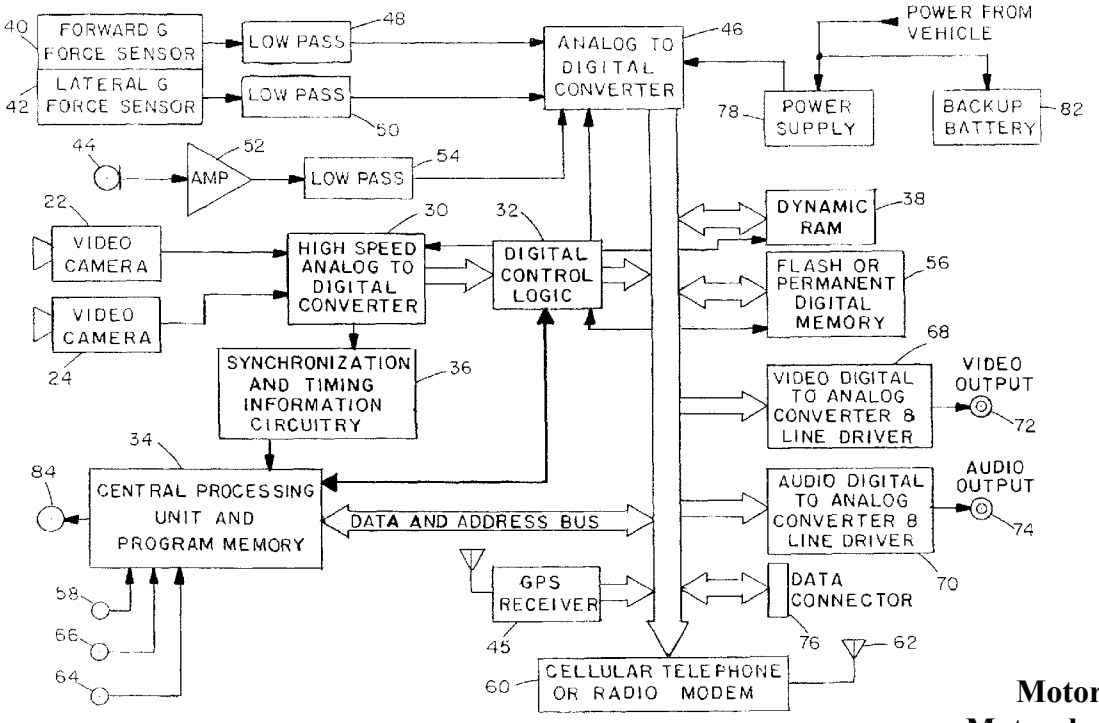
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To view the complete listing of prior art documents cited during the proceeding for Reexamination Control Number 90/011,951, please refer to the USPTO's public Patent Application Information Retrieval (PAIR) system under the Display References tab.

Primary Examiner — Zoila Cabrera

(57) **ABSTRACT**

A self-contained device for capturing video imagery in response to a triggering event may include a mirror and be mounted to a vehicle windshield in place of a conventional rear-view mirror. The device includes a housing in which the electronics and related elements of the invention are contained. These elements include one or more data sensors, at least one of which is an image sensor. Also included are a data sensor circuit and a capture circuit. The data sensor circuit responds to the triggering event, and may include data sensors coupled to vehicle systems such as a speedometer, tachometer, brake, turn signals or the like, or other data sensors such as an accelerometer or a vehicle position sensor. The triggering event may be, for example, a sudden change in acceleration indicative of an impending collision, or it may be a change in the signal provided by any such data sensor, including the image sensor. The capture circuit is coupled to the image sensor and captures a signal representing the video imagery by recording it in a digital memory, by transmitting it to a remote location, or by other suitable means. The capture circuit terminates capture of the signal in response to the data sensor circuit sensing a triggering event. The captured data thus describe circumstances leading up to the time of the triggering event. The data can be analyzed to help police, insurance or other investigative personnel understand those circumstances.



EX PARTE REEXAMINATION CERTIFICATE ISSUED UNDER 35 U.S.C. 307

THE PATENT IS HEREBY AMENDED AS INDICATED BELOW.

Matter enclosed in heavy brackets [ ] appeared in the patent, but has been deleted and is no longer a part of the patent; matter printed in italics indicates additions made to the patent.

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

Claims **1-8**, **12**, **13**, **15**, **16** and **39** are cancelled.

New claims **42-44** are added and determined to be patentable.

Claims **9-11**, **14**, **17-38**, **40** and **41** were not reexamined.

42. A vehicle-mounted device for capturing video imagery in response to a triggering event, comprising:

a housing;

an image sensor mounted to said housing, said image sensor sensing optical phenomena representing said video imagery;

a data sensor circuit within said housing and in part responsive to said triggering event; and

a capture circuit within said housing; said capture circuit comprising:

a non-volatile memory comprising addressable digital storage; and

a volatile, dynamic random-access memory configured as a continuous-loop buffer, said volatile memory coupled to said non-volatile memory and coupled to said image sensor; said volatile memory capturing a signal representing said video imagery from said image sensor in a first-in, first-overwritten manner, and, responsive to said data sensor circuit sensing the triggering event, terminating capture of said signal and copying the captured signal representing said video imagery to said non-volatile memory, wherein the non-volatile memory and the volatile, random-access memory comprise a two-tier system with a first tier that records data using a continuous-loop scheme by employing wrap-around memory addressing, in which the highest memory location in a predetermined addressing sequence is adjacent or next to a lowest and a second tier that stores the data in response to the triggering event, wherein in response to the triggering event, the second tier provides more permanent storage for data than is provided for data stored in the first tier, and wherein data stored in the second tier is only overwritten in response to a system reset operation.

43. A vehicle-mounted device for capturing video imagery in response to a triggering event, comprising:

a housing;

an image sensor mounted to said housing, said image sensor sensing optical phenomena representing said video imagery;

a data sensor circuit within said housing and in part responsive to said triggering event; and

a capture circuit within said housing; said capture circuit comprising:

a non-volatile memory comprising addressable digital storage; and

a volatile, dynamic random-access memory configured as a continuous-loop buffer, said volatile memory coupled to said non-volatile memory and coupled to said image sensor; said volatile memory capturing a signal representing said video imagery from said image sensor in a first-in, first-overwritten manner, and, responsive to said data sensor circuit sensing the triggering event, terminating capture of said signal and copying the captured signal representing said video imagery to said non-volatile memory, wherein the non-volatile memory and the volatile, random-access memory comprise a two-tier system with a first tier that records data using a continuous-loop scheme by employing wrap-around memory addressing, in which the highest memory location in a predetermined addressing sequence is adjacent or next to a lowest and a second tier that stores the data in response to the triggering event, wherein in response to the triggering event, the second tier provides more permanent storage for data than is provided for data stored in the first tier, wherein data stored in the second tier is only overwritten in response to a system reset operation, and wherein security measures prevent an inadvertent or unauthorized resetting operation from being performed.

44. A vehicle-mounted device for capturing video imagery in response to a triggering event, comprising:

a housing;

an image sensor mounted to said housing, said image sensor sensing optical phenomena representing said video imagery;

a data sensor circuit within said housing and in part responsive to said triggering event; and

a capture circuit within said housing; said capture circuit comprising:

a non-volatile memory comprising addressable digital storage; and

a volatile, dynamic random-access memory configured as a continuous-loop buffer, said volatile memory coupled to said non-volatile memory and coupled to said image sensor; said volatile memory capturing a signal representing said video imagery from said image sensor in a first-in, first-overwritten manner, and, responsive to said data sensor circuit sensing the triggering event, terminating capture of said signal and copying the captured signal representing said video imagery to said non-volatile memory, wherein the non-volatile memory and the volatile, random-access memory comprise a two-tier system with a first tier that records data using a continuous-loop scheme by employing wrap-around memory addressing, in which the highest memory location in a predetermined addressing sequence is adjacent or next to a lowest and a second tier that stores the data in response to the triggering event, wherein in response to the triggering event, the second tier provides more permanent storage for data than is provided for data stored in the first tier, wherein data stored in the second tier is only overwritten in response to a system reset operation, wherein security measures prevent an inadvertent or unauthorized resetting operation from being performed, and wherein the security measures include placing a reset button inside of the housing.

* * * * *

Appendix J

US006421080B1

(12) **United States Patent**
Lambert

(10) **Patent No.: US 6,421,080 B1**
(45) **Date of Patent: Jul. 16, 2002**

(54) **DIGITAL SURVEILLANCE SYSTEM WITH PRE-EVENT RECORDING**

(75) Inventor: **Tim A. Lambert**, Lexington, KY (US)

(73) Assignee: **Image Vault LLC**, New Albany, IN (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(22) Filed: **Nov. 5, 1999**

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(52) **U.S. Cl.** **348/143**
(58) **Field of Search** 348/143, 150, 348/151, 152, 153, 154, 155, 156, 159; H04N 7/18, 9/47

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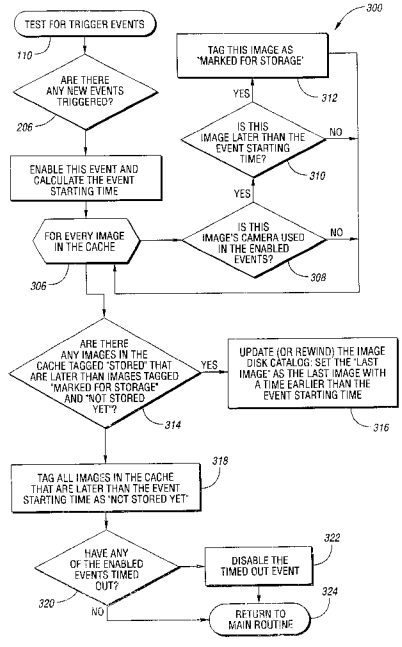
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Primary Examiner—Nhon Diep
(74) *Attorney, Agent, or Firm*—Brooks & Kushman P.C.

(57) **ABSTRACT**

An image recording system and method for use with a surveillance system having at least two cameras provides true pre-event recording for multiple input sources to improve video on demand storage control. More specifically, an image recording subsystem is connected to the cameras for receiving generated video images, and storing the received images in a temporary storage device having a storage capacity large enough to store video images generated over a predetermined period of time. The image recording subsystem is arranged to continuously record video images into the temporary storage device such as a cache memory, and in response to the occurrence of a triggering event, subsequently record the temporarily stored video images into a long-term storage device for later retrieval. The image recording system is arranged to determine the occurrence of overlapping triggering events, and automatically "rewind" the sequential long term storage process so that any images associated with an earlier triggering event but occurring in time after a later triggering event that have already been stored to long term storage are properly reordered to occur after any earlier occurring images associated with the later triggering event.

19 Claims, 3 Drawing Sheets



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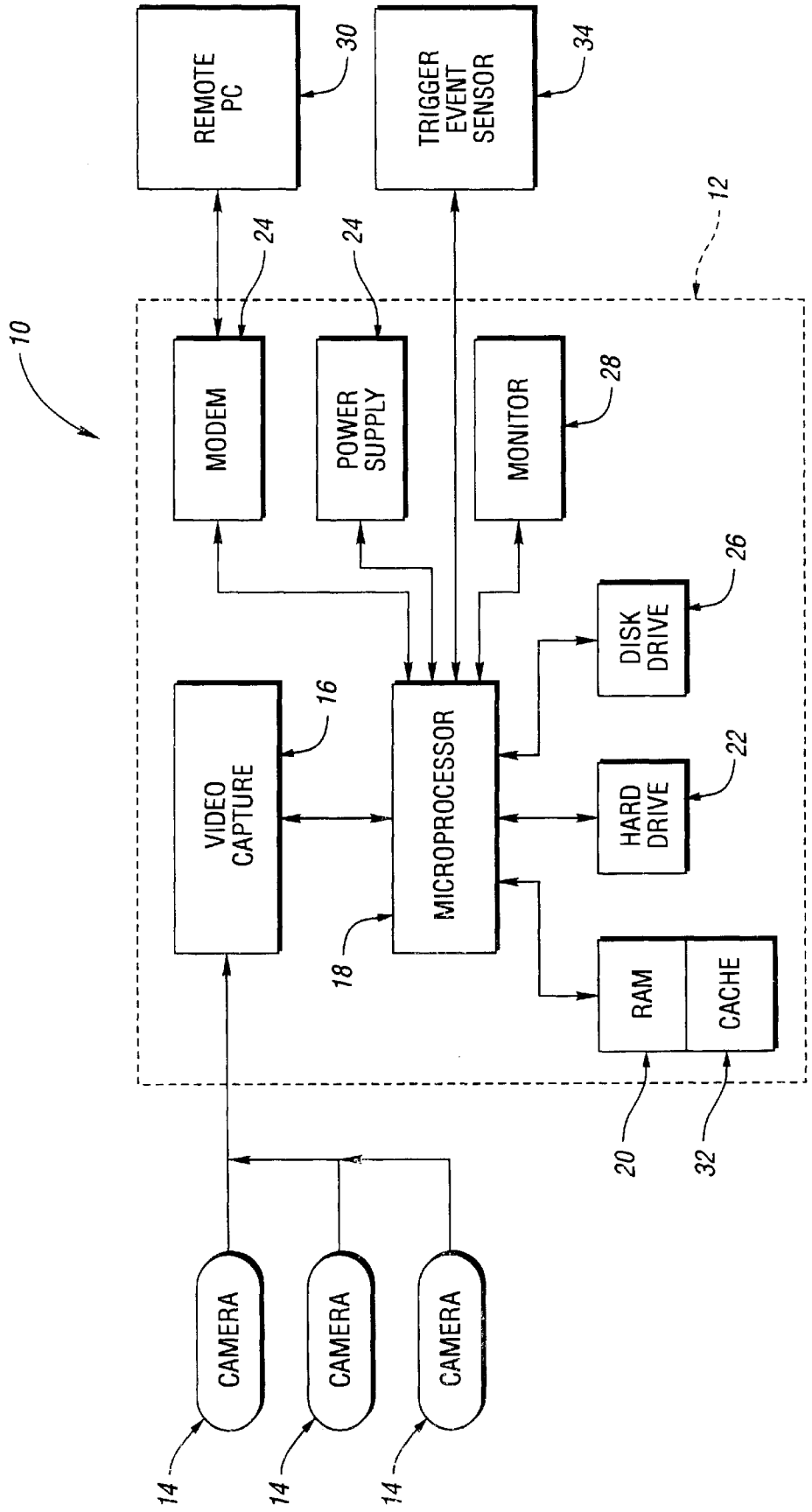

REMOTE PC
30
TRIGGER EVENT SENSOR
34
12
24
24
10
MODEM
POWER SUPPLY
MONITOR
28
26
DISK DRIVE
16
VIDEO CAPTURE
MICROPROCESSOR
22
HARD DRIVE
18
RAM
CACHE
20
32
CAMERA
CAMERA
CAMERA
14
14
14

Fig. 1

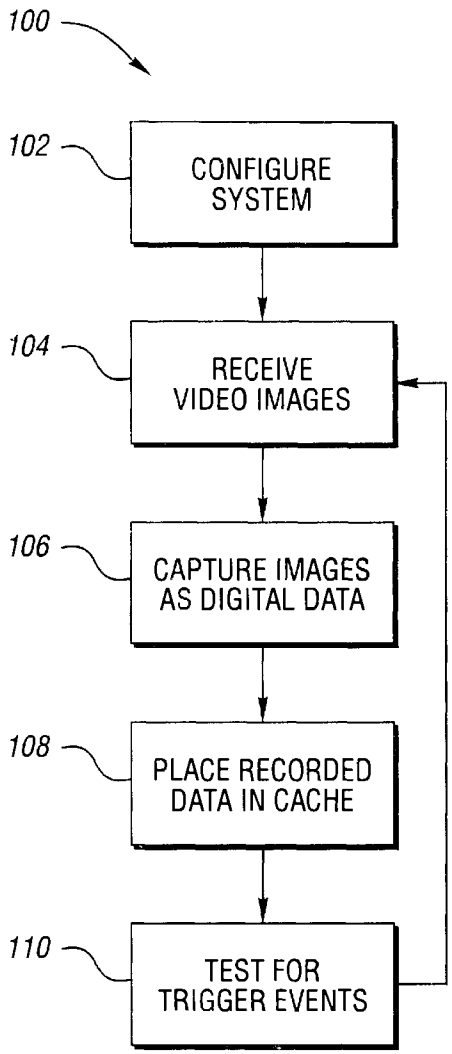

100
102
CONFIGURE SYSTEM
104
RECEIVE VIDEO IMAGES
106
CAPTURE IMAGES AS DIGITAL DATA
108
PLACE RECORDED DATA IN CACHE
110
TEST FOR TRIGGER EVENTS

Fig. 2

200
PLACE RECORDED DATA IN CACHE
108
OVERWRITE OLDEST IMAGE IF CACHE IS FULL
202
TAG LATEST IMAGE AS "NOT STORED YET" AND "NOT MARKED FOR STORAGE"
204
DO THE ENABLED EVENTS USE THE LATEST IMAGE'S CAMERA?
206
NO
YES
TAG LATEST IMAGE "MARKED FOR STORAGE"
208
ARE THERE ANY IMAGES TAGGED "MARKED FOR STORAGE" AND "NOT STORED YET?
210
NO
YES
WRITE THIS IMAGE TO DISK AND TAG IT AS "STORED"
212
HAVE 4 IMAGES BEEN WRITTEN TO DISK IN THIS PASS?
214
YES
NO
RETURN TO MAIN ROUTINE
216

Fig. 3

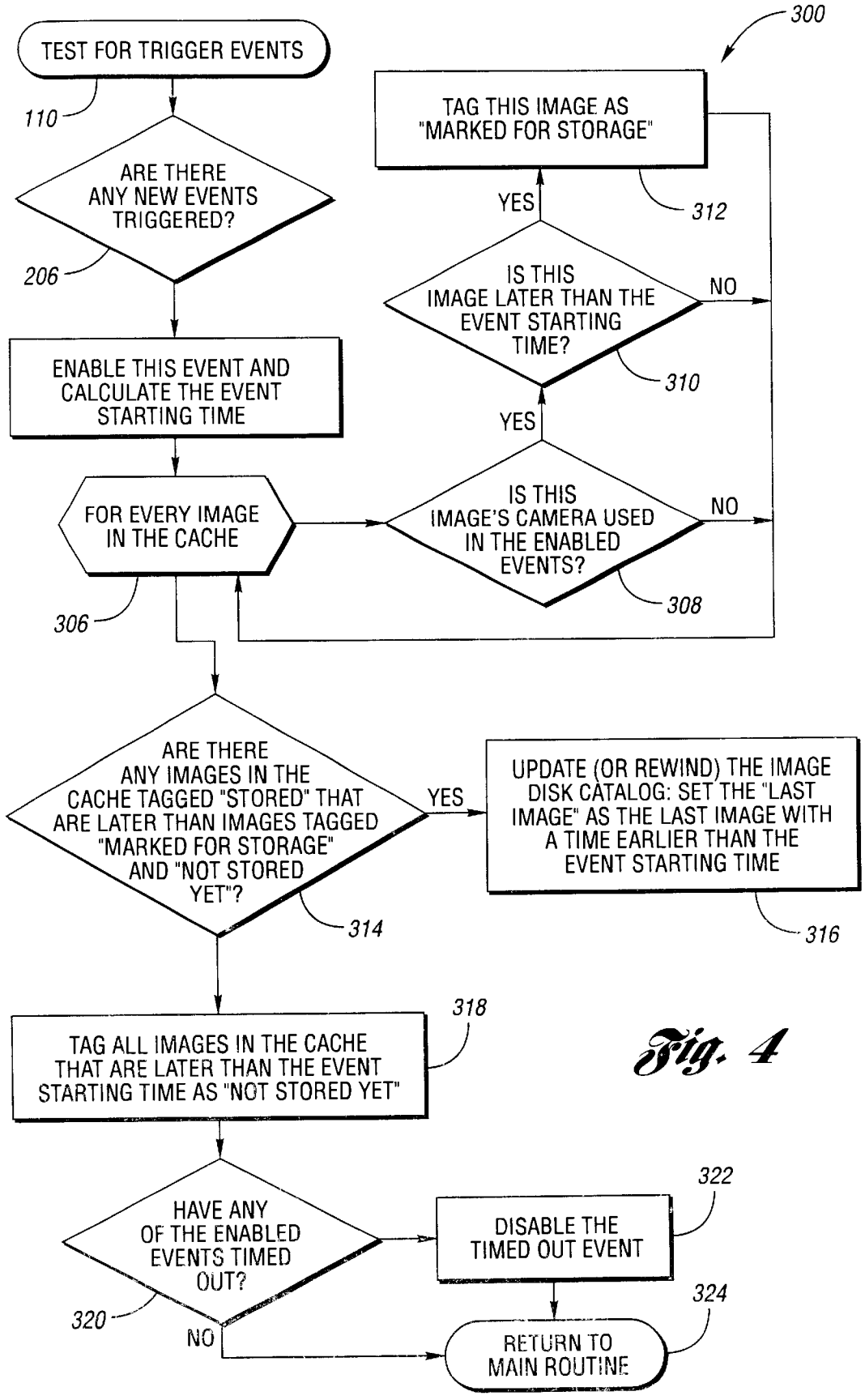

300
TEST FOR TRIGGER EVENTS
110
ARE THERE ANY NEW EVENTS TRIGGERED?
206
ENABLE THIS EVENT AND CALCULATE THE EVENT STARTING TIME
FOR EVERY IMAGE IN THE CACHE
306
IS THIS IMAGE'S CAMERA USED IN THE ENABLED EVENTS?
308
NO
YES
IS THIS IMAGE LATER THAN THE EVENT STARTING TIME?
310
NO
YES
TAG THIS IMAGE AS "MARKED FOR STORAGE"
312
ARE THERE ANY IMAGES IN THE CACHE TAGGED "STORED" THAT ARE LATER THAN IMAGES TAGGED "MARKED FOR STORAGE" AND "NOT STORED YET"?
314
YES
UPDATE (OR REWIND) THE IMAGE DISK CATALOG: SET THE "LAST IMAGE" AS THE LAST IMAGE WITH A TIME EARLIER THAN THE EVENT STARTING TIME
316
TAG ALL IMAGES IN THE CACHE THAT ARE LATER THAN THE EVENT STARTING TIME AS "NOT STORED YET"
318
HAVE ANY OF THE ENABLED EVENTS TIMED OUT?
320
NO
DISABLE THE TIMED OUT EVENT
322
RETURN TO MAIN ROUTINE
324

Fig. 4

DIGITAL SURVEILLANCE SYSTEM WITH PRE-EVENT RECORDING

TECHNICAL FIELD

The present invention generally relates to surveillance systems which capture and store visual information generated by one or more surveillance cameras, and more particularly to an improved recording arrangement allowing such systems to be triggered by occurrence of a particular event while still recording the entire event.

BACKGROUND ART

Surveillance systems which record images from one or more video cameras or closed circuit televisions systems are well known in the art. These systems allow time sequential visual records to be stored as analog signals on videotape or digital images in a personal computer (PC) memory device for later review and analysis. A common problem for all such systems is balancing the availability of a finite amount of physical space for storage of captured signals with the potentially large amount of information which may need to be recorded in carrying out continual surveillance over long periods of time. One known approach for addressing this problem involves only activating image recording in response to specific triggering events, such as opening of a door, operation of a cash register or ATM, or tripping of a sensor. By triggering recording only when particular events occur, such arrangements not only significantly reduce the amount of video information to be recorded, but also assure the images that are stored have the highest probability of being of interest.

While such event triggered systems effectively eliminate the need for large information storage space, the requirement that recording does not begin until after occurrence of one of the events insures that the period of time just preceding the event will never be recorded. Unfortunately, it is this preceding period of time which tends to be of greatest interest when later analyzing the recorded information. Therefore, a need exists for an improved surveillance system capable of reducing the need for the large storage space without reducing the system's capability to record information likely to be the most useful.

DISCLOSURE OF INVENTION

Therefore, it is an object of the present invention to provide a surveillance and image capture system and method which overcomes the above-noted problems by constantly recording surveillance information into temporary and reusable storage, and recording such information for long-term storage and subsequent retrieval upon the occurrence of multiple and overlapping predefined triggering events.

It is another object of the present invention to provide a digital image recording arrangement for use in a surveillance system which continuously records digital image data from multiple video sources into a cache memory to create a pre-event image data store, and subsequently stores the pre-event digital image data in proper time sequential order from each of the multiple video sources into long-term data storage for later retrieval and analysis upon the occurrence of one or more overlapping triggering events from any one or all of the video sources.

It is yet another object of the present invention to provide a digital image recording arrangement for use in a surveillance system which is capable of true pre-event image recording for systems having multiple image input sources.

In accordance with these and other objects of the present invention, pre-event recording is achieved by providing an image recording system for use with a surveillance system having at least two cameras, wherein the recording system includes a processor connected to the at least two video cameras for receiving generated video images and image creation time identifying information, a temporary storage device connected to the processor and having a storage capacity large enough to store video images generated over a predetermined period of time, a long-term storage device also connected to the processor, and a sensor arrangement for detecting an occurrence of a pre-defined triggering event associated with each camera. The processor is arranged to continuously record video images from each camera into the temporary storage device, and in response to the sensor arrangement detecting the occurrence of a triggering event associated with any of the at least two cameras, subsequently record temporarily stored video images generated by the associated camera into the long term storage device.

In accordance with one aspect of the present invention, the sensor arrangement is arranged to detect an occurrence of overlapping pre-defined triggering events, and the image recording processor is further arranged to subsequently record the temporarily stored video images generated by each camera associated with the detected triggering events into the long-term storage device. The image recording processor is further arranged to detect that images from an earlier triggering event but occurring after a starting time for a later triggering event have been recorded into the long-term storage device, and in response, automatically altering the sequence of images recorded to the long-term storage device to place the images associated with each overlapping triggering event in a combined oldest to latest time sequence.

In accordance with another aspect of the present invention, a method for recording video images in a surveillance system having at least two cameras includes receiving video images generated by the at least two video cameras and determining an image creation time for each received image, and recording the received video images in a temporary storage device having a storage capacity large enough to store video images generated over a predetermined period of time. Upon detecting an occurrence of a pre-defined triggering event associated with one of the cameras, the temporarily stored video images generated by the associated camera into a long-term storage device while continuing to maintain any images recorded in the temporary storage device generated by any camera not associated with triggering event.

In accordance with still another aspect of the present invention, the method detects an occurrence of overlapping pre-defined triggering events associated with different cameras, and in response to each triggering event, subsequently records temporarily stored video images generated by each camera associated with the detected triggering events into a long-term storage device. In addition, upon detecting that images from an earlier triggering event but occurring after a starting time for a later occurring triggering event have been recorded into the long-term storage device, the sequence of images recorded to the long-term storage device is automatically altered to place the images associated with each overlapping triggering event in a combined oldest to latest time sequence.

In accordance with other aspects of the present invention, the received video images are captured as digital image data and compressed before recording in the temporary storage device. The temporary storage device can be implemented as

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a cache memory, and the oldest video images in the temporary storage device are automatically overwritten when the storage capacity is filled.

Thus, the present invention provides a true pre-event recording arrangement for multiple video input sources that is further capable of handling the occurrence of overlapping triggering events by automatically "rewinding" the sequential long term storage process so that any images associated with an earlier triggering event but occurring in time after a later triggering event that have already been stored to long term storage are properly reordered to occur after any earlier occurring images associated with the later triggering event.

The above objects and other objects, features, and advantages of the present invention are readily apparent from the following detailed description of the best mode for carrying out the invention when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a block diagram of a surveillance and image recording system in accordance with the present invention;

FIG. **2** is a flow chart illustrating a main processing loop for pre- event image recording in accordance with the present invention;

FIG. **3** is a flow chart illustrating a cache/digital image storage control subroutine in accordance with the present invention; and

FIG. **4** is a flow chart illustrating an event triggering determination control subroutine in accordance with the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

FIG. **1** shows a block diagram of a surveillance system having a digital image recording system **10** in accordance with a preferred embodiment of the present invention. System **10** includes a recording subsystem **12** connected to at least two or more video cameras **14**, such as CCTV cameras, which are positioned to provide video monitoring of a predetermined area. Recording subsystem **12** is typically installed on a customer's site in a nonconspicuous location. Recording subsystem **12** preferably includes a stand-alone personal computer (PC) configured with at least one video capture board **16**, power supply (not shown), microprocessor **18**, memory (RAM) **20**, one or more hard drives **22**, a modem **24**, and disk drive **26**. The modem allows remote access and control. In the embodiment shown, recording subsystem **12** operates as a digital replacement for analog video cassette recorders typically employed in CCTV systems. A monitor **28** is optional.

A remote monitoring subsystem **30** can be included and programmed to allow a user to directly access the recording subsystem from a remote location via modem **24**. Such access programming preferably requires input of a correct phone number and password corresponding to subsystem **12** before allowing access to view stored images or configure the recording subsystem.

As described below, recording subsystem **12** is programmed to continually capture video images provided by each camera **14** as digital data. Captured image data is then compressed using suitable data compression techniques to reduce the size of the image data, such as to approximately one-twelfth the original size in an exemplary embodiment. The compressed image data is then temporarily stored as an image data file in a cache memory **32** preferably having space for storage of 60–400 images depending on the amount of RAM installed in subsystem **12**. Suitable identifying information such as date and time of the original image, image size, and a camera identifier are stored with the compressed image data file or in a separate but related catalog data file.

More specifically, capture board **16** receives and converts an incoming video signal stream of pixel values that represent brightness and color. The capture board transfers the pixel values as image data to cache **32** in RAM memory **20** for temporary storage using direct memory access (DMA). The pixel values stored in cache are then transformed using Wavelet processing, and the transformation results compressed in accordance with a bit-encoding scheme. As described below, the compressed data can be selectively stored as a new image file in long-term storage on hard drive **22** and/or disk drive **26**, or added to an existing stored image file. The stored image files allow video information recorded over pre-determined lengths of time to be organized and accumulated for later retrieval and analysis. Once an existing image file becomes completely filled, all corresponding catalog data is preferably appended to the same image file, and closed to any further recording. A new image file is subsequently opened in the system memory. Image data that is not recorded to long-term storage is ultimately written over by subsequent image data.

In accordance with the present invention, captured and compressed images are continually recorded into the temporary memory, and subsequently stored are selectively recorded into long-term storage only upon detecting a triggering event. Examples of triggering events include transactions at point-of-sale terminals and automated banking teller machines (ATM), output signals from motion sensors and security alarms, and a control signal sent by a remote computer system. Apparatus for detecting such events is well known to one having ordinary skill in the art. Suitable detecting apparatus is denoted as a sensor arrangement **34**, and detects the occurrence of at least one of the above-identified events and provides a corresponding output signal for input to recording subsystem **12**.

The image data stored in the temporary memory just prior to detection of a triggering event qualifies as pre-event activity, and will be copied to the long-term memory along with contemporaneously or post-event image data to advantageously provide an image record of events occurring just prior to a triggering event in combination with those generated after the triggering event. This allows the image recording arrangement of the present invention to reduce the amount of image data which needs to be stored without compromising the potential usefulness of the stored image record.

Overall operation of the image recording process of the present invention is illustrated in the flowcharts of FIGS. **2–4**. More specifically, a main processing loop **100** is shown in FIG. **2**, a cache and digital image storage control subroutine **200** is shown in FIG. **3**, and an event triggering determination control subroutine **300** is shown in FIG. **4**. In a preferred embodiment, programming for subsystem **12** includes an event manager arranged to maintain a list of triggering event inputs, and at least one user-configurable parameter associated with each event. For example, configurable parameters can include a list of cameras to be saved to long-term storage in association with the occurrence of specific types of events, the length of time preceding a triggering event from which pre-event image data is to be tagged and copied to long-term storage from the cache, and the length of time following a triggering event in which new

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image data will be copied from cache into long-term memory. Configuration of the system is generally denoted as being part of the main processing loop at block **102**.

Video images are received from the plurality of cameras at block **104**, and captured as digital image data and compressed at block **106**. The compressed image data is then stored as temporary image data in cache **32** in accordance with subroutine **200** as denoted at block **108**. The cache maintains a list of dynamic frames consisting of the compressed image data as well as the number of bytes in the compressed image, the date and time that the image was captured, and camera identification data indicating the camera from which the image was captured. As described below in conjunction with FIG. **3**, after a predetermined number of images, e.g., four in a preferred embodiment, have been copied from the cache, the system then executes subroutine **300** to determine: (1) occurrence of any new triggering event, and (2) timing out of any old triggering events.

Referring now to FIG. **3**, as indicated at block **202**, system **12** automatically reuses the cache memory when storing data into the cache if the list of dynamic frames has become full. More specifically, system **12** is programmed to reuse the cache by overwriting the oldest dynamic frame with a new image file when the cache is full. As shown in block **204**, the last image stored in the cache is tagged to indicate that the image has not yet been copied to disk, and has not yet been marked for storage. Then, at block **206**, a determination is made as to whether any ongoing enabled or triggering events use the camera that the generated the latest image. If so, the image is tagged "marked for storage" at block **208**. Otherwise, the process proceeds to block **210** and determines on an image by image basis whether there are currently any images stored in the cache that have been "marked for storage" but not yet stored to disk. If such an image is found, the image is then copied or written to disk, and the image file in the cache is tagged as "stored" as denoted at block **212**. As shown at block **214**, the preferred embodiment is arranged to process and write to disk four images through each pass of the subroutine **200**. However, this is not to be construed as limiting as more or less image files can be processed in any given cycle. It is further noted that none of the images in the cache are removed from cache when written to disk. The images are only copied to a disk when marked for storage. The images in the cache are only removed as a result of the above-described cache reuse arrangement. The process then returns to main processing loop **100** as shown at block **216**.

Referring now to FIG. **4**, as indicated at block **302**, system **12** determines if any new triggering events have occurred since the last cycle. If there is a new triggering event, the event is enabled and the event starting time is determined at block **304**. Recording subsystem **12** is programmed to calculate a starting time as being equal to the current time minus the amount of time already stored as part of the pre-event recording associated with this event. The process then proceeds to a subloop **306** and determines for every image in the cache whether the image was produced by the camera(s) associated with the new triggering event as shown at block **308**. If the image being processed was not generated by a camera associated with the triggering event, the process returns to block **306** and processes the next image. Otherwise, as indicated at block **310**, the process determines whether the image is later in time than the event starting time, and if later, tags the image for storage to the disk as indicated at block **312**. Otherwise, the process return to block **306**.

Once all the images have been analyzed, the process proceeds to block **314** to determine if there are any images in the cache that have been tagged "stored"to disk but are later in time than images that have been tagged "marked for storage"but have not yet been copied to disk. If there are later stored images, then as denoted at block **316**, the last image residing in the long term storage, i.e., the disk, is reset or "rewound" to correspond to the last image with a time earlier than the event starting time. After this step is completed, or if there are no later images already stored to disk, all images in the cache that are later than the event starting time are tagged to indicate that they have not yet been stored to disk as indicated at block **318**. Thus, by this process, all later occurring images that have already been written to disk will be written over with earlier occurring images, and then subsequently copied again from cache in their proper sequential order. Implicit in the operation of blocks **310**/**314** is that the long-term storage can not be rewound back to a point in time earlier then the oldest image still residing in cache. Otherwise, later occurring images that have already been written over in cache could not be rewritten to disk.

At the end of this process, or if there were no new triggering events as determined at block **302**, the process jumps to block **320** to determine if any of on-going events have timed-out. If so, the timed-out event(s) are disabled at block **322**. The process then returns to the main processing loop as indicated at block **324**.

The following is an example of video image transfer control from the cache during overlapping triggering events from different cameras in accordance with the present invention. As shown in each of the five tables, the cache includes 20 entries for storing the latest images captured from a camera **1** and a camera **2** in a continuous alternating one second sampling interval. Thus, if a first triggering event occurs at 25 seconds, the cache will contain the following entries:

TABLE 1

Cache Entry	Camera ID	Marked for Storage	Stored Yet	Time (Seconds)
1	1			25
2	2			24
3	1			23
4	2			22
5	1			21
6	2			20
7	1			19
8	2			18
9	1			17
10	2			16
11	1			15
12	2			14
13	1			13
14	2			12
15	1			11
16	2			10
17	1			9
18	2			8
19	1			7
20	2			6

If the predetermined parameters call for storage of 15 seconds of pre-event for camera **1**, after the first event is processed the cache entries will be modified as follows:

TABLE 2

Cache Entry	Camera ID	Marked for Storage	Stored Yet	Time (Seconds)
1	1	Y		25
2	2			24
3	1	Y		23
4	2			22
5	1	Y		21
6	2			20
7	1	Y		19
8	2			18
9	1	Y		17
10	2			16
11	1	Y		15
12	2			14
13	1	Y		13
14	2			12
15	1	Y		11
16	2			10
17	1			9
18	2			9
19	1			7
20	2			6

If a second triggering event is detected at 30 seconds, the cache entries will have been modified as follows at the time of the second event (note that the marked images have been tagged as already being written to disk/long term storage):

TABLE 3

Cache Entry	Camera ID	Marked for Storage	Stored Yet	Time (Seconds)
1	2			30
2	1			29
3	2			28
4	1			27
5	2			26
6	1	Y	Y	25
7	2			24
8	1	Y	Y	23
9	2			22
10	1	Y	Y	21
11	2			20
12	1	Y	Y	19
13	2			18
14	1	Y	Y	17
15	2			16
16	1	Y	Y	15
17	2			14
18	1	Y	Y	13
19	2			12
20	1	Y	Y	11

The parameters for the second event call for recording of 15 seconds of Pre-Event on camera 2. Thus, after the second event is processed, the cache entries will have been modified as follows:

TABLE 4

Cache Entry	Camera ID	Marked for Storage	Stored Yet	Time (Seconds)
1	2	Y		30
2	1			29
3	2	Y		28
4	1			27
5	2	Y		26
6	1	Y	Y	25
7	2	Y		24
8	1	Y	Y	23
9	2	Y		22
10	1	Y	Y	21
11	2	Y		20
12	1	Y	Y	19
13	2	Y		18
14	1	Y	Y	17
15	2	Y		16
16	1	Y	Y	15
17	2			14
18	1	Y	Y	13
19	2			12
20	1	Y	Y	11

As is evident from Table 4, the images from camera **2** captured between 16 seconds and 24 seconds will be written to the disk out of sequence. Therefore, in accordance with the present invention, the image catalog on the disk is backed up such that the last image will now be at 15 seconds, and the images in the cache later the 15 second entry are marked as "Not Yet Stored" as follows:

TABLE 5

Cache Entry	Camera ID	Marked for Storage	Stored Yet	Time (Seconds)
1	2	Y		30
2	1			29
3	2	Y		28
4	1			27
5	2	Y		26
6	1	Y		25
7	2	Y		24
8	1	Y		23
9	2	Y		22
10	1	Y		21
11	2	Y		20
12	1	Y		19
13	2	Y		18
14	1	Y		17
15	2	Y		16
16	1	Y		15
17	2			14
18	1	Y	Y	13
19	2			12
20	1	Y	Y	11

Now, the next few passes through the Cache will write images at 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 28, 30 seconds to the disk.

Thus, the present invention provides a system that allows true pre-event recording for multiple video input sources by insuring that images that have been temporarily stored in the cache are maintained (unless a particular image is the oldest stored and the cache is full) in the cache even though a triggering event associated with one of the cameras has been detected. In addition, the ability to detect overlapping triggering events and subsequently "rewind" already stored but later occurring pre-event images allows the present invention to insure that images recorded to long-term storage are kept in proper time sequence.

While an embodiment of the invention have been illustrated and described, it is not intended that these embodiments illustrate and describe all possible forms of the invention. For example, while the present invention has been described in context with a digital image store arrangement, the pre-event storage process can be readily adapted for use with an analog image recording system. Therefore, the words used in the specification are words of description

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rather than limitation, and it is understood that various changes may be made without departing from the spirit and scope of the invention.

What is claimed is:

1. An image recording system for use with a surveillance system having at least two cameras comprising:

an image recording processor connected to the at least two video cameras for receiving generated video images and image creation time identifying information;

a temporary storage device connected to the image recording processor and having a storage capacity large enough to store video images generated over a predetermined period of time;

a long-term storage device connected to the image recording processor; and

a sensor arrangement for detecting an occurrence of a pre-defined triggering event associated with each camera, wherein the image recording processor is arranged to continuously record video images from each camera into the temporary storage device, and in response to the sensor arrangement detecting the occurrence of a triggering event associated with any of the at least two cameras, subsequently recording temporarily stored pre-event video images generated over a predetermined period of pre-event time by the associated camera into the long-term storage device.

2. An image recording system for use with a surveillance system having at least two cameras comprising:

an image recording processor connected to the at least two video cameras for receiving generated video images and image creation time identifying information;

a temporary storage device connected to the image recording processor and having a storage capacity large enough to store video images generated over a predetermined period of time;

a long-term storage device connected to the image recording processor; and

a sensor arrangement for detecting an occurrence of a pre-defined triggering event associated with each camera, wherein the image recording processor is arranged to continuously record video images from each camera into the temporary storage device, and in response to the sensor arrangement detecting the occurrence of a triggering event associated with any of the at least two cameras, subsequently recording temporarily stored video images generated by the associated camera into the long-term storage device,

wherein the sensor arrangement is arranged to detect an occurrence of overlapping pre-defined triggering events associated with different cameras, and the image recording processor is further arranged to subsequently record the temporarily stored video images generated by each camera associated with the detected triggering events into the long-term storage device, said image recording processor being further arranged to detect that images from an earlier triggering event but occurring after a starting time for a later triggering event have been recorded into the long-term storage device, and in response, automatically altering the sequence of images recorded to the long-term storage device to place the images associated with each overlapping triggering event in a combined oldest to latest time sequence.

3. The image recording system of claim **1** wherein the image recording processor is further arranged to determine an event starting time for each triggering event as being equal to a current time minus the predetermined period of pre-event time, and tag for recording to the long-term storage device any video image recorded in the temporary storage device having a creation time after the event starting time.

4. The image recording system of claim **1** wherein the temporary storage device comprises a cache memory.

5. The image recording system of claim **1** wherein the long term storage device comprises a disk data storage device.

6. The image recording system of claim **1** wherein the image recording processor comprises a video capture arrangement for capturing the received video images as digital image data.

7. The image recording system of claim **6** wherein the image recording processor is further arranged to compress the digital image data before recording in the temporary storage device.

8. The image recording system of claim **1** wherein the image recording processor is further arranged to determine the oldest video image stored in the temporary storage device based on the creation time identifying information, and automatically overwrite the oldest video image if the temporary storage device becomes filled.

9. A method for pre-event recording video images in a surveillance system having at least two cameras comprising:

receiving video images generated by the at least two video cameras and determining an image creation time for each received image;

recording the received video images in a temporary storage device having a storage capacity large enough to store video images generated over a predetermined period of time;

detecting an occurrence of a pre-defined triggering event associated with one of the cameras; and

in response to detecting the occurrence of the triggering event, subsequently recording temporarily stored pre-event video images generated over a predetermined period of pre-event time by the associated camera into a long-term storage device while continuing to maintain any images recorded in the temporary storage device generated by any camera not associated with triggering event.

10. A method for pre-event recording video images in a surveillance system having at least two cameras comprising:

receiving video images generated by the at least two video cameras and determining an image creation time for each received image;

recording the received video images in a temporary storage device having a storage capacity large enough to store video images generated over a predetermined period of time;

detecting an occurrence of a pre-defined triggering event associated with one of the cameras;

in response to detecting the occurrence of the triggering event, subsequently recording temporarily stored video images generated by the associated camera into a long-term storage device while continuing to maintain any images recorded in the temporary storage device generated by any camera not associated with triggering event;

detecting an occurrence of overlapping pre-defined triggering events associated with different cameras;

in response to each triggering event, subsequently recording temporarily stored video images generated by each

camera associated with the detected triggering events into a long-term storage device;

detecting that images from an earlier triggering event but occurring after a starting time for a later occurring triggering event have been recorded into the long-term storage device; and

in response, automatically altering the sequence of images recorded to the long-term storage device to place the images associated with each overlapping triggering event in a combined oldest to latest time sequence.

11. The method of claim **10** wherein detecting overlapping triggering events comprises detecting a new triggering event while long term recording for an earlier triggering event is enabled, and calculating a new starting time as being equal to the current time minus the amount of time already stored as part of the pre-event recording associated with this event.

12. The method of claim **11** further comprising analyzing each image stored in the temporary storage device and tagging for long-term storage any images associated with either event having a creation time occurring after the new starting time.

13. The method of claim **12** further comprising:

determining if any images in the cache that have been tagged for long-term storage have a later creation time than images that have been tagged for storage but have not yet been recorded to the long-term storage device;

setting the last image for recording in the long-term storage device to correspond to the last image with a time earlier than the new starting time; and

tagging all images stored in the temporary storage device that have a creation later than the new starting to indicate that the images have not yet been recorded to long-term storage.

14. The method of claim **9** further comprising determining an event starting time equal to a current time minus the predetermined period of pre-event time in response to detection of a triggering event, and tagging for recording in the long-term storage device any video image recorded in the temporary storage device having a creation time after the event starting time.

15. The method of claim **9** wherein recording the video images into a temporary storage device comprises storing the video images as image data in a cache memory.

16. The method of claim **9** wherein recording the temporarily stored video images into long-term storage comprises storing the video images as data in a disk data storage device.

17. The method of claim **9** further comprising capturing the received video images as digital image data.

18. The method of claim **17** further comprising compressing the digital image data before recording in the temporary storage device.

19. The method of claim **9** further comprising determining an oldest video image stored in the temporary storage device based on the creation time, and automatically overwriting the oldest video image if the temporary storage device becomes filled.

* * * * *

Appendix K

US006088635A

United States Patent [19]

Cox et al.

[11] Patent Number: 6,088,635

[45] Date of Patent: Jul. 11, 2000

[54] **RAILROAD VEHICLE ACCIDENT VIDEO RECORDER**

[75] Inventors: **Todd Cox**; **Chris Amet**, both of Alpharetta; **Mark McDougald**, Woodstock; **Duane A. Knight**, Alpharetta; **Cheuk Nam Yuen**, Woodstock, all of Ga.

[73] Assignee: **Roadtrac, LLC**, Roswell, Ga.

[21] Appl. No.: **09/261,937**

[22] Filed: **Mar. 3, 1999**

Related U.S. Application Data

[60] Provisional application No. 60/102,037, Sep. 28, 1998.

[51] **Int. Cl.**[7] **B61L 3/00**

[52] **U.S. Cl.** ..... **701/19**; 246/115; 246/167 R; 246/185; 340/438; 340/937; 701/35; 701/213

[58] **Field of Search** ..... 701/19, 29, 35, 701/70, 213; 340/937, 988, 989, 425.5, 436, 438; 307/9.1; 246/167 R, 114 R, 115, 114 A, 117, 122 R, 123, 185

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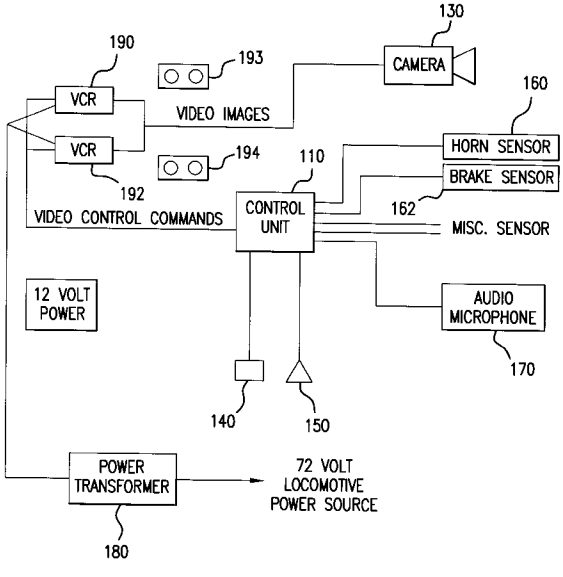
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Primary Examiner—William A. Cuchlinski, Jr.
Assistant Examiner—Edward Pipala
Attorney, Agent, or Firm—Needle & Rosenberg, P.C.

[57] **ABSTRACT**

A method and monitoring unit for recording the status of a railroad vehicle prior to a potential accident. In a monitoring unit mounted in or on a railroad vehicle, such as a locomotive, a video camera is provided to continuously view a scene that the railroad vehicle approaches. The monitoring unit continuously monitors the status of an emergency brake of the railroad vehicle and the status of a horn of the railroad vehicle. Video signals from the video camera are continuously stored. A control unit in the monitoring unit detects the application of both the emergency brake and blast of the horn within a predetermined time window. Video signals from the video camera are captured for a predetermined period of time after detecting that the application of the emergency brake and horn blast within the predetermined time window.

20 Claims, 5 Drawing Sheets



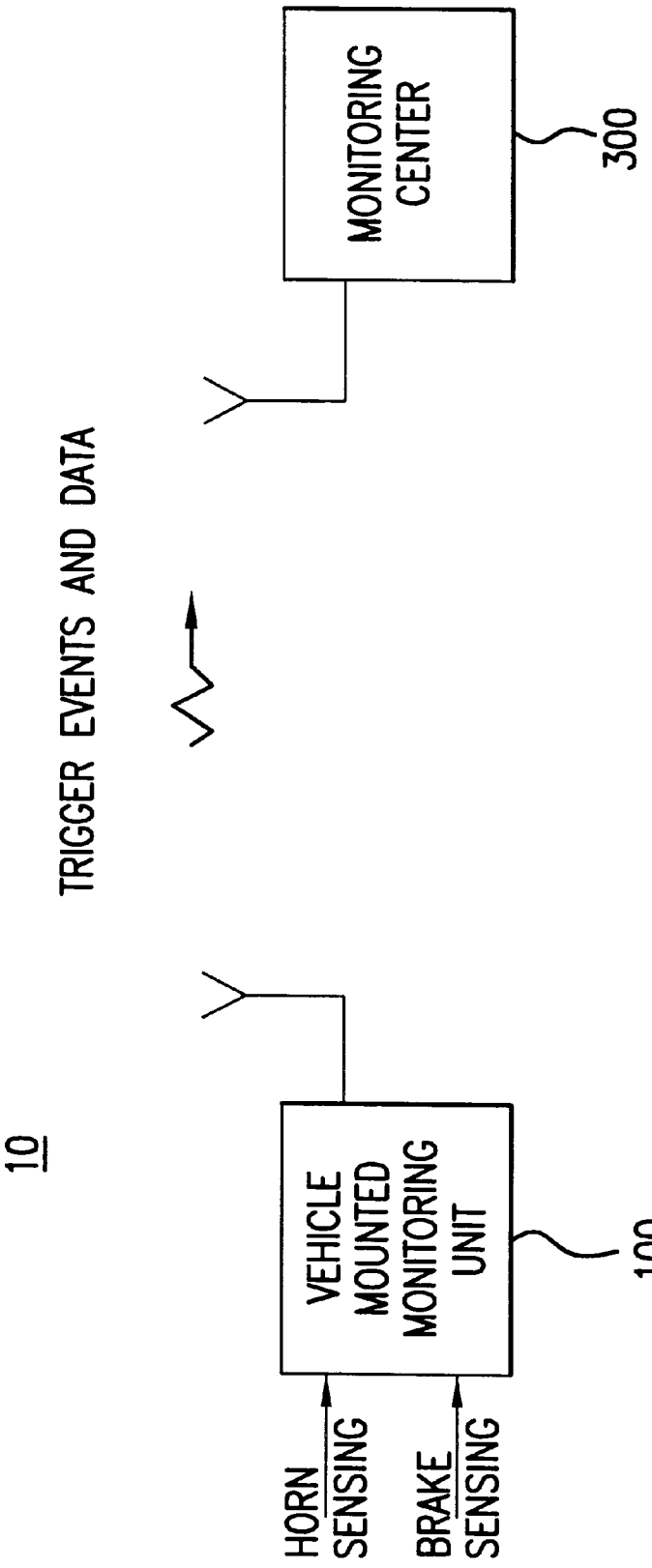

MONITORING CENTER
300
TRIGGER EVENTS AND DATA
10
VEHICLE MOUNTED MONITORING UNIT
100
HORN SENSING
BRAKE SENSING

FIG. 1

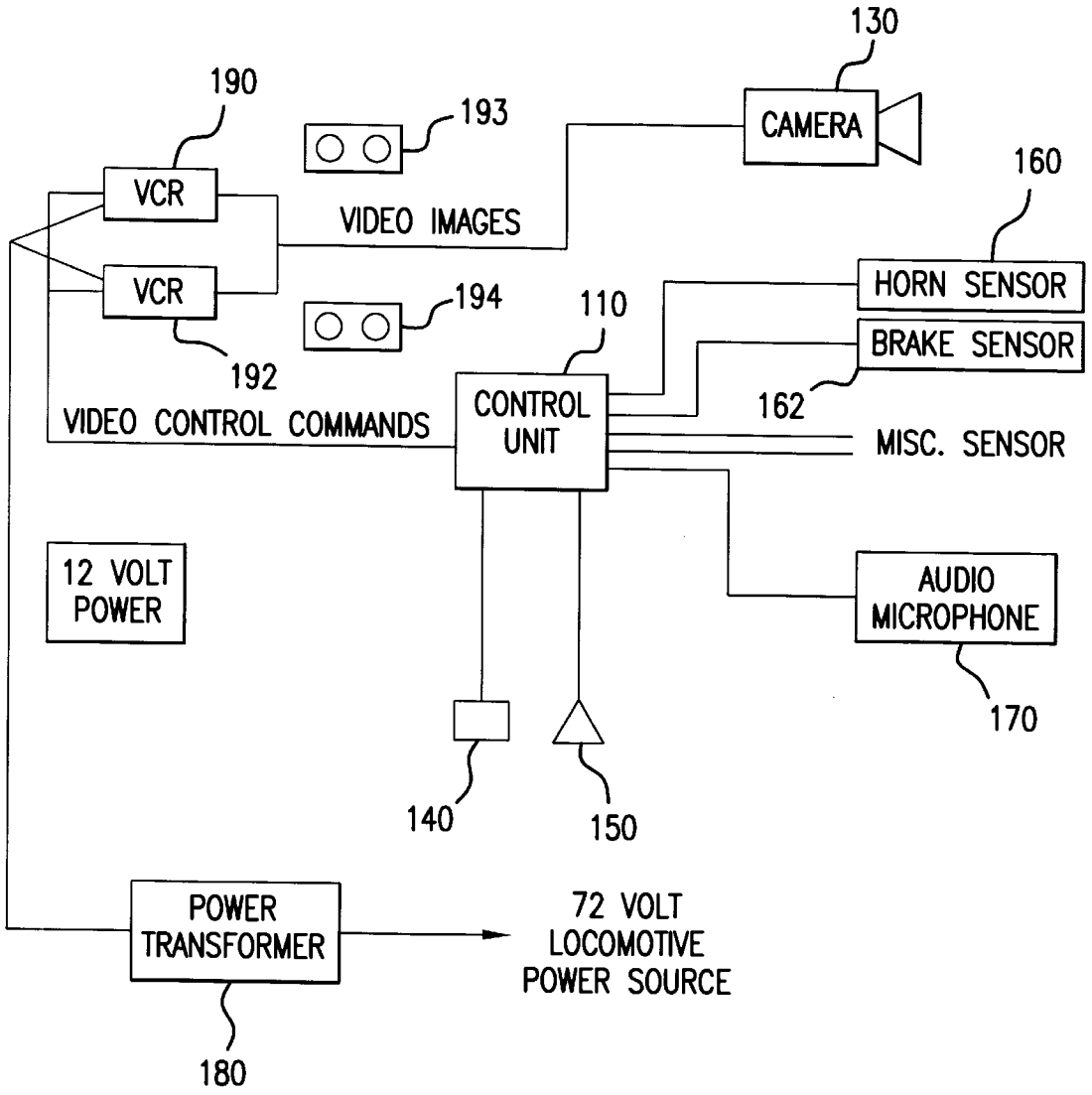

130
CAMERA
190
193
VCR
VIDEO IMAGES
160
HORN SENSOR
VCR
194
110
BRAKE SENSOR
192
VIDEO CONTROL COMMANDS
CONTROL UNIT
162
MISC. SENSOR
12 VOLT POWER
AUDIO MICROPHONE
170
140
150
POWER TRANSFORMER
72 VOLT LOCOMOTIVE POWER SOURCE
180

FIG.2

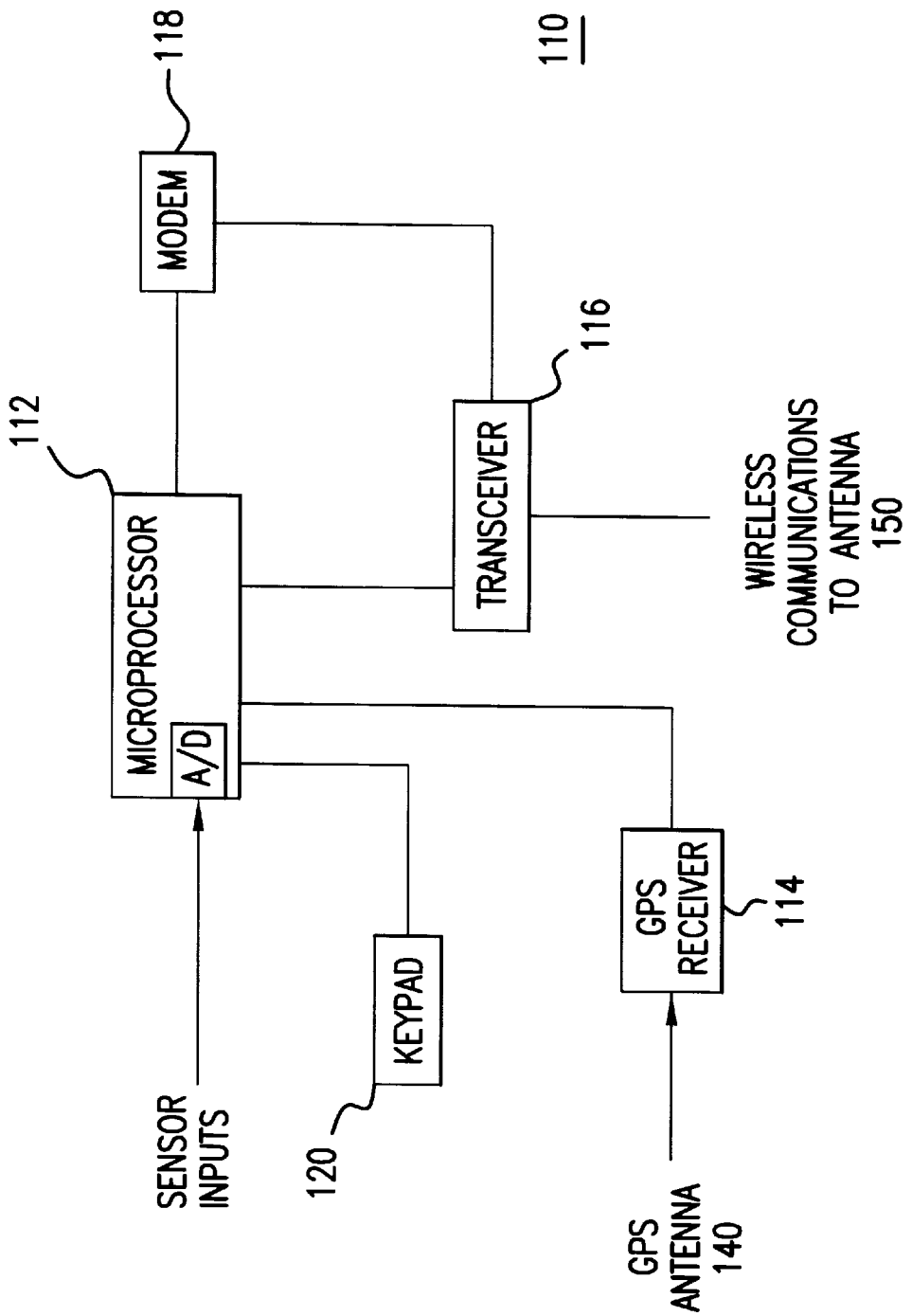

110
118
MODEM
112
MICROPROCESSOR
A/D
116
TRANSCEIVER
WIRELESS COMMUNICATIONS TO ANTENNA 150
SENSOR INPUTS
120
KEYPAD
GPS RECEIVER
114
GPS ANTENNA 140

FIG.3

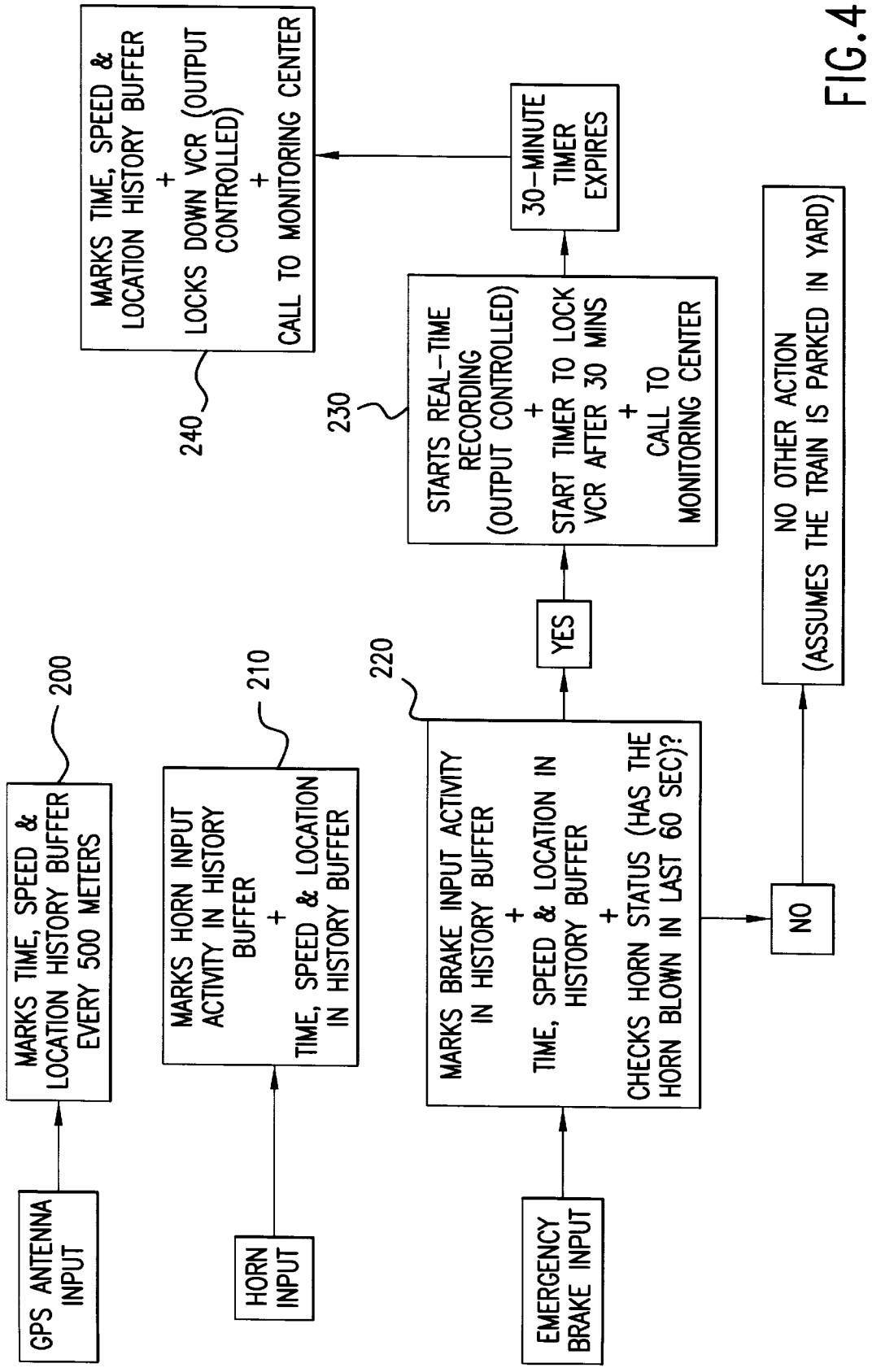

GPS ANTENNA INPUT
MARKS TIME, SPEED & LOCATION HISTORY BUFFER EVERY 500 METERS
200
HORN INPUT
MARKS HORN INPUT ACTIVITY IN HISTORY BUFFER + TIME, SPEED & LOCATION IN HISTORY BUFFER
210
EMERGENCY BRAKE INPUT
MARKS BRAKE INPUT ACTIVITY IN HISTORY BUFFER + TIME, SPEED & LOCATION IN HISTORY BUFFER + CHECKS HORN STATUS (HAS THE HORN BLOWN IN LAST 60 SEC)?
220
YES
NO
STARTS REAL-TIME RECORDING (OUTPUT CONTROLLED) + START TIMER TO LOCK VCR AFTER 30 MINS + CALL TO MONITORING CENTER
230
30-MINUTE TIMER EXPIRES
MARKS TIME, SPEED & LOCATION HISTORY BUFFER + LOCKS DOWN VCR (OUTPUT CONTROLLED) + CALL TO MONITORING CENTER
240
NO OTHER ACTION (ASSUMES THE TRAIN IS PARKED IN YARD)

FIG. 4

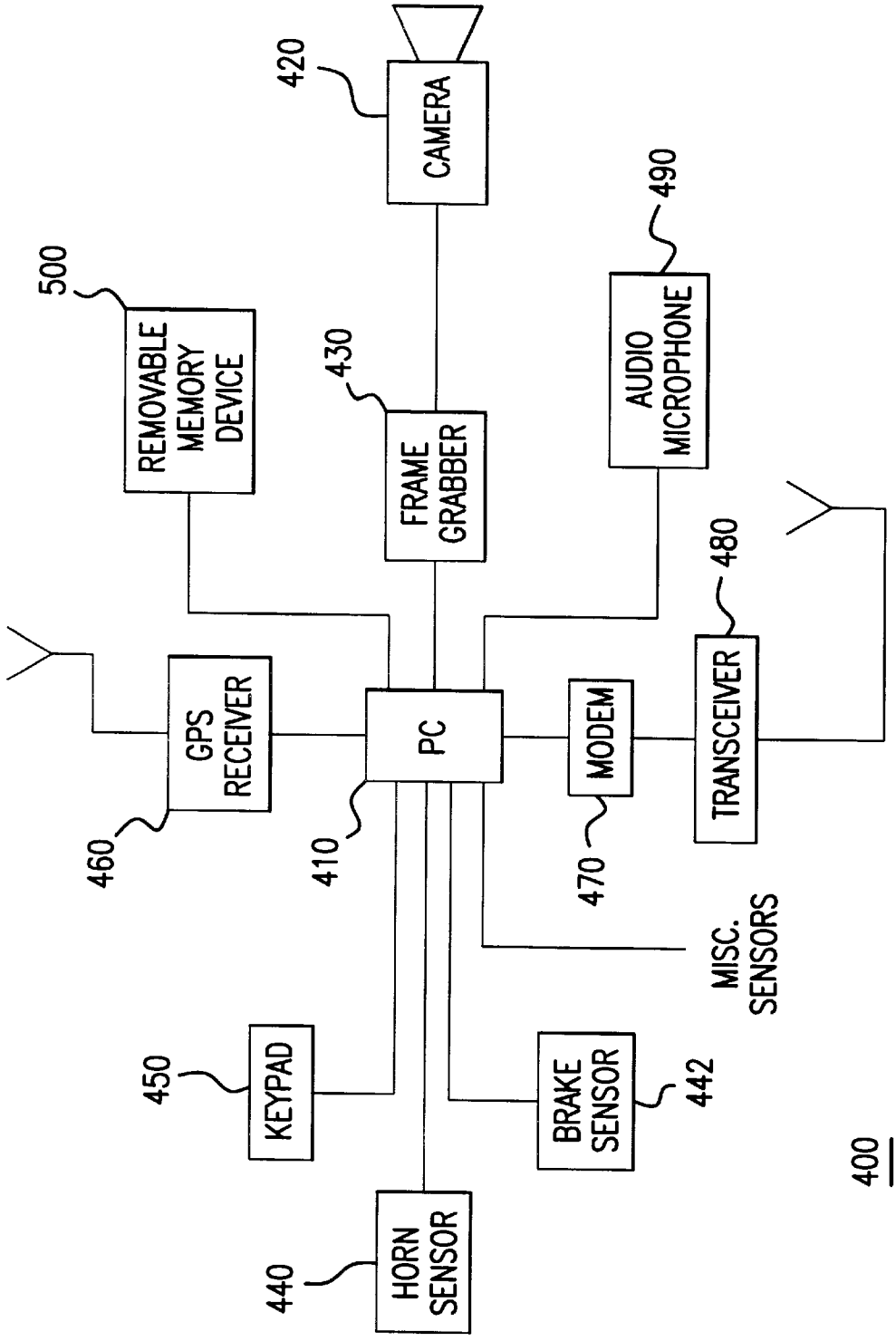

420
CAMERA
490
AUDIO MICROPHONE
500
REMOVABLE MEMORY DEVICE
430
FRAME GRABBER
480
TRANSCEIVER
GPS RECEIVER
PC
MODEM
460
410
470
MISC. SENSORS
450
KEYPAD
BRAKE SENSOR
442
440
HORN SENSOR
400

FIG.5

RAILROAD VEHICLE ACCIDENT VIDEO RECORDER

This application claims the benefit of U.S. Provisional Application No. 60/102,037 filed Sep. 28, 1998, entitled "System and Method for Capturing the Status of a Railroad Vehicle and Railroad Crossings."

BACKGROUND OF THE INVENTION

Railroad operators are responsible for activating a whistle prior to crossing each highway or road intersection. Frequently, in investigating railroad collisions, it is necessary to determine railroad vehicle speed at the time at which the emergency brake was applied and the location at which the emergency brake was applied, with respect to the railroad crossing or other obstacle in the railroad vehicle's path. Further, the investigation of a collision involving an object and a railroad vehicle at a railroad crossing requires information as to the status of the railroad crossing. That is, it is necessary to know whether the railroad crossing is unmarked, marked, signaled, or gated at the time of the accident to evaluate the means by which a motorist was (or was not) informed of an approaching railroad vehicle, and whether the motorist was prevented from crossing the tracks in front of the approaching railroad vehicle.

Currently, there is no existing technology that verifies whistle activation and records the vehicle speed, time and location of whistle activation as the railroad vehicle approaches the crossing. This information can be later recalled from an in-vehicle device via a direct connection, a removable memory card, or wireless transmission and stored in a permanent database for use in analysis. This information can concurrently be monitored and stored along with the horn activation data.

Likewise, there is currently no technology that allows for the capture and storage of the status of the railroad crossings. This information can be recalled from an in-vehicle device via a direct connection, a removable cassette, or wireless transmission and stored in a permanent database for use in an accident investigation analysis.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of the system according to the present invention.

FIG. **2** is a block diagram illustrating the railroad vehicle mounted monitoring device in accordance with one embodiment of the present invention.

FIG. **3** is a block diagram of the control unit of the monitoring device shown in FIG. **1**.

FIG. **4** is a flow chart showing the monitoring method according to the present invention.

FIG. **5** is a block diagram illustrated the railroad vehicle mounted monitoring unit according to an alternative embodiment of the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring first to FIG. **1**, the system **10** according to the present invention comprises a vehicle mounted monitoring unit **100** and a monitoring center **300**. The vehicle mounted monitoring unit **100** is designed to be mounted on a railroad vehicle and detect certain events associated with the railroad vehicle's approach and passage through a railroad crossing. To this end, the monitoring unit **100** senses application of the horn and application of the brakes on the railroad vehicle. The monitoring unit **100** continuously collects video information from a video camera positioned on the vehicle to view the approaching railroad crossing. When a condition is detected that is indicative of the railroad vehicle's approach to a railroad crossing or other important conditions, the monitoring unit **100** terminates recording of video information after a predetermined period of time has elapsed.

Turning to FIG. **2**, the monitoring unit **100** according to a first embodiment is described. The monitoring unit **100** comprises a control unit **110**, a video camera **130**, a (global positioning system) GPS antenna **140**, a wireless communications antenna **150**, a horn sensor **162**, a brake sensor **164**, an audio microphone **170**, a power transformer **180**, and at least two video recording devices (VCRs) **190** and **192** each for storing video signals on a video tape **193** and **194**, respectively.

The control unit **110** receives and processes all inputs to the monitoring unit **100** to generate appropriate output signals that are coupled to wireless antenna **150** for transmission to the monitoring center **300**. Power to the monitoring unit **100** is supplied by the power transformer **180**. The power transformer **180** connects to the power source of the railroad vehicle, such as a 72 volt locomotive power source, and steps down the voltage to a suitable level, such as 12 volts for use by the various components of the monitoring unit **100**.

The video camera **130** is mounted on the railroad vehicle so as to capture realtime video images of a railroad crossing as the railroad vehicle approaches and passes through the crossing, including the activity of other vehicles at or around the railroad crossing. If necessary, more than one video camera may be provided. It is important that the video camera capture a sufficient scope of the scene to determine whether what occurs at a railroad crossing, that is, whether the crossing is properly marked, whether a motorist breached a gated crossing, etc.

Two VCRs **190** and **192** are provided because video signals from the video camera **130** are continuously recorded. The VCRs **190** and **192** both record simultaneously, but record to video tapes of differing length. The VCRs **190** and **192** will require re-winding at different times, thereby off-setting the times they will require re-winding. When the tape in one VCR runs out it can be re-wound, and recording is still occurring on the other VCR. As a result, there will always be sufficient video tape available to continuously record video signals collected from the video camera **130**. The video signals are recorded over previously recorded information until the VCRs **190** and **192** are locked down (recording terminated), as explained hereinafter. Once the VCRs **190** and **192** are locked down, they will not continue recording until they are reset manually or electronically by the control unit **110**.

The horn sensor **160** may comprise an electrical connection to the horn switch on the railroad vehicle to detect when the horn is actuated. The brake sensor **164** may comprise an electrical connection to the brake actuator on the railroad vehicle to detect when the emergency brake has been applied.

Miscellaneous other sensors may be included. For example, a vehicle speed sensor may be provided that electrically connects to an electronic speedometer on the railroad vehicle (if one exists) to continuously supply vehicle speed information.

The control unit **110** is shown in greater detail in FIG. **3**. The control unit **110** comprises a microprocessor **112** or other similar programmable processor device, a GPS receiver **114**, a wireless communications transceiver **116**, a

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modem **118** and a keypad **120**. The microprocessor **112** may include an onboard analog-to-digital (A/D) converter that receives the analog input signals from the sensors **160**, **162** and **164**, and converts them to digital signals (if they are not already in digital format) for processing. A control program is stored in a memory device, such as a RAM or ROM associated with the microprocessor **112**. The transceiver **116** is a cellular transceiver, for example, that is suitable for establishing a wireless connection to the monitoring center **300** or other remotely located station. The modem **118** modulates the status information for transmission by wireline or wireless link to the monitoring center **300**.

The GPS receiver **114** receives and processes GPS signals detected by the GPS antenna **140** so that the exact position of the railroad vehicle can be determined at any time. The GPS receiver **114** is an optional component of the control unit **110** and is used when it is desired to capture time and location information associated with an event.

Turning to FIG. **4**, the operation of the monitoring unit **100** will be described. If the form of the monitoring unit employed includes GPS capability, The positional information of the railroad vehicle is continuously updated from the GPS receiver and stored on a periodic basis. This is shown in step **200**. For example, the GPS location information is sampled every 500 meters. The control unit **110** updates the time, vehicle speed and GPS location in a first history buffer (in a working memory of the microprocessor **112**) at each sampling event. The vehicle speed is obtained either from a vehicle speed sensor or derived from consecutive samples of GPS location information.

In step **210**, the railroad vehicle horn input is sensed via the horn sensor **160**, and if a horn is detected, the control unit **110** registers it appropriately in a second history buffer and also marks the first history buffer so that the horn occurrence can be associated with the time, speed and location of the railroad vehicle.

In step **220**, the status of the emergency brake is sensed via the brake sensor **162**. If it is determined that the emergency brake is applied, the control unit **110** marks it appropriately in a third history buffer and also marks the first history buffer so that the brake occurrence can be associated with the time, speed and location of the railroad vehicle. In addition, the control unit **110** checks the status of the second history buffer to determine whether the horn was blown within a predetermined time window of the brake detection event, such as for example, 60 seconds. If the horn was blown during this predetermined time window, this is indicative that the railroad vehicle was approaching a railroad crossing (because train operators are supposed to blow the horn when approaching a crossing to alert nearby motorists) or some other obstacle potentially in the path of the railroad vehicle.

Thus, the detection of the application of the emergency brake and the detection of the blast of the railroad vehicle horn (within a predetermined period of time of the emergency brake) is indicative of a potential accident and it is flagged as a detection or alarm event. During this time, the VCRs **190** and **192** are continuously recording video of the scene. When this potential accident condition is detected, a timer in the microprocessor **112** is started and the microprocessor **112** locks down (terminates recording by) the VCRs **190** and **192** after a predetermined period of time set by the timer has elapsed (to prevent further recording of video over the critical video recorded at the time of the event). For example, the timer may last 30 minutes, after which the microprocessor **112** stops recording of the VCRs **190** and **192**. In addition, the microprocessor **112** transmits (via a cellular link, for example) an alarm message to the monitoring center **300**. When a connection is established between the monitoring center **300** and the monitoring unit **100**, the monitoring center **300** may open a connection with the audio microphone **170** in the monitoring unit **100** to listen to and record audio in the cockpit of the railroad vehicle. The alarm message to the monitoring center **300** may optionally contain GPS time and location information of the railroad vehicle at the time the event is detected.

After the expiration of the timer, in step **240**, the control unit **110** marks the time, speed and location (if this information is obtained) in the history buffer and locks down (turns off) the VCRs **190** and **192** that were recording when the detection event occurred. The control unit **110** may cause another call to be made to the monitoring station. Once the VCRs are locked down, access to the video tape in the VCRs **190** and **192** is restricted. For example, the entire monitoring device **100** may be contained in a secure "box", access to which is restricted to only certain railroad agents with a special key or code that may be entered via the keypad **120** (in which case the keypad would be externally accessible from the box). The video information captured by the VCRs **190** and **192** will reveal the activity as viewed by the video camera that prior to, during and after the event that necessitated the blowing of the horn and the application of the railroad vehicle brakes. This information can then be used to assess the true cause(s) of an accident at that time, if one should occur.

The first, second and third history buffers referred to above are memory elements internal to the control unit **110**, to which the control unit **110** writes appropriate information. Alternatively, a single history buffer of suitable size and fields may be employed for all of the monitored information.

If in step **220**, it is determined that the railroad vehicle horn was not blown within the last 60 seconds since the emergency brake was applied. If this is the case, then no further action is taken, and it is assumed that the train is not facing a potential accident situation. The VCRs **190** and **192** will continue recording.

Turning to FIG. **5**, a monitoring unit **400** according to another embodiment of the present invention is shown. The monitoring unit **400** is a fully digital version of the monitoring unit **100**. A personal computer (PC) **410** is the heart of the monitoring unit **400**. Video signals obtained by a video camera **420** are coupled to a frame grabber **430** which digitizes the video signals (segments them into frames) and outputs the digitized video to the PC **410** for storage in random access memory (RAM) in the PC **410**. Sensors, such as horn sensor **440** and brake sensor **442** are provided and are similar to those shown in the monitoring unit **100** of FIG. **1**. In addition, the monitoring unit **400** comprises a keypad **450**, optional GPS receiver **460**, modem **470**, transceiver **480**, audio microphone **490** and a removable memory device **500**. Many of these components have the same function as their counterparts shown in FIG. **1**.

The removable memory device **500** may be a hard disk drive, a portable hard disk drive (such as a Zip™ drive), a large RAM memory module, etc. The memory device **500** is a back-up storage for the status information that is collected and stored by the PC **410** of the monitoring unit **400**. In particular, the time, location, speed, horn status, brake status, video information and other sensor information of the railroad vehicle may be stored on the memory device **500**. The memory device **500** may be "removable" from the monitoring unit **400**. For example, the hard disk drive, portable hard

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disk drive or RAM memory module is of the type that can be readily removed from a port or slot associated with the PC **410**.

The operation of the monitoring unit **400** is similar to the monitoring unit **100** with a few exceptions. The video information obtained by the camera **420** is digitized and continuously stored in RAM of the PC **410**. A certain portion of the PC's RAM will be allocated to continuous video storage and information will be continuously stored (and written over previously stored video information). The PC **410** will detect activity from the horn and brake sensor **440** and **442** and lock down (terminate) the storage of incoming video information after a predetermined period of time set by a timer in the PC **410**. This is similar to the VCR lock down operation described above, except that the PC can do this digitally in order to capture video information for a predetermined period of time associated with a railroad crossing (potential accident) event. Consequently, the RAM of the PC **410** will contain the video information of the scene for a period of time before, during and after the activity which necessitated the blowing of the horn and application of the railroad vehicle brakes. When an event is detected, the PC **410** stores GPS location (if GPS capability is provided in the monitoring unit **400**) and other information and transmits this information via the transceiver **480** the monitoring center. As explained above, the monitoring center may open an audio link to the audio microphone **490** to listen to sounds in the railroad vehicle cockpit. In the digital version of the monitoring unit shown in FIG. **5**, it may not be necessary to terminate the recording of the video information if sufficient memory is available on the PC **410** so as not to be considered with overwriting important video information.

The foregoing description illustrates an example of the operation of the system and method according to the present invention. It should be understood that other operations and features may be included. For example, audible sounds within the train operator's cockpit may be monitored on a continuous basis to record any statements made by the operator that may be useful in determining the cause of an accident. Moreover, video images taken by the camera **130** may be continuously stored and overwritten on the video tape in predetermined time increments. Alternatively, the video images may be digitally captured and digitally stored in a suitable video memory device, and overwritten in predetermined time increments. In the event a sudden change in acceleration is detected by the collision sensor (assuming that the emergency brake was never timely applied), the VCRs **190** and **192** are locked down as described above (to retain the last predetermined amount of video prior to the event) or the video memory is no longer overwritten to likewise save a predetermined amount of video prior to the event.

In summary, the present invention is directed to a system and method for recording the status of a railroad vehicle and the railroad crossing as a railroad vehicle approaches a crossing. The time, location and speed of the railroad vehicle is continuously stored. The status of the railroad vehicle is used to trigger when to stop recording information. The status of the horn and emergency brake are monitored. Detection of a horn blast coupled with (within a predetermined period of time of) the application of the emergency brake of the railroad vehicle triggers real-time storage of video images taken by a camera on the vehicle that is viewing the scene that the railroad vehicle is approaching. The recording/storage of the video images are locked down at the expiration of a predetermined period of time in order to prevent unauthorized access to the information, thereby preserving it for later review during an accident investigation, if one is necessary. In addition, the vehicle time, location, speed horn status, brake status, and other sensor status information are stored on a memory device that can be retrieved or accessed. The data on the memory device provides a comprehensive history of the time, speed and location as sensor events to enable determination as to whether the railroad vehicle was properly operated in response to certain conditions. That is, in can be determined whether a horn was properly and timely blown and/or whether an emergency brake was properly and timely applied before an accident or potential accident occurred. Alternatively, the video and/or other vehicle status information recorded by the monitoring device **100** may be transmitted to a remote monitoring center by way or a wireline or wireless link.

The above description is intended by way of example only and is not intended to limit the present invention in any way except as set forth in the following claims.

What is claimed is:

1. A method for visually recording a potential accident of a railroad vehicle, comprising steps of:

(a) continuously monitoring the status of an emergency brake of the railroad vehicle;

(b) continuously monitoring the status of a horn of the railroad vehicle;

(c) continuously viewing with a video camera the scene that the railroad vehicle approaches;

(d) continuously storing video information from the video camera;

(e) detecting at least, the application of both the emergency brake and blast of the horn within a predetermined time window; and

(f) capturing video information from the video camera for a predetermined period of time after detecting that, at least, the application of the emergency brake and horn blast occurred within the predetermined time window.

2. The method of claim **1**, and further comprising the step of storing the time and location of the railroad vehicle when detection in step (e) is made.

3. The method of claim **2**, and further comprising the step of wirelessly transmitting to a monitoring center the time and location of the railroad vehicle associated with the detection made in step (e).

4. The method of claim **2**, wherein the step of continuously monitoring the time and location of the railroad vehicle comprises continuously receiving global positioning satellite (GPS) signals and generating time and location information therefrom.

5. The method of claim **1**, wherein the step of continuously storing video information from the video camera comprises recording video signals from the video camera simultaneously on first and second video tapes.

6. The method of claim **5**, and further comprising the steps of rewinding the first video tape once its end is reached while recording video signals on the second video tape, and rewinding the second video tape once its end is reached while recording video signals on the first video tape.

7. The method of claim **1**, wherein the step of continuously storing video information from the video camera comprises digitizing the video signals and storing them in memory of a personal computer.

8. A data recorder for use on a railroad vehicle comprising:

(a) an emergency brake sensor for detecting the application of an emergency brake on the railroad vehicle;

(b) a horn sensor for detecting the application of a horn of the railroad vehicle;

(c) a video camera suitable for mounting on the railroad vehicle to view the scene that the railroad vehicle approaches and continuously generate a video signal;

(d) a video recording device coupled to the video camera for storing the video signal output by the video camera; and

(e) a control unit coupled to, at least, the emergency brake sensor, horn sensor, and video recording device, the control unit detecting, at least, the application of the emergency brake and blast of the horn within a predetermined time window and in response thereto generating a signal to cause the video recording device to record the video signal for a predetermined period of time, and at the expiration of the predetermined period of time, terminating recording by the video recording device.

9. The data recorder of claim **8**, wherein the emergency brake sensor comprises a connection between the control unit and an emergency brake switch in the railroad vehicle, and the horn blast sensor comprises a connection between the control and a horn switch in the railroad vehicle.

10. The data recorder of claim **8**, wherein the video recording device comprises first and second VCRs each for simultaneously recording the video signal on first and second video tapes, respectively.

11. The data recorder of claim **10**, wherein the first VCR records video signals on a first video tape and the second VCR records on a second video tape, wherein the first video tape and second video tape have different lengths, and wherein the control unit controls the first VCR to rewind the first video tape once its end is reached while recording video signals on the second video tape, and controls the second VCR to rewind the second video tape once its end is reached while recording video signals on the first video tape.

12. The data recorder of claim **8**, and further comprising a global positioning system (GPS) receiver for receiving GPS signals and generating time and location information of the railroad vehicle.

13. The data recorder of claim **12**, wherein the control unit is connected to the GPS receiver and stores time and location information associated with the detection of the application of the emergency brake and horn blast within the predetermined time window.

14. The data recorder of claim **13**, and further comprising a wireless transceiver connected to the control unit, and wherein the control unit transmits an alarm message including time and location information to a monitoring center via the wireless transceiver.

15. A data recorder for use on a railroad vehicle comprising:

(a) an emergency brake sensor for detecting the application of an emergency brake on the railroad vehicle;

(b) a horn sensor for detecting the application of a horn of the railroad vehicle;

(c) a video camera suitable for mounting on the railroad vehicle to view the scene that the railroad vehicle approaches and continuously generate a video signal;

(d) a frame grabber connected to the video camera for continuously digitizing the video signal; and

(e) a control unit coupled to, at least, the emergency brake sensor, horn sensor, and frame grabber, the control unit detecting, at least, the application of the emergency brake and blast of the horn within a predetermined time window and in response thereto continuing to capture video information from the frame grabber for a predetermined period of time after the detection.

16. A method for visually recording a potential accident of a railroad vehicle, comprising steps of:

(a) monitoring the status of an emergency brake of the railroad vehicle;

(b) monitoring the status of a horn of the railroad vehicle;

(c) detecting, at least, the application of both the emergency brake and blast of the horn within a predetermined time window; and

(d) capturing video information from a video device that view a scene that the railroad vehicle approaches, the video information captured for a predetermined period of time after detecting that, at least, the application of the emergency brake and horn blast occurred within the predetermined time window.

17. The method of claim **16**, and further comprising the step of storing the time and location of the railroad vehicle when detection in step (c) is made.

18. The method of claim **17**, and further comprising the step of wirelessly transmitting to a monitoring center the time and location of the railroad vehicle associated with the detection made in step (c).

19. The method of claim **16**, wherein the step of capturing video information from the video device comprises recording video signals on a video camera.

20. The method of claim **17**, wherein the step of monitoring the time and location of the railroad vehicle comprises continuously receiving global positioning satellite (GPS) signals and generating time and location information therefrom.

* * * * *

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Appendix L

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Higgins (43) Pub. Date: Dec. 16, 2004

(54) AUTOMATED TRAFFIC VIOLATION MONITORING AND REPORTING SYSTEM WITH COMBINED VIDEO AND STILL-IMAGE DATA

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(21) Appl. No.: **10/463,880**

(22) Filed: **Jun. 12, 2003**

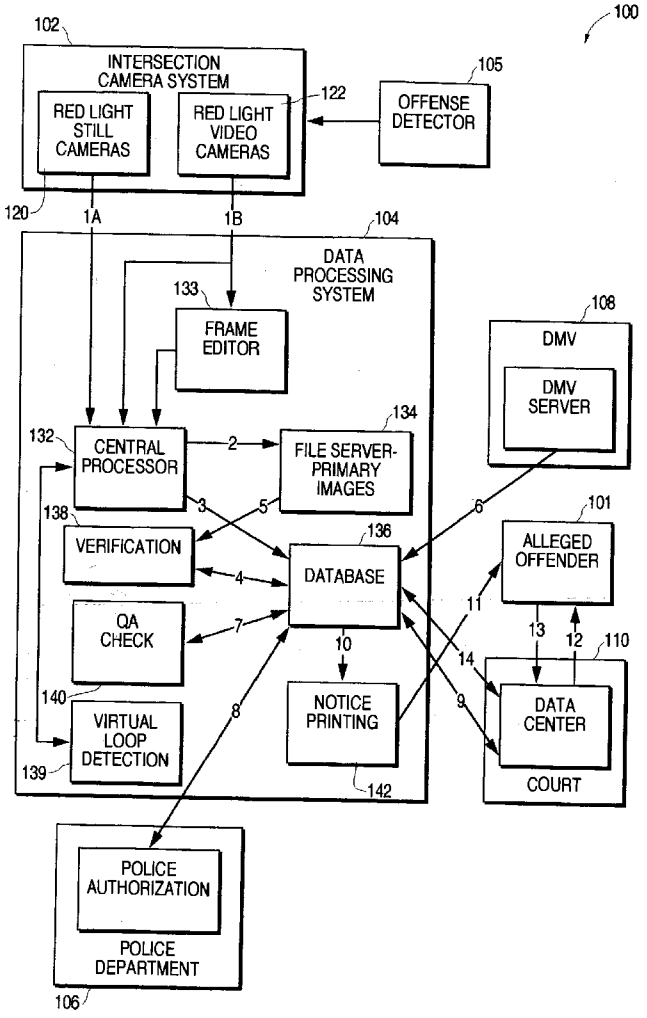
Publication Classification

(51) **Int. Cl.**[7] **H04N 7/18**

(52) **U.S. Cl.** **348/149**; 348/143

(57) **ABSTRACT**

A system for monitoring and reporting incidences of traffic violations at a traffic location is disclosed. The system comprises one or more digital still cameras and one or more digital video cameras system deployed at a traffic location. The camera system is coupled to a data processing system, which comprises an image processor for compiling vehicle and scene images produced by the digital camera system, a verification process for verifying the validity of the vehicle images, an image processing system for identifying driver information from the vehicle images, and a notification process for transmitting potential violation information to one or more law enforcement agencies. The video camera system is configured to record footage both before and after the offense is detected. The video camera system includes a non-stop video capture buffer that records the preceding few seconds of violation. The buffer holds a number of seconds of video data in memory. When an offense is detected, a timer is started. At the end of the timer period a video clip of the current buffer contents is recorded. The resulting video clip is incorporated with the conventional evidence set comprising the digital still images of the offense with the identifying data of the car and driver.



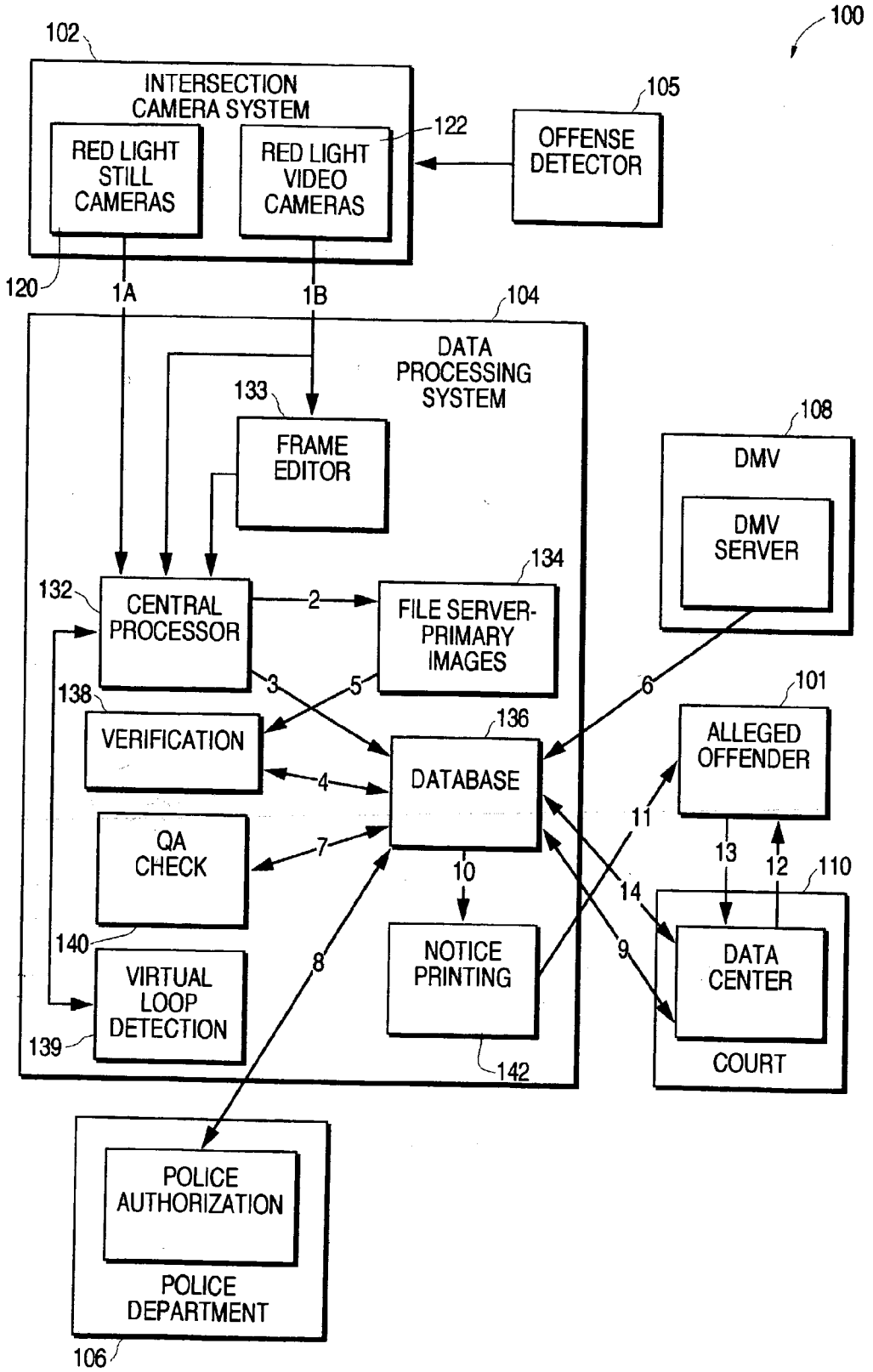
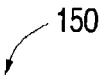

100
102
INTERSECTION CAMERA SYSTEM
RED LIGHT STILL CAMERAS
RED LIGHT VIDEO CAMERAS
122
105
OFFENSE DETECTOR
120
1A
1B
104
DATA PROCESSING SYSTEM
133
FRAME EDITOR
108
DMV
DMV SERVER
134
132
CENTRAL PROCESSOR
2
FILE SERVER-PRIMARY IMAGES
3
5
6
138
VERIFICATION
136
DATABASE
101
ALLEGED OFFENDER
4
11
QA CHECK
7
13
12
110
10
14
140
VIRTUAL LOOP DETECTION
8
NOTICE PRINTING
9
DATA CENTER
139
142
COURT
POLICE AUTHORIZATION
POLICE DEPARTMENT
106

FIG.1A



DATA PATH	INFORMATION TRANSFER
1A	4 IMAGES PER INCIDENT AND ASSOCIATED DATA SENT VIA MODEM
1B	X SECONDS OF VIDEO OF THE INCIDENT
2	PRIMARY EVIDENCE IMAGES SAVED TO FILE SERVER
3	COMPRESSED SCENE IMAGES AND INCIDENT DETAILS
4	INCIDENT DETAILS AND COMPRESSED IMAGES
5	PLATE AND FACE IMAGES
6	VEHICLE, OWNER, AND DRIVER'S LICENSE DETAILS SENT VIA MODEM
7	INCIDENT DETAILS AND COMPRESSED IMAGES
8	INCIDENT DETAILS AND COMPRESSED IMAGES SENT VIA MODEM
9	NOTICE DETAILS AND RECEIPT ACKNOWLEDGEMENT SENT VIA MODEM
10	NOTICE AND INCIDENT DETAILS
11	NOTICE TO APPEAR LETTER SENT VIA MAIL
12	PAYMENT REMINDER LETTER(S) SENT VIA MAIL
13	PAYMENT OR COURT APPEARANCE
14	NOTICE DISPOSITION INFORMATION, e.g. PAID, DISMISSED, SENT TO TRAFFIC SCHOOL, DETAILS SENT VIA MODEM

FIG.1B

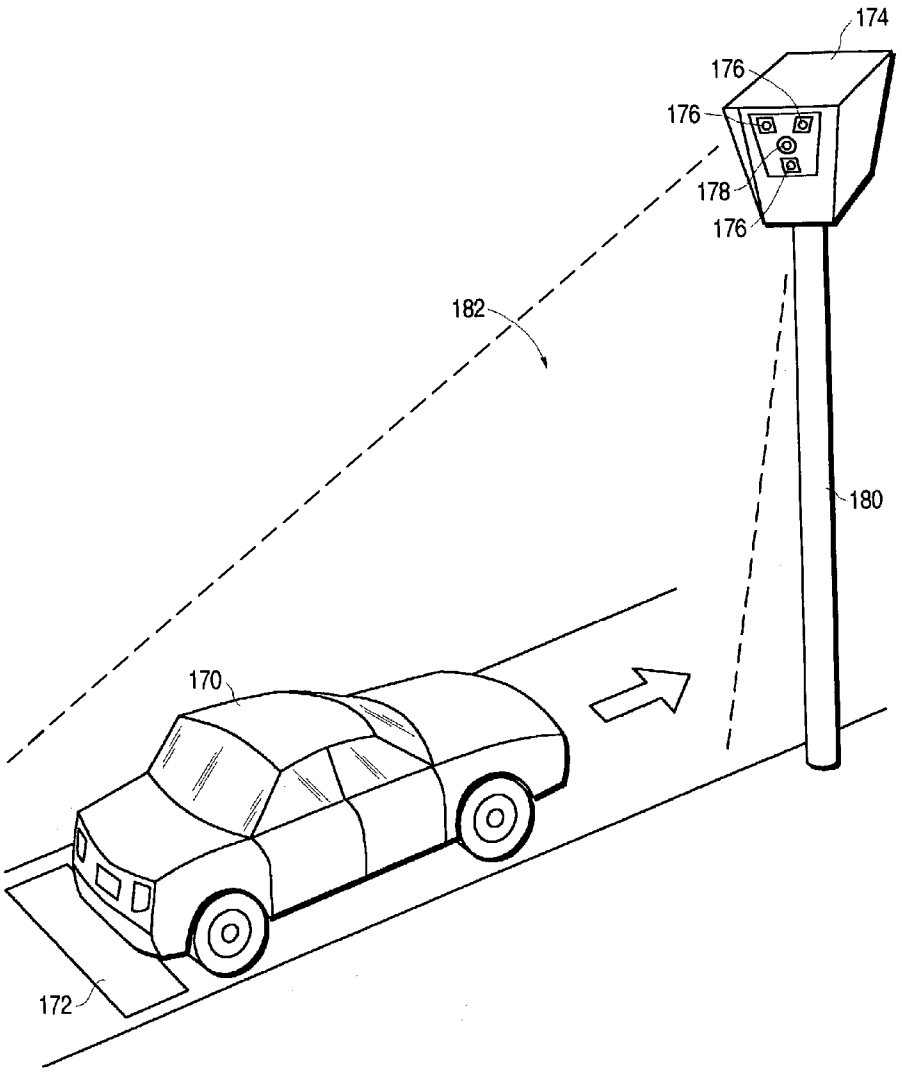


FIG.1C

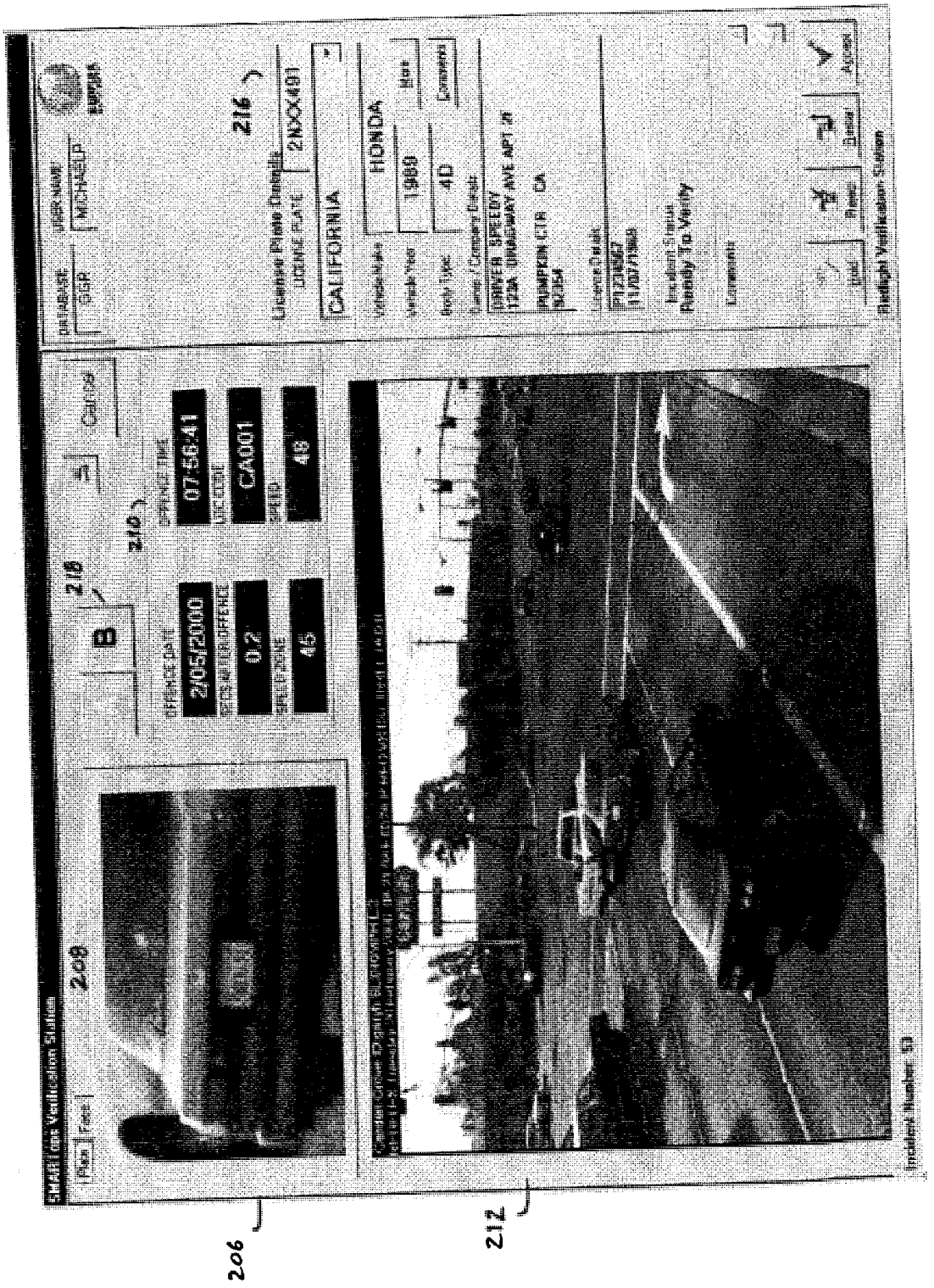

208
216
210
218
B
206
212
CA001
07:56:41
2/05/2000
02
45
48
CALIFORNIA
HONDA
1998
4D
2NXX401
DRIVER SPEEDY
123A BROADWAY AVE APT #
PUMPKIN CTR CA
Ready To Verify

FIG. 2

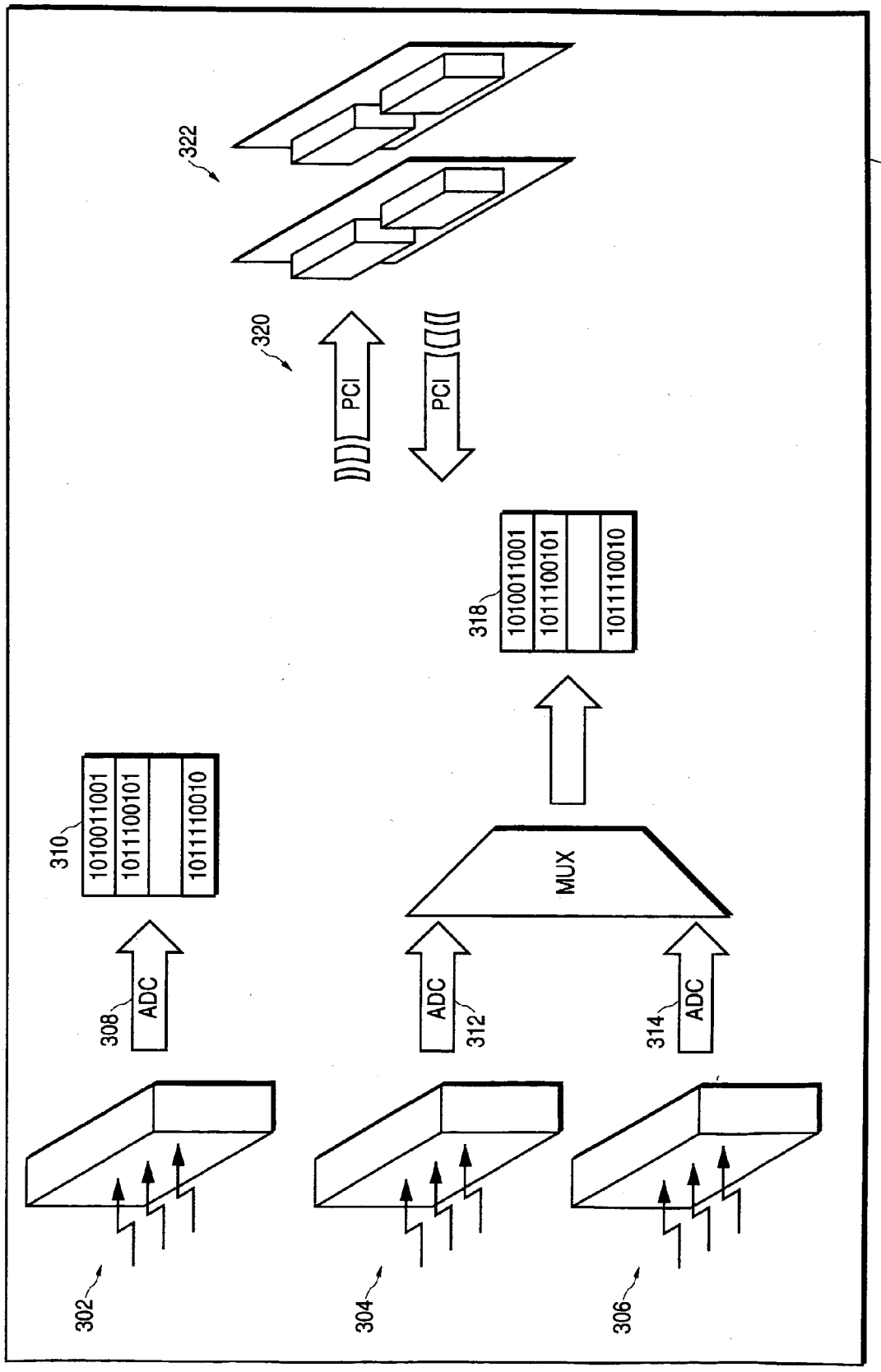

300
322
320
PCI
PCI
318
1010011001
1011100101
1011110010
MUX
310
1010011001
1011100101
1011110010
308
ADC
312
ADC
314
ADC
302
304
306

FIG.3A

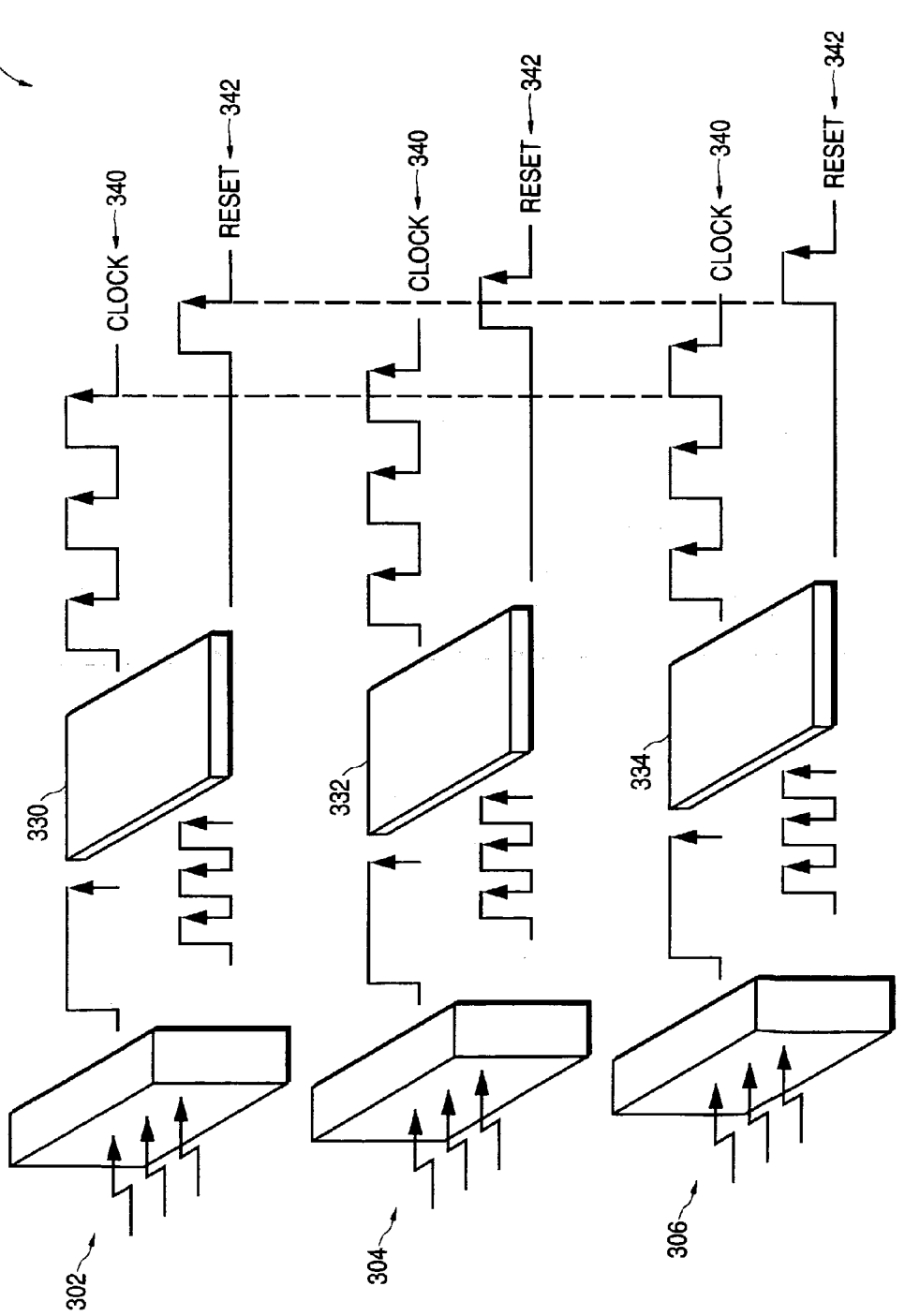

350
CLOCK
340
RESET
342
CLOCK
340
RESET
342
CLOCK
340
RESET
342
330
332
334
302
304
306

FIG.3B

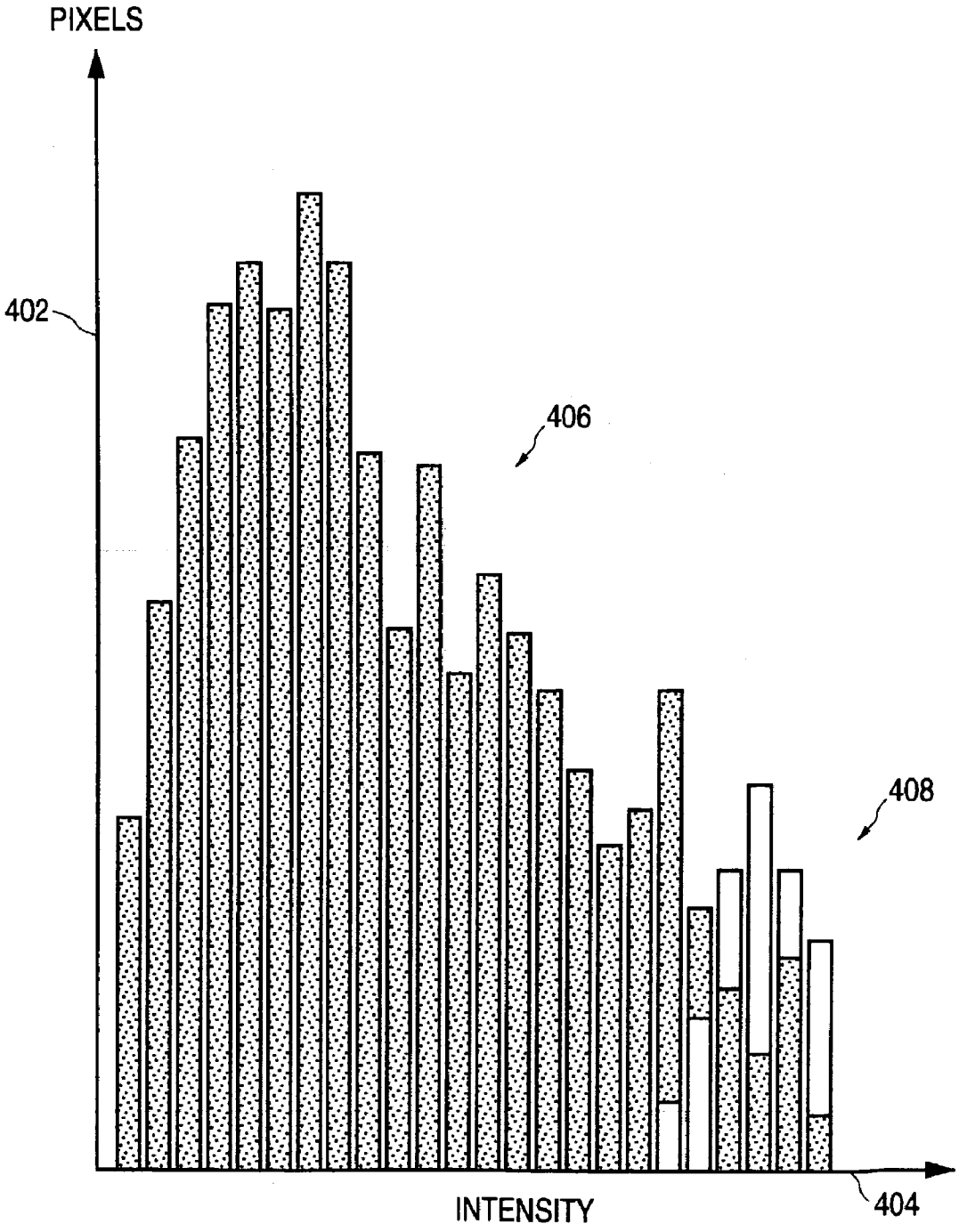


FIG.4A

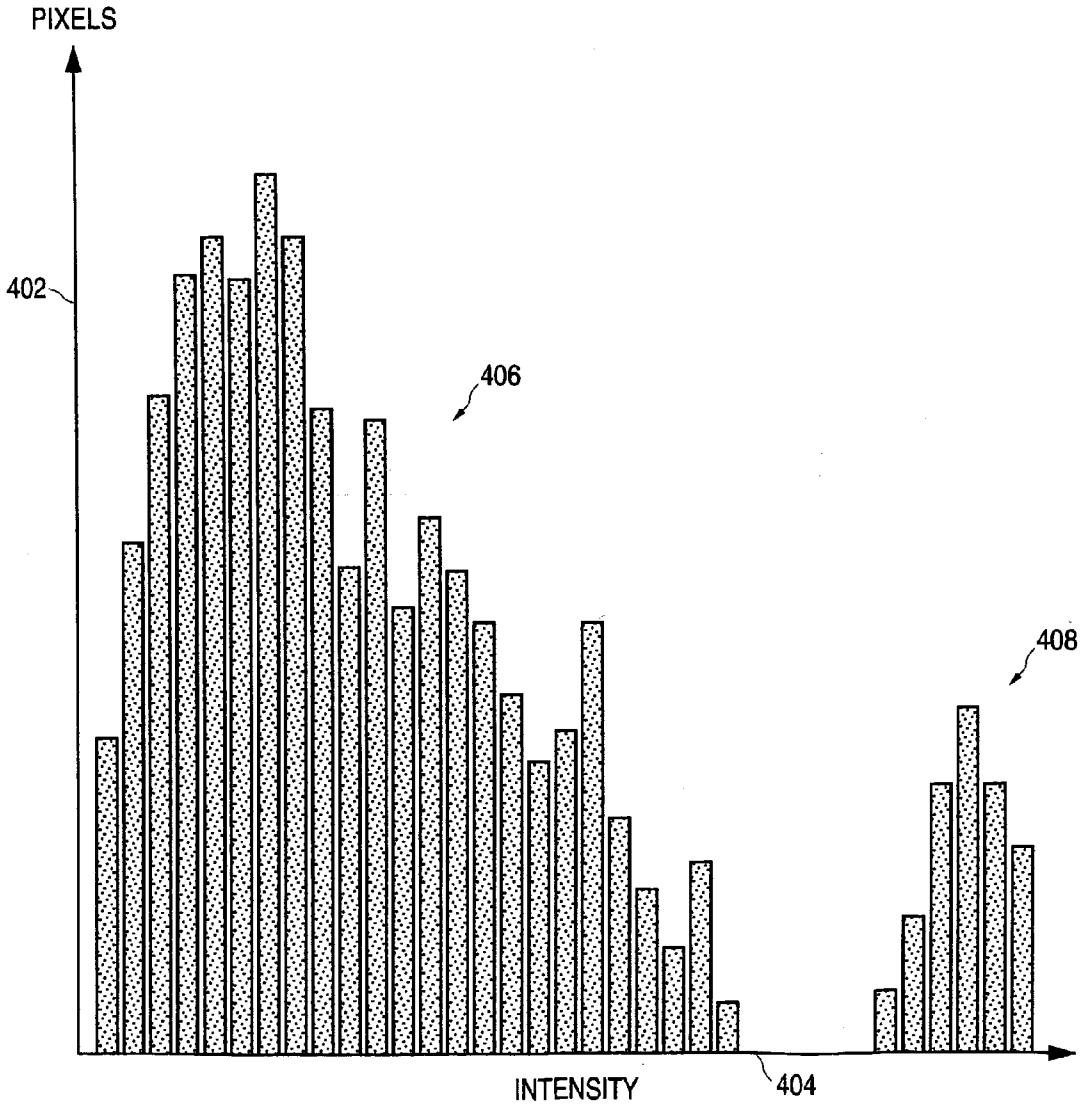


FIG.4B

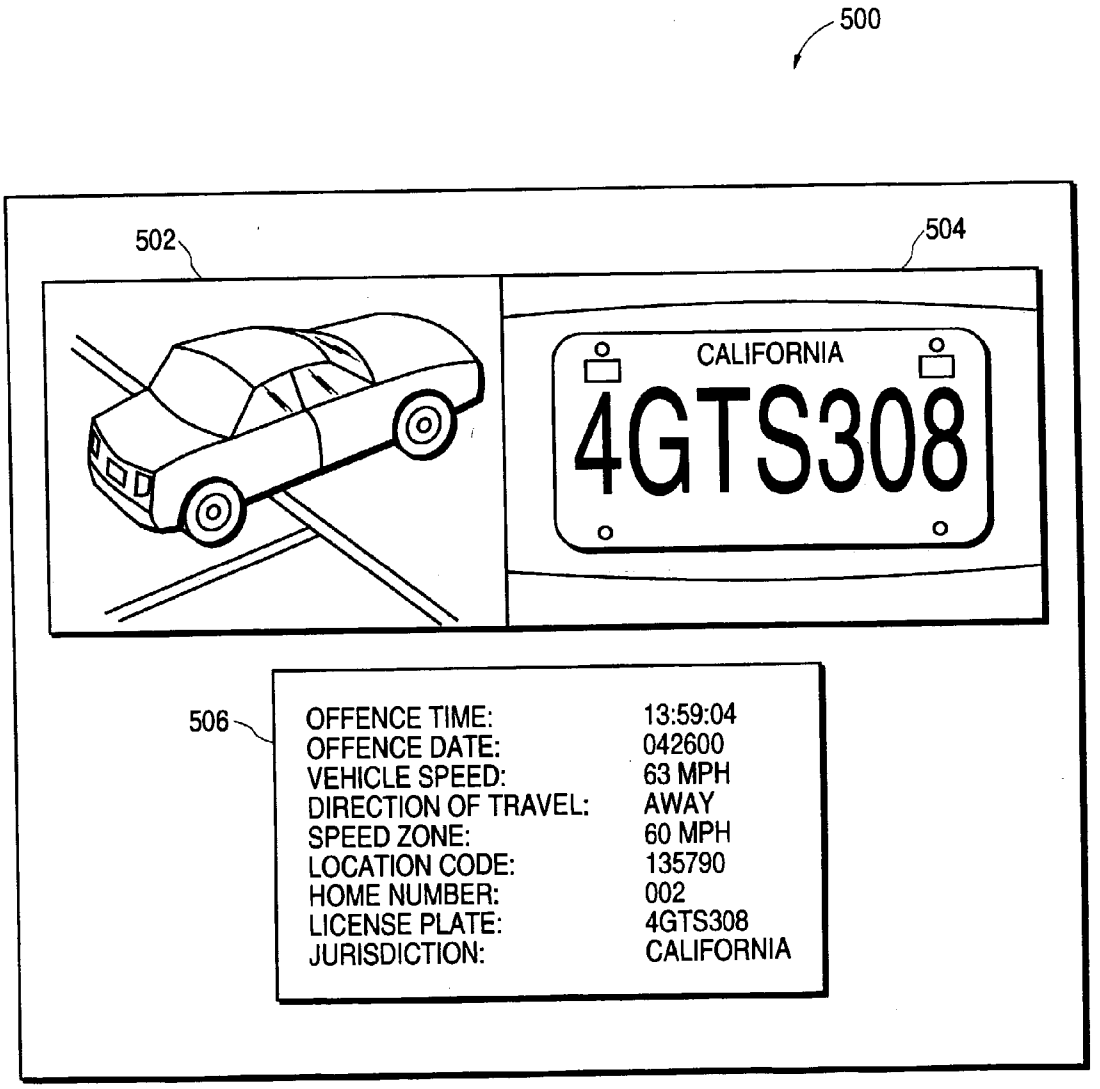

500
502
504
CALIFORNIA
4GTS308
506
OFFENCE TIME: 13:59:04
OFFENCE DATE: 042600
VEHICLE SPEED: 63 MPH
DIRECTION OF TRAVEL: AWAY
SPEED ZONE: 60 MPH
LOCATION CODE: 135790
HOME NUMBER: 002
LICENSE PLATE: 4GTS308
JURISDICTION: CALIFORNIA

FIG.5

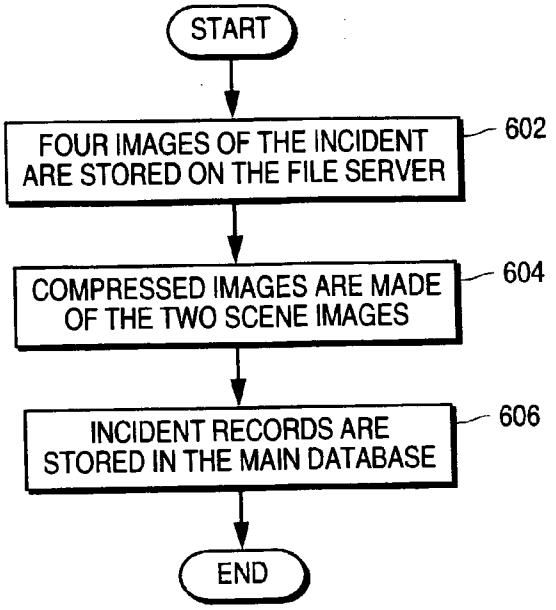

START
FOUR IMAGES OF THE INCIDENT ARE STORED ON THE FILE SERVER
602
COMPRESSED IMAGES ARE MADE OF THE TWO SCENE IMAGES
604
INCIDENT RECORDS ARE STORED IN THE MAIN DATABASE
606
END

FIG.6

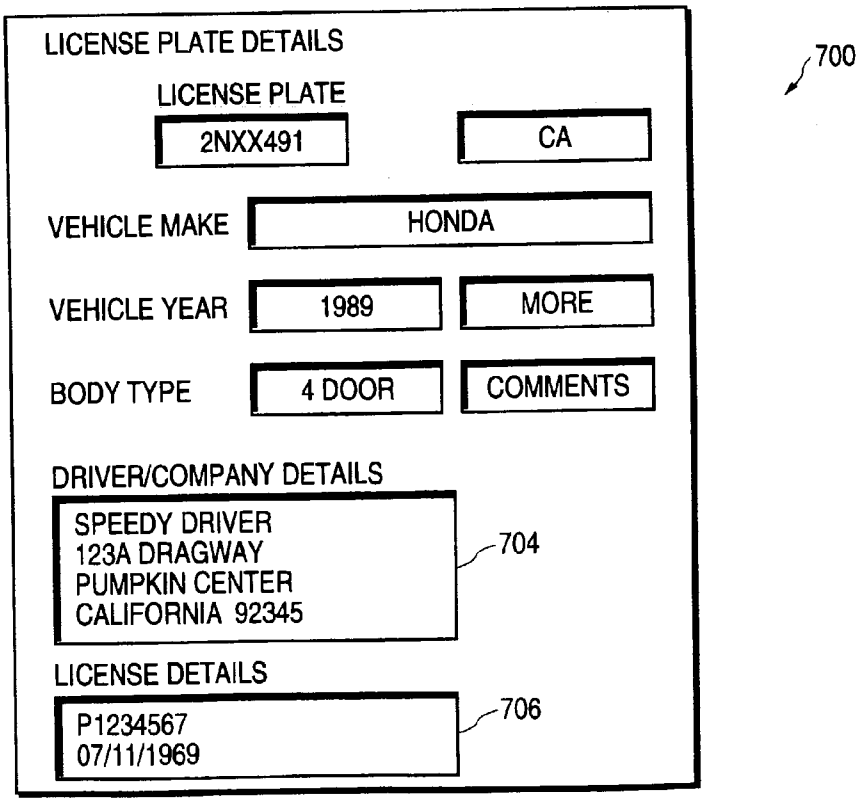

LICENSE PLATE DETAILS
LICENSE PLATE
2NXX491
CA
VEHICLE MAKE
HONDA
VEHICLE YEAR
1989
MORE
BODY TYPE
4 DOOR
COMMENTS
DRIVER/COMPANY DETAILS
SPEEDY DRIVER
123A DRAGWAY
PUMPKIN CENTER
CALIFORNIA 92345
704
LICENSE DETAILS
P1234567
07/11/1969
706
700

FIG.7

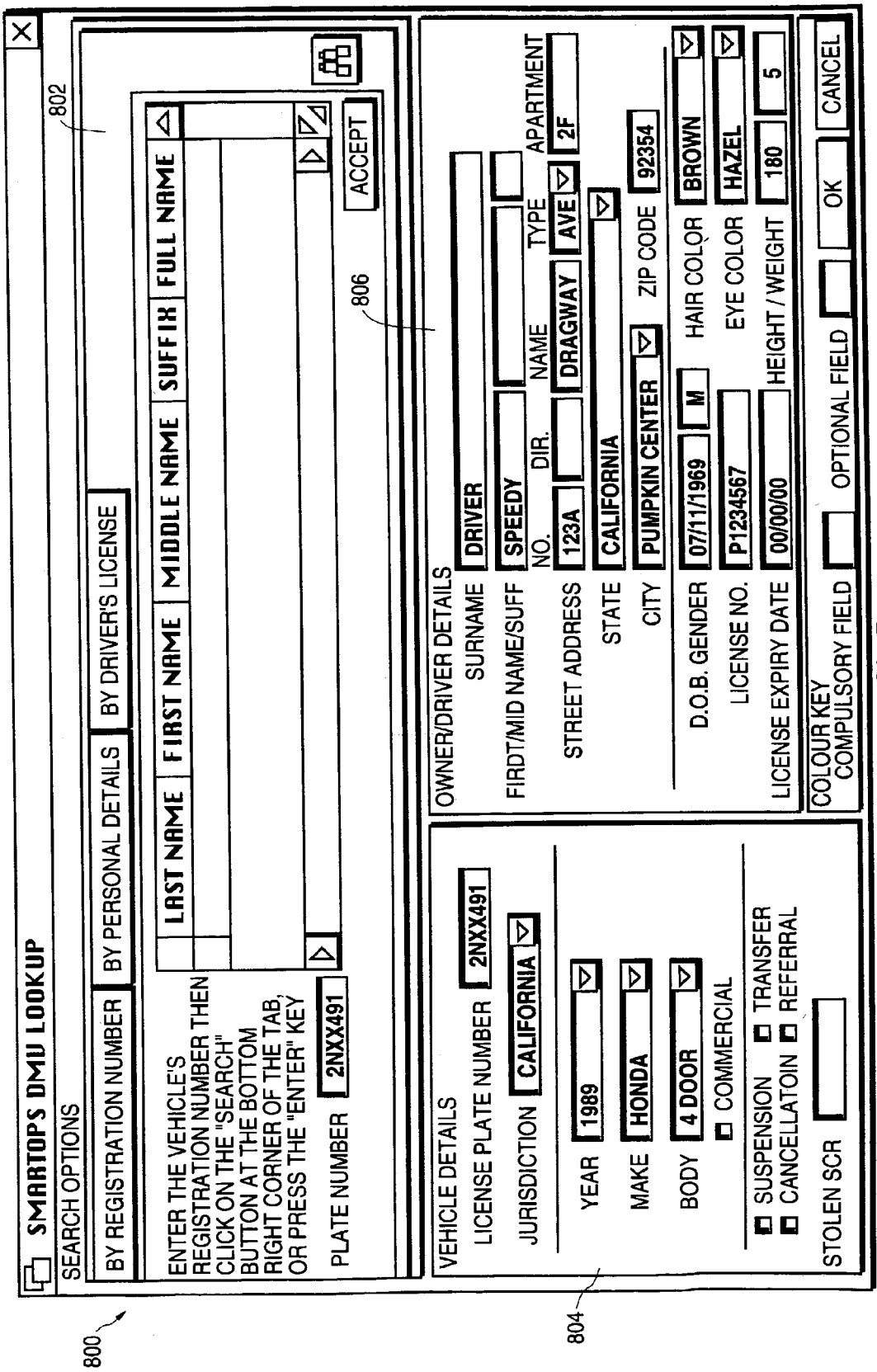

SMARTOPS DMV LOOKUP
SEARCH OPTIONS
BY REGISTRATION NUMBER
BY PERSONAL DETAILS
BY DRIVER'S LICENSE
ENTER THE VEHICLE'S REGISTRATION NUMBER THEN CLICK ON THE "SEARCH" BUTTON AT THE BOTTOM RIGHT CORNER OF THE TAB, OR PRESS THE "ENTER" KEY
PLATE NUMBER 2NXX491
LAST NAME
FIRST NAME
MIDDLE NAME
SUFFIX
FULL NAME
ACCEPT
802
806
OWNER/DRIVER DETAILS
SURNAME DRIVER
FIRDT/MID NAME/SUFF SPEEDY
NO. 123A
DIR.
NAME DRAGWAY
TYPE AVE
APARTMENT 2F
STREET ADDRESS
STATE CALIFORNIA
CITY PUMPKIN CENTER
ZIP CODE 92354
D.O.B. GENDER 07/11/1969 M
HAIR COLOR BROWN
LICENSE NO. P1234567
EYE COLOR HAZEL
LICENSE EXPIRY DATE 00/00/00
HEIGHT / WEIGHT 180 5
COLOUR KEY COMPULSORY FIELD
OPTIONAL FIELD
OK
CANCEL
VEHICLE DETAILS
LICENSE PLATE NUMBER 2NXX491
JURISDICTION CALIFORNIA
YEAR 1989
MAKE HONDA
BODY 4 DOOR
COMMERCIAL
SUSPENSION
TRANSFER
CANCELLATOIN
REFERRAL
STOLEN SCR
800
804

FIG.8

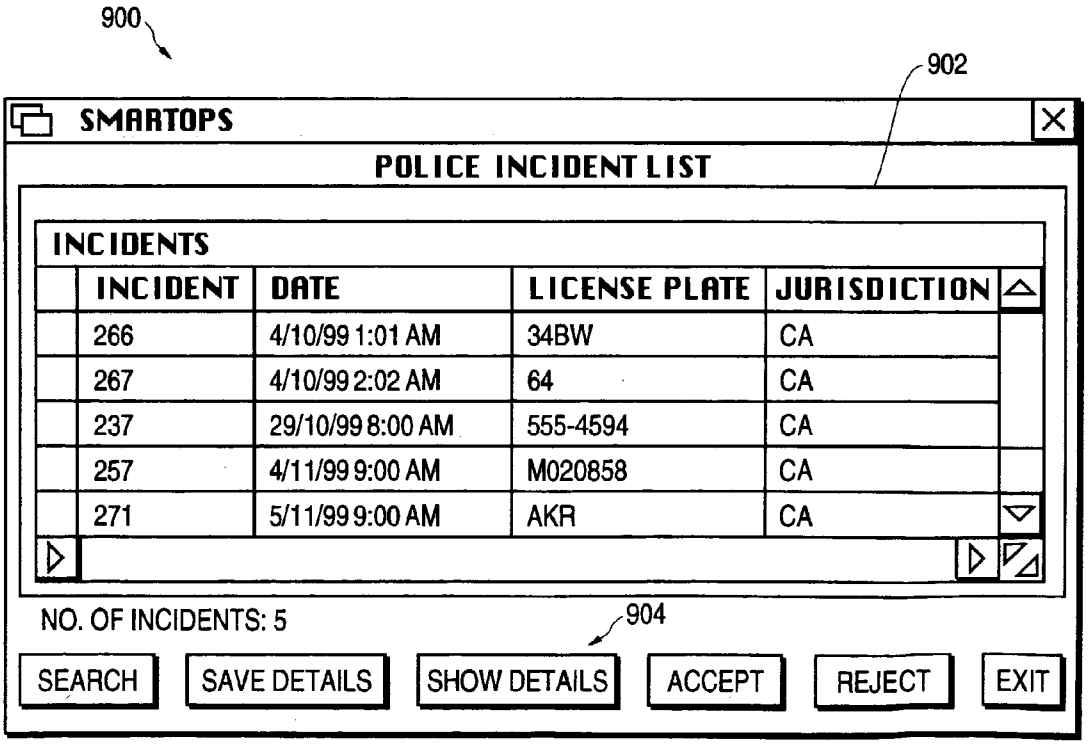

900
902
SMARTOPS
POLICE INCIDENT LIST
INCIDENTS
INCIDENT
DATE
LICENSE PLATE
JURISDICTION
266
4/10/99 1:01 AM
34BW
CA
267
4/10/99 2:02 AM
64
CA
237
29/10/99 8:00 AM
555-4594
CA
257
4/11/99 9:00 AM
M020858
CA
271
5/11/99 9:00 AM
AKR
CA
NO. OF INCIDENTS: 5
904
SEARCH
SAVE DETAILS
SHOW DETAILS
ACCEPT
REJECT
EXIT

FIG.9A

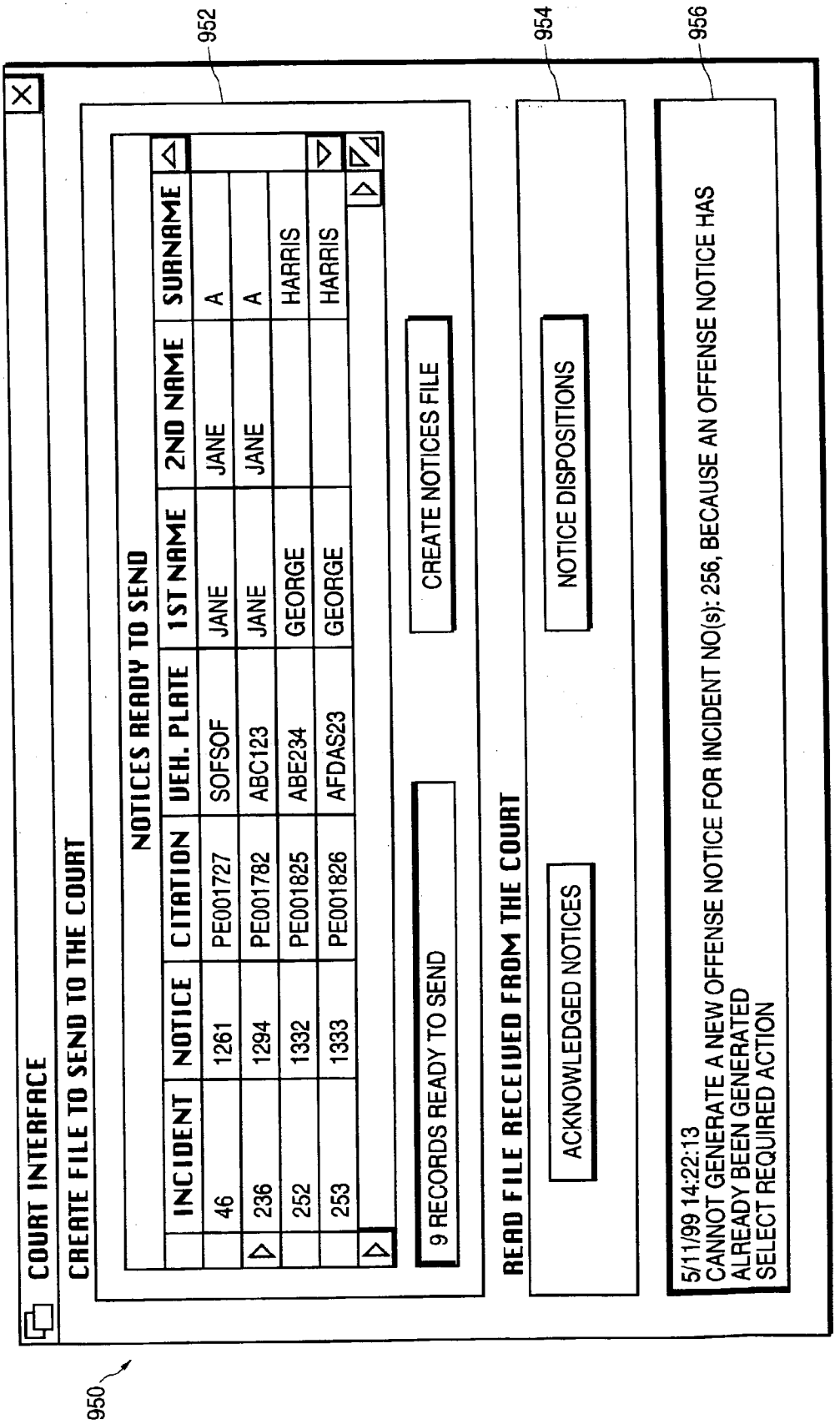

950
952
954
956
COURT INTERFACE
CREATE FILE TO SEND TO THE COURT
NOTICES READY TO SEND
INCIDENT
NOTICE
CITATION
VEH. PLATE
1ST NAME
2ND NAME
SURNAME
46
1261
PE001727
SOFSOF
JANE
JANE
A
236
1294
PE001782
ABC123
JANE
JANE
A
252
1332
PE001825
ABE234
GEORGE
HARRIS
253
1333
PE001826
AFDAS23
GEORGE
HARRIS
9 RECORDS READY TO SEND
CREATE NOTICES FILE
READ FILE RECEIVED FROM THE COURT
ACKNOWLEDGED NOTICES
NOTICE DISPOSITIONS
5/11/99 14:22:13
CANNOT GENERATE A NEW OFFENSE NOTICE FOR INCIDENT NO(s): 256, BECAUSE AN OFFENSE NOTICE HAS
ALREADY BEEN GENERATED
SELECT REQUIRED ACTION

FIG.9B

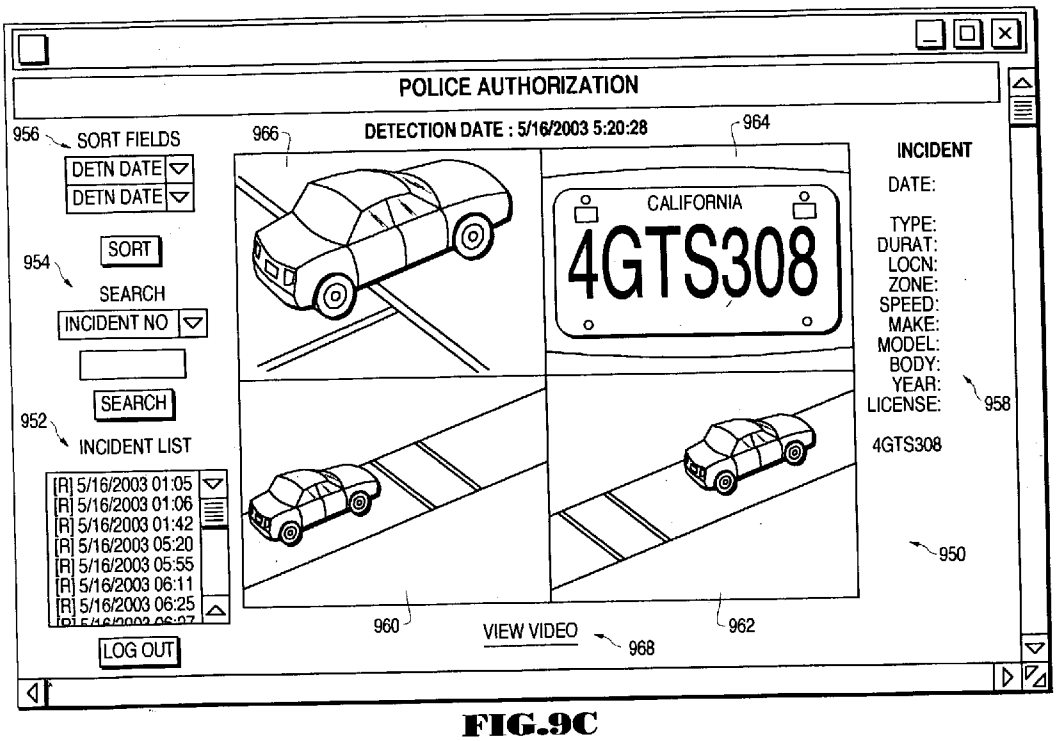

POLICE AUTHORIZATION
956
SORT FIELDS
DETN DATE
DETN DATE
SORT
954
SEARCH
INCIDENT NO
SEARCH
952
INCIDENT LIST
[R] 5/16/2003 01:05
[R] 5/16/2003 01:06
[R] 5/16/2003 01:42
[R] 5/16/2003 05:20
[R] 5/16/2003 05:55
[R] 5/16/2003 06:11
[R] 5/16/2003 06:25
LOG OUT
966
DETECTION DATE : 5/16/2003 5:20:28
964
CALIFORNIA
4GTS308
960
VIEW VIDEO
968
962
INCIDENT
DATE:
TYPE:
DURAT:
LOCN:
ZONE:
SPEED:
MAKE:
MODEL:
BODY:
YEAR:
LICENSE:
958
4GTS308
950

FIG.9C

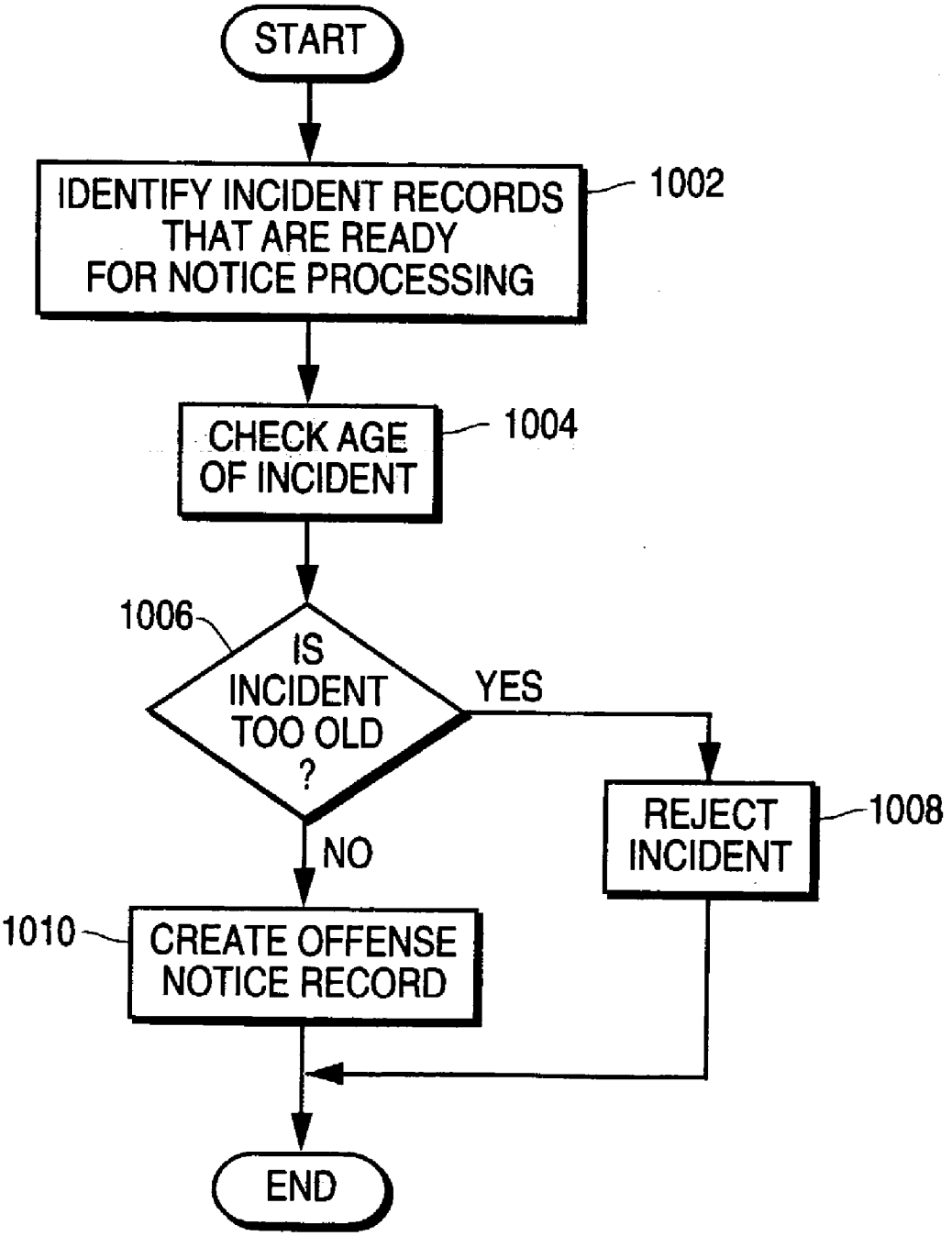

START
IDENTIFY INCIDENT RECORDS THAT ARE READY FOR NOTICE PROCESSING
1002
CHECK AGE OF INCIDENT
1004
1006
IS INCIDENT TOO OLD ?
YES
NO
REJECT INCIDENT
1008
1010
CREATE OFFENSE NOTICE RECORD
END

FIG.10

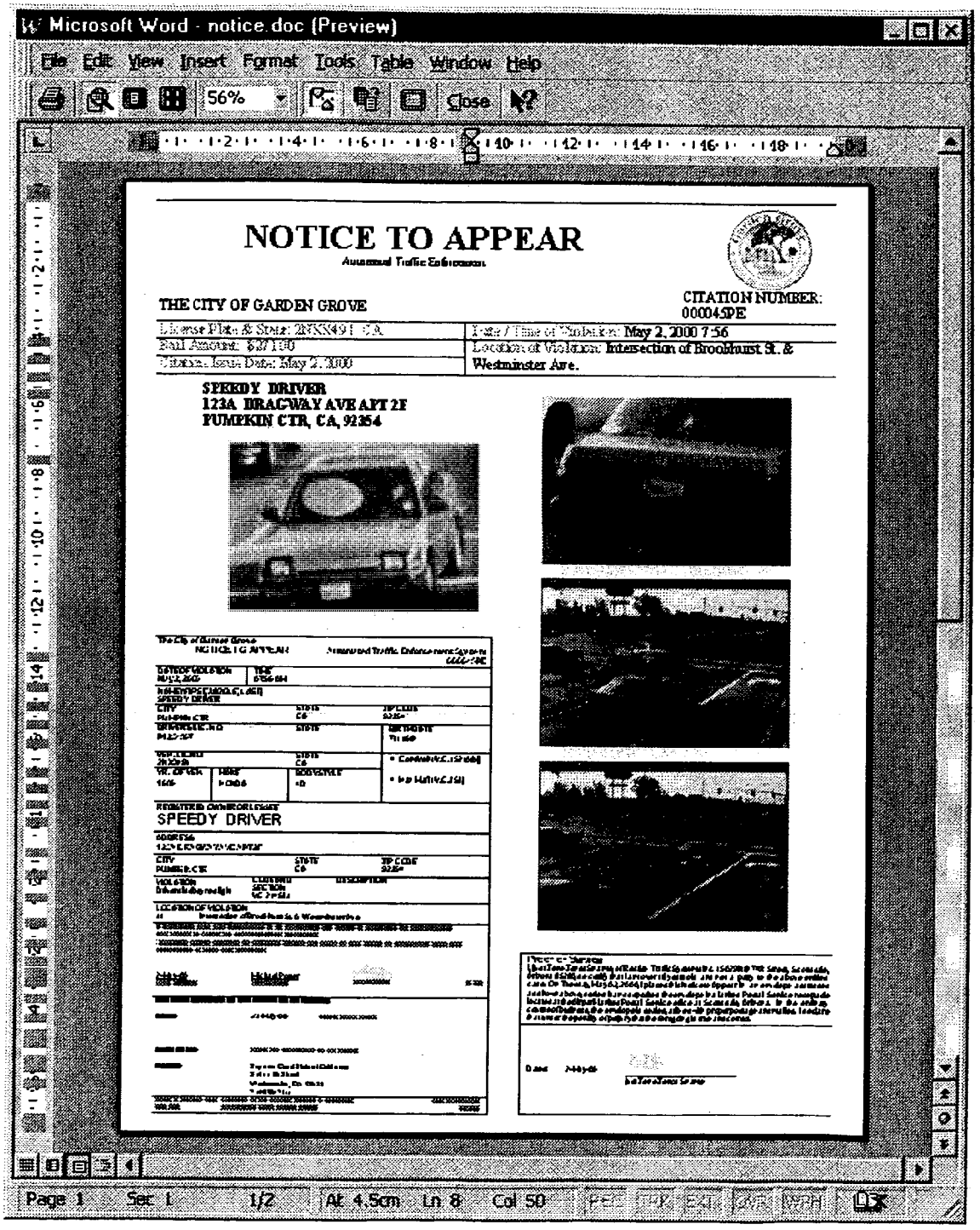

Microsoft Word - notice.doc (Preview)
File Edit View Insert Format Tools Table Window Help
56%
Close
NOTICE TO APPEAR
THE CITY OF GARDEN GROVE
CITATION NUMBER:
000045PE
Date / Time of Violation: May 2, 2000 7:56
Location of Violation: Intersection of Brookhurst St. & Westminster Ave.
SPEEDY DRIVER
123A BRACWAY AVE APT 2F
PUMPKIN CTR, CA, 92354
SPEEDY DRIVER
Page 1 Sec 1 1/2 At 4.5cm Ln 8 Col 50

FIG. 11

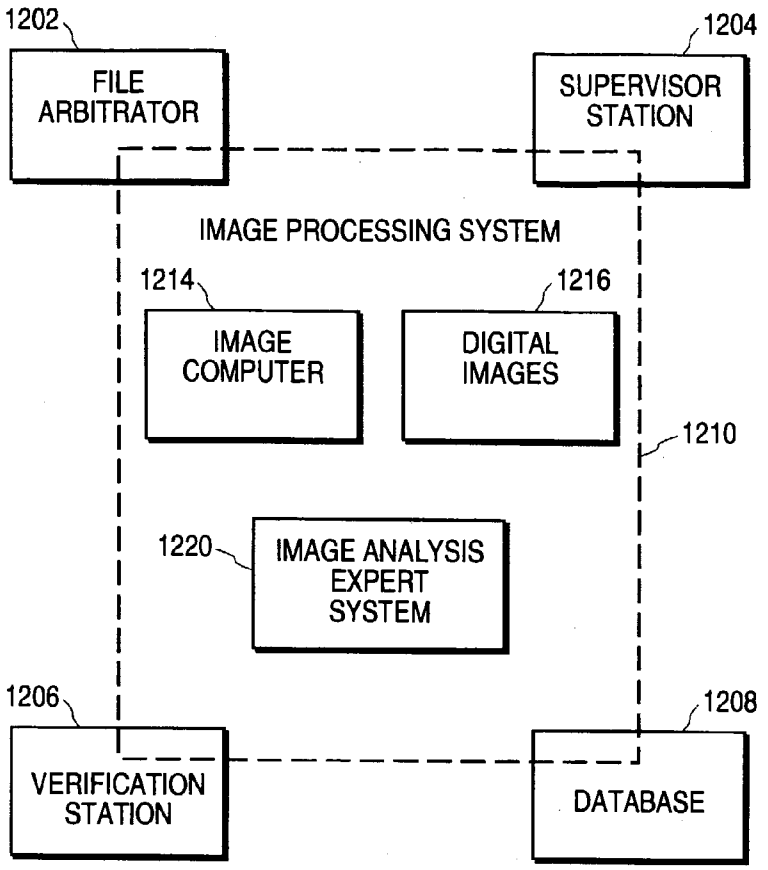

1202
FILE ARBITRATOR
1204
SUPERVISOR STATION
IMAGE PROCESSING SYSTEM
1214
IMAGE COMPUTER
1216
DIGITAL IMAGES
1210
1220
IMAGE ANALYSIS EXPERT SYSTEM
1206
VERIFICATION STATION
1208
DATABASE

FIG.12

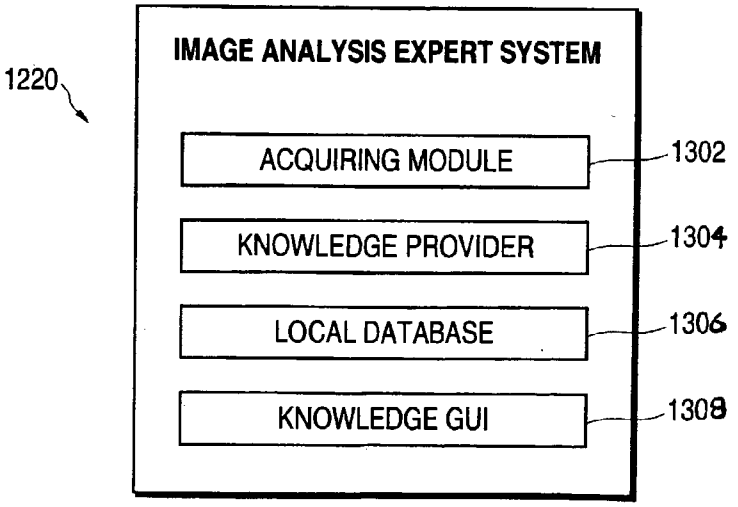

1220
IMAGE ANALYSIS EXPERT SYSTEM
ACQUIRING MODULE
1302
KNOWLEDGE PROVIDER
1304
LOCAL DATABASE
1306
KNOWLEDGE GUI
1308

FIG.13

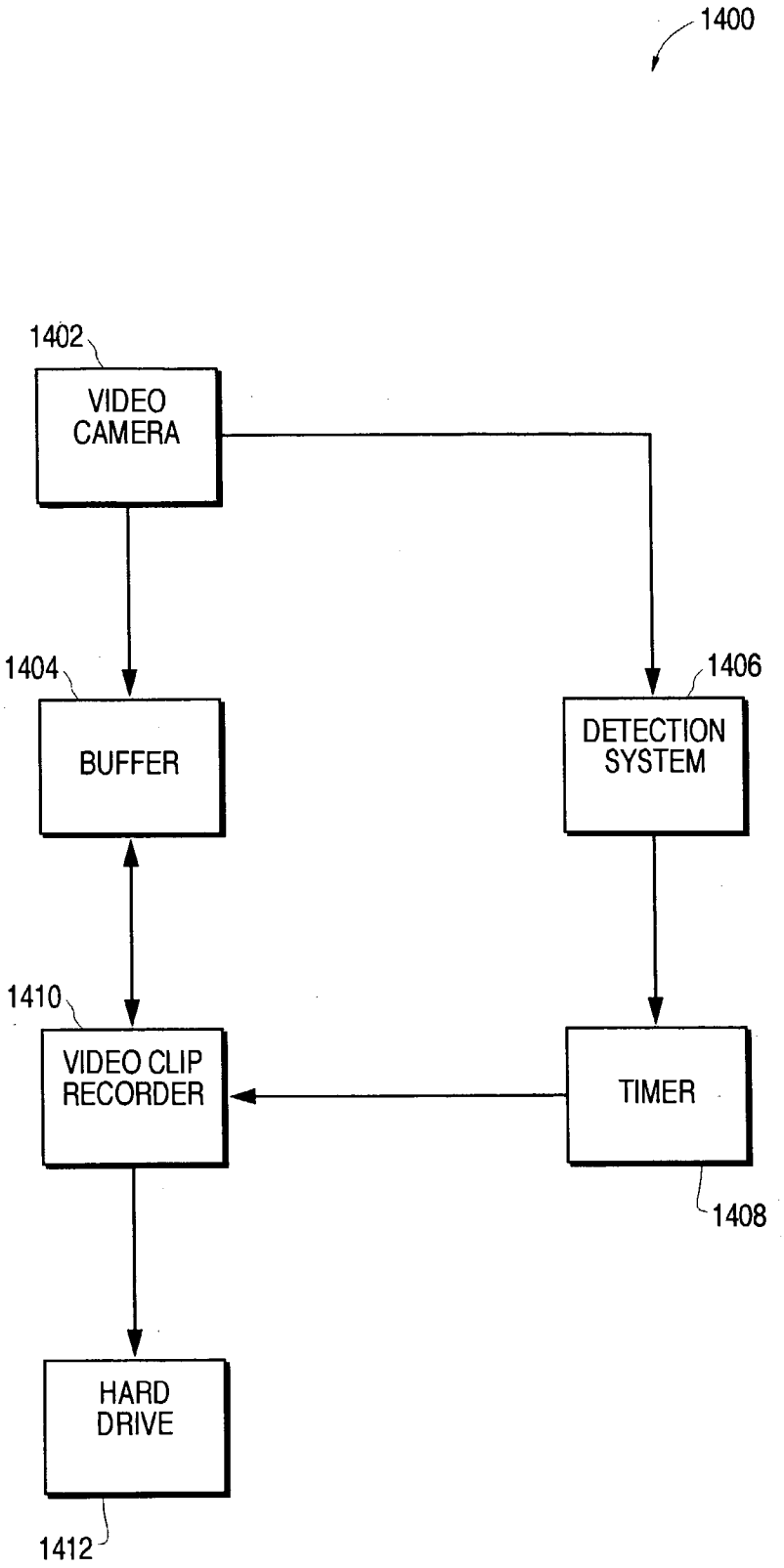

1400
1402
VIDEO CAMERA
1404
BUFFER
1406
DETECTION SYSTEM
1410
VIDEO CLIP RECORDER
TIMER
1408
HARD DRIVE
1412

FIG.14

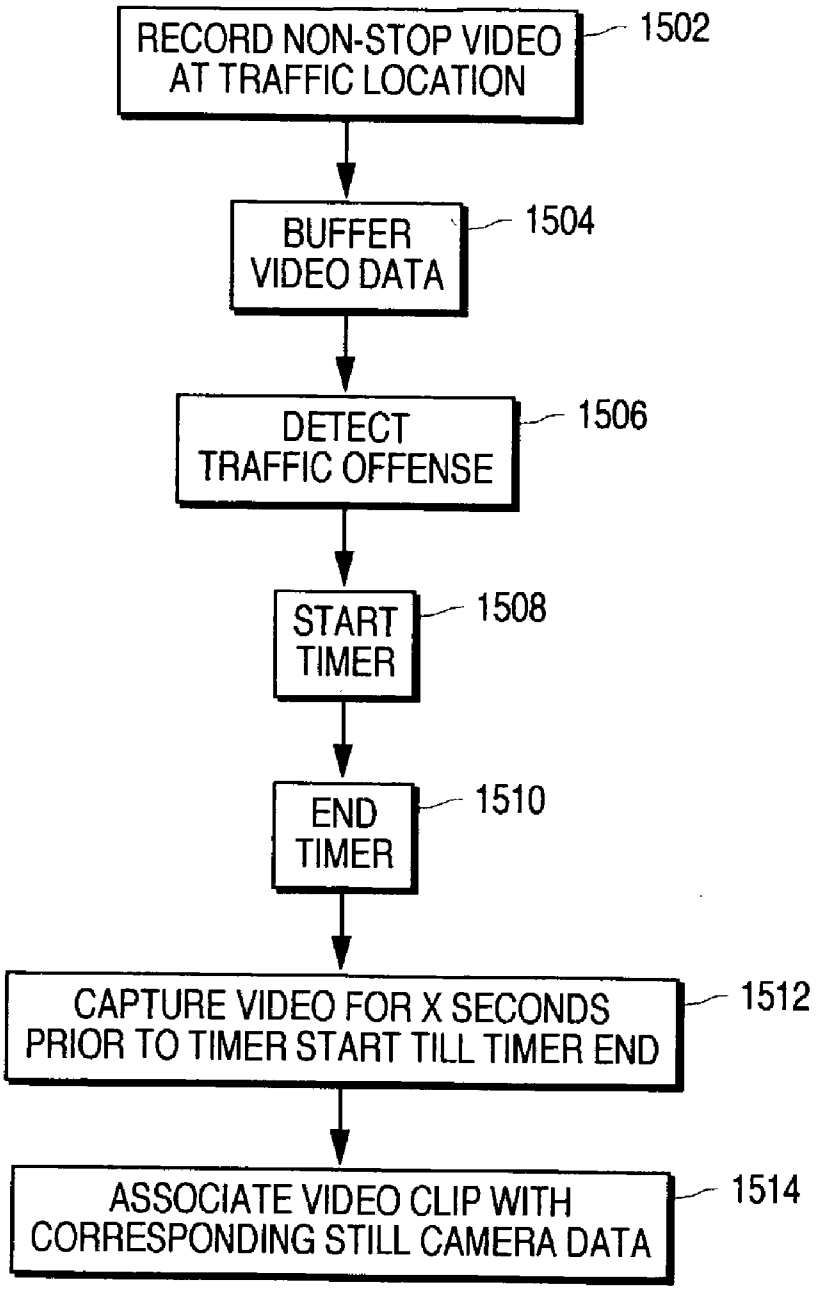

RECORD NON-STOP VIDEO AT TRAFFIC LOCATION
1502
BUFFER VIDEO DATA
1504
DETECT TRAFFIC OFFENSE
1506
START TIMER
1508
END TIMER
1510
CAPTURE VIDEO FOR X SECONDS PRIOR TO TIMER START TILL TIMER END
1512
ASSOCIATE VIDEO CLIP WITH CORRESPONDING STILL CAMERA DATA
1514

FIG.15

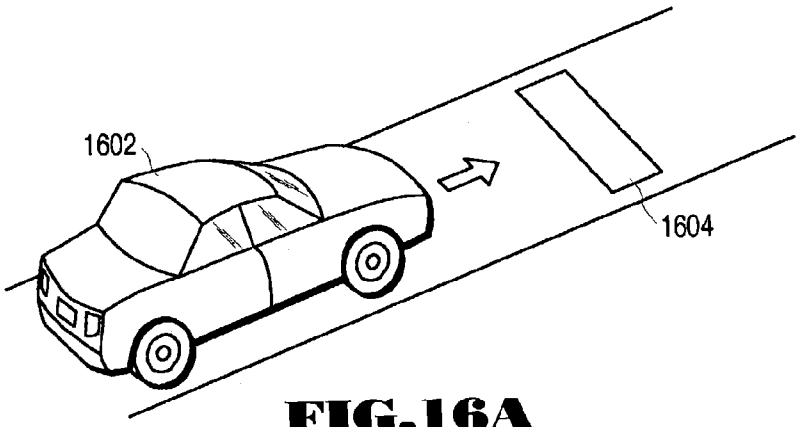


FIG.16A

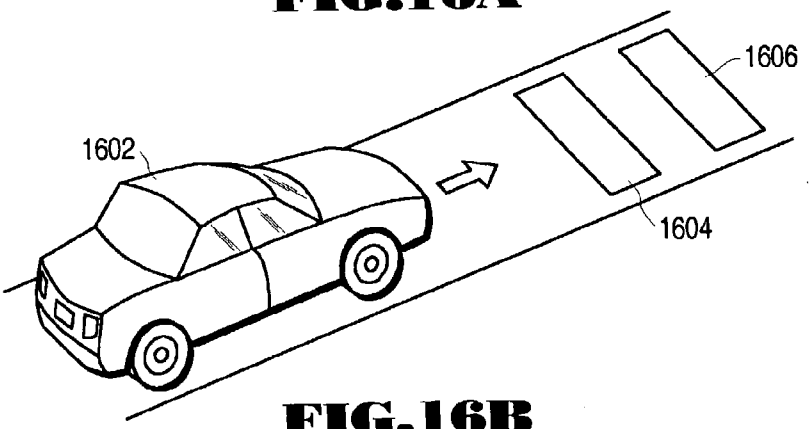


FIG.16B

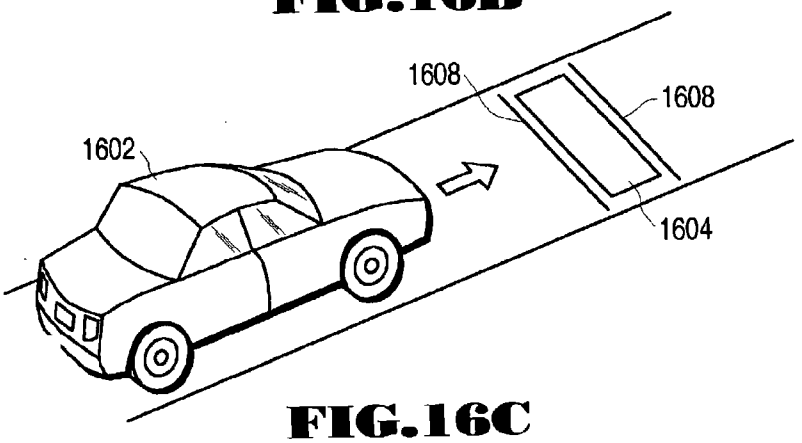


FIG.16C

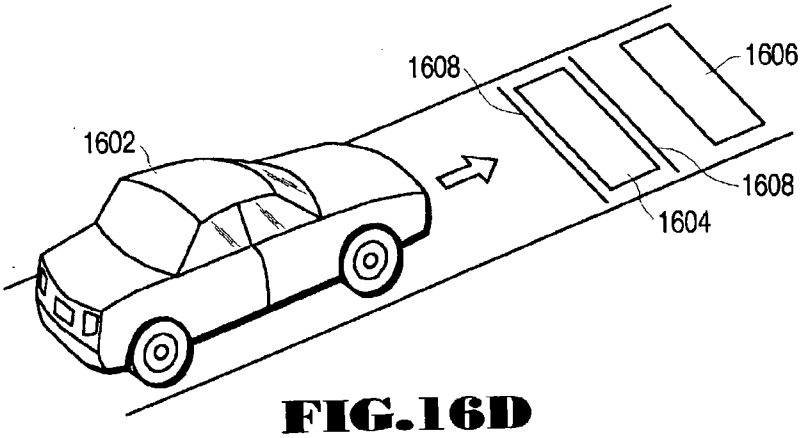


FIG.16D

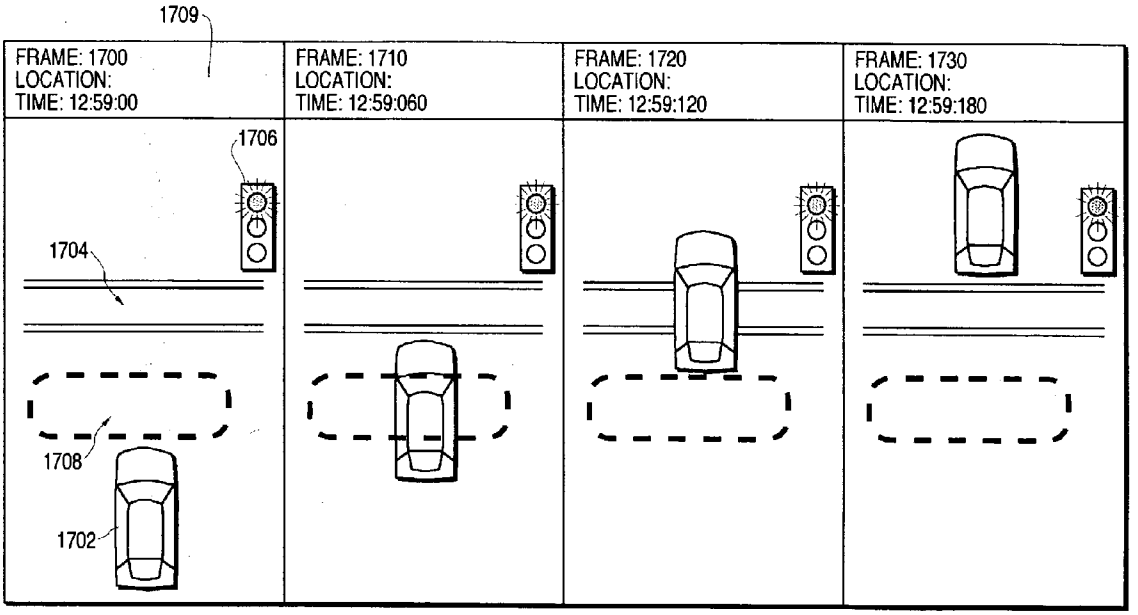

1709
FRAME: 1700
LOCATION:
TIME: 12:59:00
FRAME: 1710
LOCATION:
TIME: 12:59:060
FRAME: 1720
LOCATION:
TIME: 12:59:120
FRAME: 1730
LOCATION:
TIME: 12:59:180
1706
1704
1708
1702

FIG.17

AUTOMATED TRAFFIC VIOLATION MONITORING AND REPORTING SYSTEM WITH COMBINED VIDEO AND STILL-IMAGE DATA

FIELD OF THE INVENTION

[0001] The present invention relates generally to traffic monitoring systems, and more specifically to a system for detecting and monitoring the occurrence of traffic offenses and providing video and still photographic evidence of offenses to traffic enforcement agencies.

BACKGROUND OF THE INVENTION

[0002] Camera-based traffic monitoring systems have become increasingly deployed by law enforcement agencies and municipalities to enforce traffic laws and modify unsafe driving behavior, such as speeding running red lights or stop signs, and making illegal turns. The most effective programs combine consistent use of traffic cameras supported by automated processing solutions that deliver rapid ticketing of traffic violators, with other program elements including community education and specific targeted road safety initiatives like drunk-driving enforcement programs and license demerit penalties. However, many current traffic enforcement systems using photographic techniques have disadvantages that generally do not facilitate efficient automation and validation of the photographs required for effective use as legal evidence.

[0003] Digital-based red-light camera systems have come to replace traditional 35 mm analog-based cameras and photographic techniques to acquire the photographic evidence of traffic offenses. In the field of traffic enforcement technologies, capturing vehicle offense data involves a compromise between storage space requirements and image resolution. Typically, an offense is recorded as a number of still images of the vehicle together with some pertinent information such as speed, time of offense, and so on.

[0004] Red-light violation recording has traditionally been done with still cameras, either digital or wet film, or with video camera systems. These systems suffer from a number of shortcomings. For example, still images typically do not convey enough information to assess the circumstances surrounding a violation. A vehicle forced to enter an intersection after the traffic signals are red while yielding to an emergency vehicle will be shown as a violator on still images and the vehicle's driver will be prosecuted if the emergency vehicle does not appear in the still images. Also, at many intersections vehicles are permitted to turn during a red light if they first stop. Still images do not show the acceleration and speed of a vehicle and cannot determine if the vehicle has progressed unlawfully, i.e., without first stopping. For speed enforcement, vehicle speed must be determined from the vehicle detection device and imprinted on the photograph. Errors in the vehicle's detected speed will not be apparent on the photograph, as still images do not convey any impression of speed. Although multiple still photographs may be taken to show speed across two or more points, this solution results in increased image capture and storage requirements and causes the camera to be occupied for the duration of the image sequence.

[0005] Image resolution is critical to providing sufficient information to resolve important scene details such as the identifying data comprising the vehicle license (registration) plate and the driver's face. However, increasing image resolution also increases data storage requirements.

[0006] To solve the problem of providing contextual or background evidence surrounding a potential traffic offense at a photo-monitored location, video has been incorporated in some red-light traffic systems. However, the advent of video has certain significant disadvantages. Most notably, when an enforcement agency wishes to use video in their evidence set, the problems related to transmission bandwidth and data storage is significantly compounded. Digital video technology generates data at a vastly greater rate than digital still-image technology, given the same resolution. Although video footage has been used for identification and prosecution of vehicles in violation of traffic laws, the generally low resolution of present video systems makes it difficult to determine the fine details required for prosecution, such as the vehicle license plate or the features of the driver's face. The low resolution problem also requires the video camera to be close to the detected vehicle or to physically move and track the vehicle, both of which are major disadvantages when used in automated traffic monitoring systems. Although high-resolution video cameras can be employed for identification and prosecution of vehicles in violation of traffic laws, if the information from a high-resolution video camera is stored digitally, the amount of file storage required makes it difficult or impractical to store and communicate the amount of information generated. This is especially true for systems that do not provide efficient video clips, but rather shoot and transmit long loops of constant video data.

[0007] The standard start/stop capturing mechanism available in almost all video capture systems is inadequate to satisfy the requirement for providing footage both before and after the offense is detected. By the time the offense is detected it is too late to start a video capture sequence. It is also generally difficult to anticipate an offense and preemptively commence video capture. Furthermore, where the footage from a video system is recorded on magnetic tape the retrieval of information is time consuming and finding a specific violation or incident cannot be done instantaneously.

SUMMARY AND OBJECTS OF THE INVENTION

[0008] It is an object of embodiments of the present invention to combine high-resolution still digital images and low-resolution video into a single set of information to be used to record the instances of traffic violations in a manner that minimizes data transfer and storage requirements.

[0009] It is a further object of embodiments of the present invention to incorporate a "before" and "after" video sequence that enables reviewers to identify mitigating or aggravating circumstances immediately following or preceding a traffic offense detection.

[0010] It is yet a further object of embodiments of the present invention to provide a means of visually verifying the speed of the detected vehicle without using multiple high-resolution still images.

[0011] It is also an object of embodiments of the present invention to provide a means for easy retrieval of specific incidents or driver/car information from stored or archived data.

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[0012] A system for capturing both high-resolution detail and video footage of a traffic offense in single evidence set from a single offense-capturing device is disclosed. The system comprises a networked digital camera system strategically deployed at a traffic location. The camera system is remotely coupled to a data processing system. The data processing system comprises an image processor for compiling vehicle and scene images produced by the digital camera system, a verification process for verifying the validity of the vehicle images, an image processing system for identifying driver information from the vehicle images, and a notification process for transmitting potential violation information to one or more law enforcement agencies.

[0013] The networked digital camera system houses a conventional still-image digital camera system and a video camera system. The video camera system is configured to record footage both before and after the offense is detected. This provides the law enforcement agency with a more complete record of the events leading up to and following on from the offense itself. This may assist agency staff to better perceive the context of the offense or even detect further offenses by the same vehicle. For instance, a still-imaging system will detect a car both before and after the line at a red light, but with video the offense processing staff may also note that the car entered the intersection to yield to emergency vehicles, or that the car also lost control and became involved in an accident.

[0014] The video camera system includes a non-stop video capture buffer that records activity at the location, including the moments preceding the offense. A buffer holds a number of seconds of video data in memory. When an offense is detected, the system starts a timer. At the end of the timer period, a portion of the video (video clip) of the current buffer contents is extracted and stored. The resulting video clip is then incorporated with the conventional evidence set comprising the digital still images of the offense with the identifying data of the car and driver.

[0015] The combination of still and video footage solves the problems associated with the demand for video and the need for high resolution and low storage and transmission costs. Because the still-images continue to provide the high resolution necessary to extract important details from the evidence set, the video record can be captured using low resolution technologies that do not unduly tax the storage and data transmission systems.

[0016] Other features and advantages of the present invention will be apparent from the accompanying drawings and from detailed description that follows.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The present invention is illustrated by way of example and not limitation in the figures of the accompanying drawings, in which like references indicate similar elements, and in which:

[0018] **FIG. 1A** is a block diagram that illustrates the overall traffic violation processing system, according to one embodiment of the present invention;

[0019] **FIG. 1B** is a table that outlines some of the information transferred along the data paths illustrated in **FIG. 1A** for an exemplary traffic violation monitoring and reporting incidence;

[0020] **FIG. 1C** illustrates the deployment of a traffic violation camera system at a traffic location, according to one embodiment of the present invention;

[0021] **FIG. 2** illustrates a photographic image and accompanying reporting information provided by the camera system and data processing system of **FIG. 1A**, according to one embodiment of the present invention;

[0022] **FIG. 3A** is a block diagram illustration of a multiple element CCD intersection camera system, according to one embodiment of the present invention;

[0023] **FIG. 3B** illustrates the multiple element camera system of **FIG. 3A** in conjunction with a synchronous timing source, according to one embodiment of the present invention;

[0024] **FIG. 4A** illustrates a histogram of a pixel intensity for an intersection image, according to one embodiment of the present invention;

[0025] **FIG. 4B** illustrates the histogram of **FIG. 4A** with the license plate image isolated from the background scenery image;

[0026] **FIG. 5** illustrates an infringement set provided by an imaging processing system, according to one embodiment of the present invention;

[0027] **FIG. 6** is a flowchart that illustrates the steps that are executed by the central processor when incident information is received from an intersection camera system, according to one embodiment of the present invention;

[0028] **FIG. 7** illustrates the DMV details area of the verification screen, according to one embodiment of the present invention;

[0029] **FIG. 8** illustrates a DMV lookup screen, according to one embodiment of the present invention;

[0030] **FIG. 9A** illustrates an example of a police authorization module interface screen, according to one embodiment of the present invention;

[0031] **FIG. 9B** illustrates an example of a court interface screen generated by the court interface module, according to one embodiment of the present invention;

[0032] **FIG. 9C** illustrates a police authorization review interface that can be used by police personnel to review the photos and video clip of an incident;

[0033] **FIG. 10** is a flowchart that illustrates the steps of creating a traffic offense notice, according to one embodiment of the present invention;

[0034] **FIG. 11** illustrates a notice preview displayed in a user interface screen, according to one embodiment of the present invention;

[0035] **FIG. 12** illustrates the traffic camera office infringement processing system components, according to one embodiment of the present invention;

[0036] **FIG. 13** illustrates the components of an image analysis expert system, according to one embodiment of the present invention;

[0037] **FIG. 14** is a block diagram that illustrates the main components of the video camera system illustrated in **FIG. 1A**;

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[0038] **FIG. 15** is a flowchart illustrating the steps of capturing a video clip of a detected offense, according to one embodiment of the present invention;

[0039] **FIG. 16A** illustrates a detection system using a single inductive loop installed in the road surface;

[0040] **FIG. 166B** illustrates a detection system using two inductive loops installed in the road surface;

[0041] **FIG. 16C** illustrates a detection system using an inductive loop interposed between two piezo strips installed in the road surface;

[0042] **FIG. 16D** illustrates a detection system using an inductive loop interposed between two piezo strips with an additional inductive loop installed in the road surface; and

[0043] **FIG. 17** illustrates a detection of a vehicle using a virtual video loop, according to one embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0044] An automated system for monitoring and reporting incidences of traffic violations utilizing both still and video camera systems is described. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide an understanding of the present invention. It will be evident, however, to those of ordinary skill in the art that the present invention may be practiced without the specific details. In other instances, well-known structures and devices are shown in block diagram form to facilitate explanation. The description of preferred embodiments is not intended to limit the scope of the claims appended hereto.

[0045] **FIG. 1A** is a block diagram that illustrates the overall traffic violation processing system, according to one embodiment of the present invention. The main components of the traffic violation processing system **100** comprise the intersection camera system **102**, an offense detector system **105**, the data processing system **104**, the police department interface system **106**, the motor vehicle department interface **108**, the court interface **110**.

[0046] The red light camera system **102** consists of one or more still cameras **120** and one or more video cameras **122** arranged at or around the intersection or traffic location being monitored. When an alleged offender **101** commits an offense at an intersection as detected by the offense detector **105**, the red light cameras in the intersection camera system **102** sense and record the event. In one embodiment of the present invention, both digital still photographs as well as a portion of video, such as five to ten seconds of video capturing the event are recorded and sent to the data processing system **104**. The data processing system **104** then performs various data processing steps to verify and validate the driver and offense data. The data processing system **104** itself includes various components, such as central processor **132**, file server **134**, database **136**, verification module **138**, quality assurance module **140**, and notice printing module **142**. The data processing system **104** receives data from various external sources, such as the intersection cameras and motor vehicle agencies, and processes the data for further action by the appropriate law enforcement agencies.

[0047] As illustrated in **FIG. 1A**, various items of information regarding the driver and the vehicle are obtained by the data processing system **104** from selected authorities, such as a motor vehicle department through the motor vehicle department interface **108**, and a police department through the police department interface **106**. Typically this information is extracted from the still picture data obtained by the still cameras **120**. The video data captured by video cameras **122** is provided to supply contextual information relating to the event. For this embodiment, the resolution of the video camera can be lower than that of the still cameras since general scene data is being provided. This reduces data storage and transmission requirements compared to systems in which long clips of high resolution video is captured.

[0048] In an alternative embodiment of the present invention, identifying information can be extracted from the video data captured by the video cameras **122**. For this embodiment still photo images are extracted from the video clip, thus the resolution of the video camera system should be high enough to provide detailed information. An optional frame editor **133** in the data processing system can be used to isolate and label the appropriate frames to be processed as still video images. The detection system for system **100** can comprise either or both of the physical offense detector **105** or virtual loop detector **106** to trigger the capture of still and video clip data of the offense.

[0049] When the information relating to the offense is deemed to be valid, it is provided through the court interface system **110** to the appropriate court authorities.

[0050] As illustrated in **FIG. 1A**, the offense detector **105** may be embodied in a physical detection system that is placed at the intersection, such as a magnetic, optical, or electrical system that detects the presence or movement of a vehicle through the intersection. If the vehicle is detected at the wrong time or at the wrong speed, the detector **105** triggers the still and video cameras in system **102** to photograph the incident. In an alternative embodiment, the detection system for the video cameras can be implemented through a virtual loop detector process **139**. For this embodiment, a virtual loop or trigger is defined within the field of view captured by the video cameras **122**. When the vehicle is photographed or video-taped in this virtual location at an improper time, a timer for capturing a video clip from the video footage is triggered.

[0051] For the system shown in **FIG. 1A**, various data paths, numbered 1 to 14, are provided among the components and sub-components of system **100**. **FIG. 1B** is a table that outlines some of the information transferred along these data paths in a typical traffic violation monitoring and reporting incidence. Together, Table **150** in **FIG. 1B**, and the data paths shown in **FIG. 1A** constitute a data flow process for the traffic violation processing system **100**. As shown in **FIGS. 1A and 1B**, the data provided by the intersection camera system **102** consists of still photos **1A** and video data **1B**. There can be any number of still photos for the incident, typically four to six separate digital photos, and any length video clip of the incident, typically four to ten seconds of video surrounding the incident. Because the still photos and video clip are provided by separate camera systems **120** and **122**, they can provide photographic data at different resolutions. To minimize the transmission bandwidth and data storage requirements, the still photos can be generated and

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processed at high resolution to provide highly accurate identification and evidentiary images, while the video data can be of lower resolution, since it is primarily intended to provide background information.

[0052] If the red light cameras in the intersection camera system **102** detect a violation incident, a number of images (typically, four) of the incident, along with associated data (such as time and vehicle speed) are captured and transmitted to the central processor **132** of the data processing system **104**. These images and the associated data comprise the primary evidence of the violation and are saved in the primary images file server **134**. The central processor produces compressed scene images and incident details, and transmits these to database **136** for storage. In one embodiment, a violation is detected though the use of known wireless transmission methods, such as radar or similar waves, or through light beam detection methods, or similar techniques to determine whether a vehicle is traveling too fast or has run a red light or stop sign. Alternatively, the violation is detected through the use of physical ground loops placed within the road surface. The presence of a car in the proximity of a loop at an improper time in relation to traffic lights or other controls will signal the occurrence of a potential traffic violation.

[0053] The images captured by the intersection camera system still cameras **120** typically include at least one image of the vehicle committing the violation (i.e., running the red light), as well as images of the vehicle license plate and driver's face to provide car and driver identification information. The license plate and driver's face images are transmitted from the primary image file server to the verification module **138**. Based on the vehicle license plate information, the details of the vehicle and its owner are then accessed at an appropriate motor vehicles department **108**, and transmitted to the database **136**. Along with the still picture images, a video clip of the violation is also captured by video cameras **122**. The video data is then associated with the corresponding still image data for viewing by the authorities. This allows the amount of data that is required to be generated and transferred to be reduced from about 80 Mbytes of data (for current systems that transmit only high resolution video data) to about 2.5 Mbytes of data for a combination of low-resolution video and high-resolution still images.

[0054] The incident details and compressed images stored in the database **136** are next sent to the quality assurance module **140**. Once the quality assurance module has checked the incident data for accuracy and integrity, the details and compressed images are sent to an appropriate police agency **106**. If the police authorize a notice to be sent to the identified driver, notice details are sent to the appropriate court **110** by the data processing system **104**. The notice and incident details are also transmitted from the database **136** to the notice printing module **142** of the data processing system **104**. The prepared notice is then sent to the alleged offender **101** by the data processing system **104**. Follow-up correspondence, such as payment reminder letters, may be sent to the alleged offender from the court **110**. The alleged offender may then submit payment or make a court appearance to satisfy the notice. A notice of the disposition of the violation is then sent from the court **110** to the data processing system **104** and stored in the database **136**. This completes the data processing loop for a typical violation, according to one embodiment of the present invention.

[0055] The structure and operation of the sub-components of each of the main components of traffic violation processing system **100** will be described in greater details in the description that follows.

[0056] Intersection Camera System

[0057] A typical enforcement application of the digital camera component **102** of system **100** is in the area of red-light offense detection. For this application, the still camera or cameras **120** of camera system **102** are strategically placed at an intersection to monitor and record incidences of drivers disobeying a red light. When a vehicle is detected approaching the stop line of a monitored lane, it is tracked and its speed is calculated. If the vehicle is detected entering the intersection against the traffic signal, an evidentiary image set is captured. The event of the images being captured and the relevant details recorded is referred to as an 'incident', which may be defined as a potential offense. In one embodiment of the present invention, the evidentiary set consists of four incident images comprised of the following: a scene shot A, which is a scene shot of the intersection prior to the incident vehicle crossing the stop line; scene shot B, which is a scene shot of the intersection when the incident vehicle is seen to have failed to obey the traffic signal; frontal face zoom shot that attempts to identify the driver of the incident vehicle; and a license plate zoom shot that attempts to isolate the vehicle's license plate area only to identify the vehicle. In one embodiment, the still images captured by the digital camera system **120** are in TIFF or JPEG format, although other digital formats are also possible.

[0058] In relation to a potential violation, there are a number of details recorded for each image. These include, the date and time of the incident, the location of the incident, the lapsed time since the traffic signal turned red, and the camera identification. A short video clip of the incident is also recorded and associated with the still image data.

[0059] The captured data is assigned a 'digital signature', encrypted, and then transmitted from the digital camera system **102** to the central processor **132** in the data processing system **104**. All four shots when transmitted have their incident details "stamped" on them. In one embodiment, this "stamped information" is embodied in a data bar that appears at the top of images seen at verification process **138** of the data processing system **104**. Each of the four shots is individually identifiable as being of a particular type, i.e., scene A, scene B, face shot, and plate shot. **FIG. 11** represents a Notice to Appear that includes the photographic images and accompanying reporting information that is provided by the camera system and data processing system of **FIG. 1A**, according to one embodiment of the present invention. As can be seen in **FIG. 11**, the four photographs include the driver's face shot, the license plate shot, and the scene A and scene B shots. The composition and production of the Notice to Appear illustrated in **FIG. 11** will be described in greater detail below.

[0060] The intersection cameras may be controlled remotely to facilitate system analysis checks and to take test shots. For test diagnostics, a log of captured test shots are recorded. Test shots can be treated as normal and exported

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to the data processing system for insertion into the database as with 'ordinary' shots. Should it become necessary to prove to a court that a camera system was operating correctly at the time a particular incident was detected, the test shots form part of the chain of evidence, which is used to provide evidence of the cameras functioning correctly.

[0061] The intersection camera systems are interconnected at the detection site to provide the required camera and flash coordination. Each camera is strategically located to provide the optimum field of view for the desired captured image. The enforcement camera that is equipped/interfaced with the vehicle tracking technology is positioned to effectively record both scene images as well as the license plate area shot. A supplement camera can be positioned to image the offending vehicle driver. The camera and processing systems are interconnected using standard local area network typologies. The camera system **102** can also be configured to send secure (encrypted) incident data and image information to the data processing system **104** over a computer network line, such as modem and telephone line.

[0062] **FIG. 1C** illustrates the deployment of an intersection camera system at an intersection, according to one embodiment of the present invention. The cameras and processing circuitry are housed in a body **174** that is placed on a pole or other support structure **180** above the monitored location, typically adjacent to a traffic light or stop sign. The height and position of the camera system is selected to allow a sufficient field of view **182** of the monitored location. A loop detector **172** placed in the roadway detects the improper presence or movement of a vehicle **170** at the monitored location. This is used to trigger the cameras to capture photographic evidence of the offense. In one embodiment, the housing holds three separate digital still cameras **176** and a single video camera **178**. Depending upon implementation constraints and system capabilities, different camera configurations may be used, such as one or several still and/or video cameras housed at single or distributed locations around the location. If a sufficiently high-resolution video camera is utilized, a single video camera may be used from which both video and still images can be extracted.

[0063] Portions of the data processing system **104** illustrated in **FIG. 1A** may be housed within the body **174**. For example a computer that includes central processor **132** may be closely coupled to the cameras **176** and **178** within housing **174**. Alternatively, housing **174** may be configured to hold only the cameras **176** and **178**. In this case, hardwire, wireless, or telephonic network connections can be used to couple the cameras to the central processor and other components of the data processing system **104**. This system can be provided in a separate housing at the location or at a remote location some distance from the monitored location.

[0064] Still Camera System

[0065] In a preferred embodiment of the present invention, the traffic violation processing system **100** utilizes digital camera technology for the still cameras **120**. Such a digital camera system targets specific areas of interest with a system consisting of several imaging elements. The advantage of such a configuration is the targeting of resolution where it is needed, while preserving the rationale that the extracted images are captured at the same moment in time.

[0066] Charge-Coupled Device (CCD) imaging elements can be used for the digital still cameras. These typically provide spatial and dynamic resolution that is equal to or better than 35 mm celluloid-based film. In the intersection camera system **102**, a scaleable multi-element digital camera system designed specifically for traffic enforcement applications is used. This camera system is specifically designed to address the issues of image resolution, dynamic range, and imaging rates (i.e., frame per second) towards the special requirements of offense prosecutability where the images form the primary evidence.

[0067] A CCD is an image acquisition device capable of converting light energy emitted or reflected from an object into an electrical charge that is directly proportional to the entering light's intensity. This charge or pixel can then be sampled and converted into the digital domain. The digital pixel information is cached and transferred to RAM (Random Access Memory) in a host computer system in bursts via a local bus where further processing and final storage occurs.

[0068] The fundamental imaging requirement for prosecutability of an image is clear identification of the offense committed and identification of the offending vehicle. In a multiple camera system, each imaging element must be synchronized and triggered concurrently to ensure all captured images correlate the same event that is the exact time base.

[0069] **FIG. 3A** illustrates a multiple element CCD intersection camera system for use in still cameras **120**, according to one embodiment of the present invention. Camera system **300** in **FIG. 3A** illustrates a representative camera system comprising a primary CCD **302** and two secondary CCDs **304** and **306**. The CCDs **302**, **304**, and **306** convert the incoming light into electronic charge. The charge is then moved through an analog shift register to provide a serial stream of charge data, similar to a bucket brigade. For camera system **300**, image data from primary CCD **302** is processed through an ADC (Analog to Digital Converter) process **308** to produce digital data streams **310**. The image data from the two secondary CCD cameras **304** and **306** are each processed through respective ADC processes **312** and **314** and input to a multiplexer **316** to produce digital data streams **318**.

[0070] The basic operation of the CCD in camera system **300** is next described. For each camera, the CCD image sensing area is configured into horizontal lines containing several pixels. As light enters the silicon in the image sensing area, free electrons are generated and collected inside photosensitive potential wells. The quality of the charge collected in each pixel is a linear function of the incident light and the exposure time. After exposure, the charge packets are transferred from the image area to the serial register at the rate of one line per clock pulse. Once an image line has been transferred into the serial register, the serial register gate can be clocked until all of the charge packets are moved out of the serial register through a buffer and amplification stage producing an analog signal. This signal is sampled with high-speed ADC devices to produce a digital image.

[0071] Color sensing is achieved by laminating a striped color filter with RGB (Red, Green, Blue) organization on top of the image sensing area. The stripes are precisely aligned to the sensing elements, and the signal charged columns can be multiplexed during the readout into three separate regis

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ters with three separate outputs corresponding to each individual color. Each red, green, and blue pixel from the CCD is processed by a high-resolution analogue to digital converter capable of high sampling rates. Once in the digital domain, the pixel charge is held in cache as it waits for a data transfer window to be made available by the host computer system for transfer into host RAM.

[0072] In one embodiment of the present invention, the image data is transferred from the CCDs **302**, **304**, and **306** to the host system RAM **322** using a PCI (Peripheral Component Interconnect) interface **320**. For many present computer systems, PCI has become the local bus standard for interconnecting chips, expansion boards, and processors. The original PCI architecture implements a 32-bit multiplexed address and data bus.

[0073] In accordance with standard PCI usage, in camera system **300**, communication between devices on the PCI bus occurs through a mechanism of burst transfers. A burst transfer consists of the establishment of a bus master (an I/O cycle—in order for the initiator of the burst to attain master status on the bus) and the bus slave (target) relationship. The length of the burst is negotiated at the beginning of the transfer, and may be of any length. At burst completion, the receiving end (target) terminates the communication after the pre-determined amount of information has been received. Only one bus master device can communicate on the bus at a time. Other devices cannot interrupt the burst process because they do not have master status.

[0074] The integration of the CCD imaging device directly into the final processing computer system short cuts the traditional process of capturing digital images through video based cameras, converting the composite analog signal into a digital image with the use of 'Frame Grabber' and then importing the resultant image into the host computer for processing. The losses in image quality that occur due to the digital-analog-digital conversion in these systems, limit their application for traffic enforcement purposes. Furthermore, video based cameras are typically limited in resolution and dynamic range.

[0075] Dynamic resolution is an important characteristic of the camera system **300**. Dynamic resolution defines the size of each pixel data once converted into digital form. The relationship is proportional to the CCD camera's ability to represent very small and large light intensity levels concurrently (i.e., the Signal to Noise Ratio, SNR) and is represented in Decibels (dB). Accordingly the sampling ADC is matched to exhibit an equivalent SNR.

[0076] The application of dynamic resolution in enforcement programs provides for a mechanism of identifying vehicle license plates with retro-reflective composites. When flash photography is used in the reproduction of high quality images, the light energy that is directed towards the license plate area is reflected back at a level (result of a high reflection efficiency), that is higher then the average intensity entering the camera. Consequently an optical burn effect (i.e. over exposure) appears around the area of the license plate.

[0077] The effect of optical burn, or "plate burn" is minimized with the utilization of a CCD and ADC system with a dynamic range capable of resolving the resultant intensity spectrum. A histogram of the image will reveal all scene and license plate details residing at opposing ends of the spectrum.

[0078] The license plate having the strongest intensity will appear at the highest levels and the rest of the image proportioned across the rest of the spectrum. However, most computing systems, and indeed the human eye, can only resolve **256** levels (or 48 dB=8 bits) of intensity. Typical 35 mm Celluloid film of 100 ASA is considered to have 72 dB of equivalent dynamic resolution. This dynamic range can resolve 4096 level of intensity and is represented by a 12-bit word.

[0079] To limit the volume of data and information kept for evidentiary purposes, a process of "Histogram Slicing" can be used to scale down the overall pixel data size from 12 bits down to 8 bits by selecting only 256 of the available 4096 levels. The selection criteria will ensure that the visual integrity of the image is ensured but will also normalize the overall appearance such that overexposed areas are in balance with the rest of the image. Ideally the process would be a non-linear function that is adaptive in nature to compensate for ambient and exposure conditions. The translation for speed and efficiency would be a mapping (or lookup) function.

[0080] **FIG. 4A** illustrates a histogram of pixel intensities for an intersection image, according to one embodiment of the present invention, and **FIG. 4B** illustrates the histogram of **FIG. 4A** with the license plate image isolated from the rest of the images that make up the vehicle and background scene. Details of the digital imaging process that isolates the license plate image are described in U.S. Pat. No. 6,240,217, entitled "Digital Image Processing", which is assigned to the assignee of the present invention, and which is hereby incorporated by reference. The histograms of **FIGS. 4A and 4B** illustrate the intensities of individual pixels in a traffic violation image on a pixel **402** axis versus intensity **404** axis. As illustrated in **FIG. 4A** individual pixel components for the license plate are shown as elements **408** against the pixel components for the background scene **406**. Using compression and isolation imaging techniques, the intensity of the pixels for the license plate **408** are altered relative to the intensity for the pixels for the background **406**, as illustrated in **FIG. 4B**. In this manner, the license plate is made more readable relative to the background scenery. It should be noted that the same technique could be applied to other images and components of images, such as to enhance the driver's face relative to the car.

[0081] As stated above, a typical enforcement application of the digital camera system illustrated in **FIG. 3A** is in the area of red-light offense detection. The camera system is strategically placed at an intersection to monitor and record incidences of drivers disobeying a red light. In one embodiment, the primary evidence produced is a set of two images. The first image showing a view of the intersection that encompasses the traffic light of the monitored approach, the offending vehicle prior to crossing the violation line (typically a white line such as a cross-walk) and sufficient background scene depicting the driving conditions at the time of the offense. The second image is typically of the same field of view but with the offending vehicle completely crossed over the violation line in conjunction with the red light.

[0082] The main area of interest is the vehicle position before and after the intersection. Although the overall resolution for this image is not critical, sufficient detail must

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exist to resolve features of the intersection as well as traffic signal active phase. However, in order to identify the offending vehicle the license plate details and jurisdictional information must be legible. For 35 mm wet film cameras the effective spatial resolution must be on the order of 3072× 2048 pixels. Even then the license plate details only represent 5 percent of the total number of pixels.

[0083] The architecture of the digital camera system **300** allows for the synchronous operation of multiple image elements acquiring specific area of interest all at the same interval of time. The field of view of the primary imaging element will encompass the complete intersection, the traffic signal head of the monitored approach and the offending vehicle relative position. The secondary imaging elements can be used to image the license plate area of the offending vehicle.

[0084] To ensure synchronism between each of the imaging elements the timing generators for each CCD is reset simultaneously and clocked by a single source. **FIG. 3B** illustrates the camera system **200** of **FIG. 3A** in conjunction with a synchronous timing source. Each of the three CCDs **302**, **304**, and **306** have their output signals synchronized to respective timing generator circuits **330**, **332**, and **334**. The timing generator circuits are driven by common clock **340** and reset signals **342**. The result is that each CCD will acquire and discharge the image simultaneously with the other CCD cameras. One benefit of the synchronous operation of the CCDs is that a single flash can be triggered with the resultant exposure recorded by all the CCDs.

[0085] In many circumstances, the vehicle detection system used in the tracking and identification of offending vehicles can provide actual vehicle position information such as the travel lane, speed, and direction which can be used to tighten the field of view of the secondary imaging elements, thus allowing a sharper and larger license plate area image. For example in a two-lane intersection or road environment, one of the secondary elements can be used to image one lane and another used to image the other lane. The advantage of this system is that two secondary cameras can share the same data path as either one lane or the other will only be imaged.

[0086] In many circumstances more than one camera system (incorporating the host computer, imaging elements and enforcement logic) may require supplemental camera systems to provide additional or more optimal fields of view of the offense. One such requirement is the acquisition of the offending vehicle driver's image where the primary detection camera is imaging the offending vehicle from behind as it approaches the intersection. In such cases it is impossible to achieve the required field of view resulting in the addition of a supplemental camera system.

[0087] In one embodiment of the present invention, distributed computer and network technologies, such as DCOM (Distributed Component Object Module) and the equivalent CORBA (Common Object Request Broker Architecture), are implemented by the traffic enforcement system **100** to provide a mechanism of seamless imaging element attachments. This allows for the effective increase in the number of imaging elements, while still preserving the single enforcement camera system ideology.

[0088] Video Camera System

[0089] For the system illustrated in **FIG. 1A**, the intersection camera system **102** includes a video camera system **122**. As shown in **FIG. 1C**, this camera can be a single digital video camera mounted along with the still cameras at a particular location that provides a sufficient line of sight to the monitored intersection or location. In an alternative embodiment, the video camera may be an array of two or more video cameras each providing a distinct field of view of the monitored location. The resulting videos can then each be provided separately to the data processing system **104**, or can be combined to form a composite video image.

[0090] **FIG. 14** is a block diagram that illustrates the main components of video camera system **122**. In system **1400**, video camera **1402** is a digital video camera that produces video data in PAL, NTSC or other format, which can then be processed to produce streaming video in compressed form such as MPEG, MPEG2, Quicktime, AVI, or similar formats. In one embodiment, the video camera shoots non-stop video footage of the location. The digital video data is stored in a buffer **1404**, which can be any type of memory (e.g., RAM, RAM-disk, tape, and so on) that is sufficient to hold at least a portion of the video footage shot by the camera. A detection system **1406** is coupled to the video camera **1402**. Upon detection of an offense, a timer **1408** is started. The timer is programmed to stop after a predetermined period of time. At the end of the timer period a clip or "snapshot" of the buffer contents is taken by video clip recorder **1410**. The video clip recorder takes the video clip recorded by the video camera for the time period of the timer plus a period of time prior to detection of the offense. The buffer and video clip recorder are used to provide a clip of the offense plus moments immediately before and after the offense. Thus, in order to catch, for example, six seconds prior and six seconds after an offense is detected, the buffer **1404** holds at least twelve seconds of footage in memory. When an offense is detected, the system starts a six second timer, at the end of which it takes a video clip of the current buffer contents and stores it to a persistent memory, such as hard drive **1412**. This storage (hard drive) can also be used to store the still images of the offense. Thus, the resulting video record can be incorporated with the conventional evidence set provided by the still cameras.

[0091] **FIG. 15** is a flowchart illustrating the steps of capturing a video clip of a detected offense, according to one embodiment of the present invention. In step **1502**, the video camera **1402** records a non-stop loop of video of the monitored location. This video data is buffered in buffer **1404**, step **1504**. The detection system **1406** detects a traffic offense, step **1506**. The detection of an offense triggers a timer **1408** to start for a set period of time, step **1508**. After the timer period, the timer stops, step **1510**. In step **1512**, the video clip recorder **1410** captures and clips from the buffer a video clip running from a set time prior to the offense to the end of the timer period. The video clip is then stored in a memory, such as hard drive **1412**, and associated with the still camera data of the offense, step **1514**.

[0092] As illustrated in **FIG. 14**, the video recording system incorporates a detection system **1406** for detecting the occurrence of a traffic violation. The detection system includes can consist of a physical loop or trip-wire embedded in the road surface to detect the improper presence of a

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vehicle. In one embodiment, the detection system employs one or more inductive loops installed in one or more lanes of the road surface of the monitored location. The loops may be a single inductive loop sensor, a pair of inductive loop sensors or a single inductive loop sensor interposed between a pair of piezo sensors installed in the road surface. Where a pair of inductive loop sensors is employed or where a single inductive loop sensor is interposed between a pair of piezo sensors, a second inductive loop sensor, the "secondary loop", may also be employed following the first.

[0093] **FIG. 16A** illustrates a detection system using a single inductive loop installed in the road surface. **FIG. 16B** illustrates a detection system using two inductive loops installed in the road surface. **FIG. 16C** illustrates a detection system using an inductive loop interposed between two piezo strips installed in the road surface. **FIG. 16D** illustrates a detection system using an inductive loop interposed between two piezo strips with an additional inductive loop installed in the road surface.

[0094] For the single inductive loop detector system illustrated in **FIG. 16A**, the vehicle **1602** is detected by detecting a change in magnetic field around the inductive loop sensor **1604**. The onset of the change in magnetic field (rise of the inductive loop sensor) indicates the position of the front of the vehicle over the inductive loop sensor. The return to the initial magnetic field from the change (fall of the inductive loop sensor) indicates the rear of the vehicle leaving the immediate vicinity of the inductive loop sensor. Where the magnetic field change (rise of the inductive loop sensor) is detected and does not return to normal within a set period of time it can determined that the vehicle has stopped over the inductive loop sensor.

[0095] By knowing a vehicle has stopped, the vehicle detection system has the ability to reject vehicles that come to abrupt stops at the stop line of an intersection. These "false triggers" for red light running enforcement would otherwise need to be culled manually resulting in inefficiencies in ticket processing.

[0096] **FIG. 16B** illustrates a system for detection using two inductive loops installed in road surface. Where a pair of inductive loop sensors is used, the vehicle **1602** is detected by detecting a change in magnetic field around both inductive loop sensors **1604** and **1606**. The onset of the change in magnetic field for the first inductive loop sensor **1604** indicates the position of the front of the vehicle over the inductive loop sensor and the return to the initial magnetic field of the change indictes the rear of the vehicle leaving the immediate vicintiy of the first inductive loop sensor. The onset of the change in magnetic field for the second inductive loop sensor **1606** indicates the position of the front of the vehicle and the return to the initial magnetic field of the change indicates the rear of the vehicle leaving the immediate vicinity of the second inductive loop sensor.

[0097] By calculating the difference in time between detecting the front or the vehicle each inductive loop sensor and dividing this time by the distance between the inductive loop sensors gives the speed of the vehicle across the two inductive loop sensors, that is:

Vehicle Speed (m/S)=Distance between loops (m)/Time between loops (S)

[0098] Similarly, by calculating the difference in time between detecting the rear of the vehicle at each inductive loop sensors and dividing this time by the distance between inductive loop sensors gives the speed of the vehicle across the two inductive loop sensors.

[0099] Further, by calculating the time between the rise and fall of either inductive loop sensor and multiplying it by the speed of the vehicle gives the approximate length of the vehicle, that is:

Approximate Vehicle Length (m)=Vehicle speed (m/S)×Time between loop rise and fall (S)

[0100] This calculation can be made more accurate by subtracting the width of the inductive loop sensor from the calculated length, that is:

Vehicle Length (m)=[Vehicle speed (m/S)×Time between loop rise and fall (S)]−Loop width (m)

[0101] Where the magnetic field change is detected for one or both inductive loop sensors and does not return to normal within a set period of time it can determined that the vehicle has stopped over the inductive loop sensor.

[0102] **FIG. 16C** illustrates detection using an inductive loop **1604** interposed between two piezo strips **1608**. Where a single inductive loop sensor is interposed between two piezo strips the vehicle **1602** is detected as per the single loop detector system illustrated in **FIG. 16A**, i.e., the onset of the change in magnetic field (rise of the inductive loop sensor) indicates the position of the front of the vehicle and the return to the initial magnetic field from the change (fall of the inductive loop sensor) indicates the rear of the vehicle. As the vehicle passes over each piezo sensor its presence is detected by way of an electric signal or pulse generated as the vehicle's weight through the tires presses down on the piezo sensor strips **1608**. An accurate determination of the vehicle speed is given by calculating the difference in time between detecting either front axle passing over the piezo sensors and dividing this time by the distance between piezo sensors to give the vehicle speed, that is:

Vehicle Speed (m/S)=Distance between piezo sensors (m)/Time between piezo sensors (S)

[0103] As for the two-inductive loop sensor sytem, by calculating the time between the rise and fall of either inductive loop sensor and multiplying it by the speed of the vehicle gives the approximate length of the vehicle, that is:

Approximate Vehicle Length (m)=Vehicle speed (m/S)×Time between loop rise and fall (S)

[0104] This calculation can be made more accurate by subtracting the width of the inductive loop sensor from the calculated length, that is:

Vehicle Length (m)=[Vehicle speed (m/S)×Time between loop rise and fall (S)]−Loop width (m)

[0105] Using a single inductive loop sensor interposed between two piezo strips for vehicle detection also provides the ability to count the number of axles each vehicle has. An electric signal or pulse is generated by the weight of each of the vehicle's axles as they pass over the piezo sensor. The number of pulses detected between the rise of the inductive loop sensor and the fall of the inductive loop sensor is equal to the number of axles the vehicle has, that is:

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$$\text{Number of Vehicle Axles} = \sum_{t=loop\_rise}^{t=loop\_fall} (\text{Pulses From Piezo sensor})$$

[0106] By calculating the number of axles the vehicle has, and by calculating the length of the vehicle, the vehicle can then be classified by vehicle type according to standard, readily available, vehicle classification charts or tables, as car, truck, bus, and so on. Thus, by knowing the vehicle type then the detection can be made to be vehicle type specific. The vehicle type can be used for determining whether an authorised vehicle is using a bus lane or transit way. The vehicle type can also be used for determining whether or not a vehicle is speeding according to its vehicle type, where trucks cars and busses have different speed limits.

[0107] **FIG. 16D** illustrates a system for detection using the piezo strip—inductive loop system of **FIG. 16C** with an additional inductive loop. Where the vehicle detection uses a pair of inductive inductive loop sensors, or an inductive loop sensor interposed between two piezo strips, an additional inductive loop sensor **1606** may be added after the first and second inductive loops in the case of a pair of inductive loops, or after the first inductive loop **1604** in the case of an inductive loop interposed between two piezo strips **1608**, for the purposes of detecting the vehicle at a another location or position after the first detection point. The additional vehicle detection provides the ability determine the path of the vehicle after the first detection.

[0108] This system may be to used determine if a vehicle has entered an intersection against a red light after initially stopping at the stop bar. It may also be to used determine if a vehicle has entered an intersection and stopped in the intersection.

[0109] In one embodiment, the loop and/or piezo strip sensor systems illustrated in **FIGS. 16A-16D** are embedded in the road surface in relation to an indicator, such as a stop sign or red light. In the case of an intersection, the detectors are typically placed at or near a crosswalk controlled by the traffic light. The actual placement of the sensors depends on the layout of the intersection. As shown in **FIG. 14**, the detection of vehicle through the intersection or monitored location by the sensor or sensors triggers a timer **1408** that controls the extraction of a video clip from the video loop shot by the video cameras **1402**.

[0110] Other physical detection systems can be used to provide detection of the offense. For example, a light-beam based trigger may be used instead of or in conjunction with the inductive loop/piezo strip to detect the presence of a vehicle.

[0111] In an alternative embodiment of the present invention, a virtual loop detector implemented in software or firmware is used for detection system **1406**. In this case, the data processing system **102** of **FIG. 1A** includes a virtual loop detection process **139**. This process defines a virtual loop or trigger line in the field of view that is continuously recorded by the video camera. When a vehicle is imaged in that virtual loop or on that line by the video camera at a time not allowed by the indicator or traffic light, the timer **1408** is triggered. Digital image processing techniques can be used to define the virtual loop and detect the presence of a vehicle in that area of the video at an improper time or improper speed.

[0112] **FIG. 17** illustrates a detection of a vehicle using a virtual video loop, according to one embodiment of the present invention. The example of **FIG. 17** illustrates four separate frames **1700**, **1710**, **1720**, **1730**, of video data. The field of view of the video camera shows the area around an intersection cross-walk **1704** and a traffic light **1706**. A car **1702** is seen entering the intersection on a red light. Through digital signal processing techniques, a virtual loop **1708** is defined or drawn in an area of the intersection, such as before the cross-walk **1704**. Through the use of the virtual loop **1708**, it can be detemined whether the car **1702** entered the intersection at an improper time, that is, when the light **1706** was red. Total coverage of the loop **1708** by the car **1702** when the light had been red for a certain period of time, as shown in frame **1710** can cause an offense to be detected. At this point, the timer is triggered, as illustrated in steps **1506** and **1508** in **FIG. 15**. It should be noted that depending upon the layout of the monitored location and the capabilities of the camera and processing systems, one or more virtual loops can be defined at various locations in relation to the cross-line (e.g., crosswalk **1704**).

[0113] Also shown in **FIG. 17** is a frame header **1709** displayed across the top portion of each of the frames. As illustrated in **FIG. 1A**, data processing system **104** can include a frame editor **133** that is separate from the direct link from the camera system to the central processor. This frame editor allows the system to stamp each frame of the video with certain identifying information or relevant facts. These can include the time and place of the location, duration of the lights, speed of the car, direction of travel, and other similar items of information. Use of the video frame information can also be used to determine certain facts regarding the incident such as the speed of the vehicle and any possible acceleration or deceleration through the location, by using frame rate and timing information. For example, if the video clip is twelve seconds long and the video camera shoots 28 frames per second, the resulting clip will contain 300 frames, each 60 milliseconds seconds apart. As shown in **FIG. 17**, frame **1700** was shot at time 12:59:000, frame **1710** at 12:59:060, frame **1720** at 12:59:120, frame **1730** at 12:59:180, and so on. This time information can then be used to determine speed and acceleration for the vehicle by using known distances for the location.

[0114] By correlating the header information stamped on the video frames with the information associated with each of the still photos of the event, a tightly coupled evidence set of still and video data can be combined and generated. Alternatively, in embodiments in which a single video camera is used with no still cameras for the intersection camera, the stamp information allows individual frames to be used as still images, provided that the resolution of the video camera is high enough to provide legible identifying data. To ensure the integrity of the image data that is provided to the authorities, the frame editing functions in frame editor **133** can be restricted to only data stamping to prevent undue tampering or alteration of the actual raw video data.

[0115] The detection system **1406**, in either the physical or virtual embodiments can be used to trigger both the video

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cameras **122** and still digital cameras **120** for system in which both types of cameras are used. Upon detection of an offense, the still camera or cameras shoot a series of still photos, and the timer/video clip recorder process is executed for the video camera footage.

[**0116**] Data Processing System

[**0117**] As illustrated in **FIG. 1A**, the images captured by the intersection camera system **102** are processed in data processing system **104**. Data processing system **104** includes central processor **132**, primary images file server **134**, verification module **138**, quality assurance check module **140**, database **136**, and notice printing module **142**. In general, the data processing system **102** largely processes digital still images provided by the on-site still cameras **102**. The video clip data provided by video cameras **122** is primarily provided to supply background context data for the moments surrounding the incident to help the viewer determine if there are any mitigating or aggravating circumstances. The video camera thus records footage both before and after the offense is detected. This provides the enforcement agency with a more complete record of the events leading up to and following on from the offense, thus helping to better perceive the context of the offense. For example, the video footage may show that a car entered the intersection to yield to an emergency or police vehicle responding to an emergency, or that the car was involved in a collision before or after entering the intersection.

[**0118**] The central processor **132** executes the main software program that implements the traffic violation monitoring and reporting system. The central processor **132** is designed to manage the remote camera systems and receive their incident data and image information via modem. The central processor contains its own database for recording camera system information, but also sends information to the main database **136** in the data processing system **104** for each detected incident or test shot.

[**0119**] **FIG. 6** is a flowchart that illustrates the steps that are executed by the central processor **132** when incident information is received from the digital still cameras of intersection camera system **102**, according to one embodiment of the present invention. In step **602**, four images in an appropriate digital format (e.g. GIFF, TIFF or JPEG format) are stored on the primary images file server **134** in an area which is regularly archived and which is available for read-only access by verification users. These images constitute the primary evidence, which is digitally signed to prevent any subsequent undetected manipulation. The four images typically consist of two scene images, a driver's face image, and a license plate image.

[**0120**] In step **604**, compressed images in JPEG format are made of the two scene images. An incident record is then stored in the main database **136** with associated records containing the two compressed scene images and the address path of the face and plate TIFF images, step **606**. The incident record is assigned a unique incident number, which is used to link it to all other associated records throughout its lifecycle.

[**0121**] The verification module **138** within the data processing system **104** allows trained operators to check that all of the legal and business rules relating to the incident have been met in the captured images and data. That is, the operators verify that the incident is a legitimate offense and that the driver can be readily identified. In one embodiment of the present invention, when a user logs onto the verification module **138** they are presented with a display screen which consists of five main information areas. **FIG. 2** illustrates the display of the verification module for an exemplary incident, according to one embodiment of the present invention.

[**0122**] Incidents are queued to the verification station by incident number so that the oldest incident is always processed first. Many of the verification application screens are also used in later processing applications, that may include quality assurance, a hold queue, an interstate queue, Police authorization, and an offense viewer.

[**0123**] When the incident is first loaded, the display area **206** will display the plate zoom shot. The user may then select a command **208** to view the face zoom shot. When first displayed, the uncompressed images in TIFF format will be loaded from the file server using the images' stored address paths.

[**0124**] Note that after an incident has been verified, later processing steps that use these images will load a compressed JPEG version of the image that has been stored in the database. This technique generally improves the speed of the system and keeps database file sizes to a minimum, at the cost of some small loss of image quality after the verification stage.

[**0125**] To allow easier recognition in later processing steps, the areas of interest of both plate and face shot images can be magnified by the verification user. For this function, a zoom control is provided. This control allows the image to be enlarged, panned, and allows intensity and contrast adjustments. The zoom control for face shots has an additional mask function to allow masking the identity of any passengers in the vehicle for privacy reasons. The zoomed images are used for all processing steps after the verification step. Note that the primary evidence images are not modified, only the compressed JPEG images that are stored in the database are manipulated.

[**0126**] When the incident is first loaded, the main display area **212** of the verification screen area will display the "A" scene shot. The user may click on a button **218** to view the "B" shot. These images will be displayed in JPEG format and loaded directly from the database. The A shot is taken as the vehicle crosses the stop line and the B shot is taken after the vehicle enters the intersection. As illustrated in **FIG. 2**, the "B" scene shot is displayed.

[**0127**] In **FIG. 2**, display area **210** is the data block details area. This area displays a representation of the incident details as captured on site and the incident number allocated to the details at the time of insertion of the incidence into the database from the central processor. Each image captured by the system has a data bar **212** at the top of each image to provide an additional level of security. The information in the data block **210** must match the information in the data bar **212**. This ensures that images have not been incorrectly assigned.

[**0128**] The image of **FIG. 2** also includes a Motor Vehicles Department (DMV) details area **216**. In this area the user types in the license plate details from the incident vehicle and executes a plate look-up from the DMV data

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base. In general, the DMV lookup consists of a number of automatic steps, including looking up the registration number of the vehicle to return registered owner(s) details, looking up personal details of the driver to retrieve a driver's license number for the registered owner returned from the first lookup, and looking up the driver's license to return complete driver's license details.

[0129] Following a successful lookup, the DMV details area **216** of the verification screen of **FIG. 2** will display some of the retrieved information. **FIG. 7** illustrates the DMV details area in greater detail. The license plate and vehicle information is displayed in the top half of display area **700**. The name and address of the driver, or company, if the vehicle is company-owned is displayed in display area **704**, and the driver's license information for the driver is displayed in display area **706**.

[0130] If any one of the steps of the DMV lookup is unsuccessful, a DMV lookup screen may be presented to the user. **FIG. 8** illustrates a DMV lookup screen, according to one embodiment of the present invention. The DMV lookup screen **800** allows the user to execute each of three lookup steps incrementally. The user is able to enter the various items of information, such as the vehicle registration (license plate) number, personal details of the driver, or the driver's license number. The registration number of the vehicle is entered and displayed in display area **802**, the vehicle details are entered and displayed in display area **804**, and the driver details are entered and displayed in display area **806**.

[0131] Use of the DMV lookup screen may be necessary in the event of multiple records being returned for either the registration number or the personal details lookups, i.e., if more than one owner was registered against the vehicle or if more than one person had the same name. The DMV lookup screen may also be used to modify user-defined search criteria in the event of returned owner records being flawed in some manner, such as if a "0" number was included in a name instead of an "O" letter.

[0132] The returned alleged offender details will be transferred to the relevant fields on the lower half of the DMV lookup screen **800** when the user clicks the 'Accept' button on the verification screen of **FIG. 2**. The user may execute multiple lookups if unsatisfied with the initial returned results. Each DMV lookup will be logged against a particular user and date/time stamped. The lookup log can be made viewable.

[0133] This area at the bottom right of the verification screen of **FIG. 2** shows the buttons **218** corresponding to the different ways the incident can be processed by the user, i.e. how the status of the incident should be updated.

[0134] The user may click the 'Hold' button to put the incident "on hold" if there is not enough information to accept or reject the incident. To put an incident "on hold", the user must also select the hold reason from a displayed hold reasons form. The most common reason to do this would be if the vehicle did not have an in-state registration. For this circumstance, an interstate lookup process might be implemented.

[0135] If the user decides the incident is not a valid offense, or for any other reason cannot be issued to an alleged offender, the incident can be rejected using the 'Reject' button. In this case, the user will be presented with a reject reasons form to select the reason in the same way as for hold reasons.

[0136] The user may decide to restart an incident, which would remove all zooming, masking, and also clear any DMV details that may have been returned. In the case of an incident being restarted, the history of the incident would reflect this and any DMV look-ups would also have been logged. The last option is to accept an incident as valid.

[0137] After one of the four choices has been selected, the next incident will be displayed and the process repeated. The user will have the ability to view an incident's history to date and add new comments to an incident.

[0138] In one embodiment of the present invention, the DMV lookup form **800** is also available from other applications. For example, the form may include an interstate queue application, so that when another state returns information on registration requests sent to it, the user can enter registration details against an incident. This area of the form may also be editable in the hold queue application when the incident is being 'verified' to extract name and address details from returned DMV registered owner data. It will generally not be editable in the hold queue application when the incident has already been verified, i.e., when the incident had been put on hold from the quality assurance module.

[0139] The display screen illustrated in **FIG. 2** may includes a sub-window that allows viewing the video clip of the offense. Upon requesting access and playing of the video clip, the system displays the video extracted by the video clip recorder. Typically this comprises a short video clip showing the circumstances of the offense including a few seconds before, during, and after the offense. This enables the reviewer to view the circumstances surrounding the offense.

[0140] Quality Assurance Process

[0141] The data processing system **104** of **FIG. 1A** also includes a quality assurance (QA) module **140**. In one embodiment, the QA module uses the same user interface as the verification module, illustrated in **FIG. 2**. In the QA module, the user does not have any image editing facilities and may not change any of the vehicle or alleged offender details or execute a DMV look-up. All incidents that have a status of "Accepted by Verifier" or "Accepted by Hold Operator as Verifier" will be available for quality assurance. The system tracks users who are logged in to the QA module and will not queue any work to them that they have "verified", be it at the verification application or hold queue application.

[0142] When a quality assurance session begins, the four images (plate, face, scene A, scene B) in compressed JPEG format are loaded from the database **136**. The plate and face images displayed are those that were manipulated at the verification stage **138**. Initially the scene A and zoomed plate shots are displayed. The data block details area is then populated, and the current incident status is displayed.

[0143] The user will assess the incident as presented, and may accept, reject or hold the incident. Acceptance updates the incident's status to that of "Accepted by Verifier and QA". Rejecting the incidents results in the display of the reject reasons form. The user selects a reason and confirms

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to update the incident's status to that of "Killed" (rejected). The user will be logged as the QA operator of the incident. No further action will be taken with this incident.

[0144] If the user elects to hold, a hold reasons form is displayed, and the incident's status is updated to that of "Accepted by Verifier, On Hold by QA". The user will be logged as the QA operator of the incident. As the incident was put on hold by QA, the system will flag this condition and prevent the incident from being editable at the hold queue application, i.e., only incidents that have been put on-hold from the verification application may be editable at the hold queue application. To be editable means to be able to manipulate the face and plate shots, execute a DMV lookup or to be able to edit an alleged offender's details on the DMV lookup screen.

[0145] In one embodiment of the present invention, the data processing system **104** includes a hold queue application. Incidents that may be valid but need further clarification are queued to this application. The application starts by displaying a hold queue main screen that shows a list of all incidents that are on hold that can be processed by the current user. The user may click on any listed item and then click an appropriate command to display the same screen as used in the verification application. Incidents may be put on hold by either the verification module **138** or the quality assurance module **140**. When an issue has been resolved for an incident, the operator can then advance the incident by either accepting or rejecting it. If the incident was put on hold at the verification stage, then the holds operator becomes the effective verifier.

[0146] In one embodiment of the present invention, the data processing system also includes an interstate queue module. This module appears and operates in the same manner as the hold station that deals with other incidents put on-hold. For this application, a list of registrations can be printed to be faxed to another state registration authority, so that they can provide details by return of fax. This would normally be performed after entering a search filter to list only incidents of one jurisdiction that have not been assessed. The user would then update an incident's details by finding the relevant incident. The incident may then be advanced to QA as normal.

[0147] Police Interface Modules

[0148] The traffic violation monitoring and reporting system **100** of **FIG. 1A** also includes an interface to one or more police departments **106**. The data processing application **104** provides the police department **106** the ability to select one of three modules. These are a police authorization module, an offense viewer module, and a police report module.

[0149] An exemplary structure of the police authorization module's main screen interface screen is illustrated in **FIG. 9A**. Interface screen **900** provides a list **902** of incidences by date and time, with license plate numbers for the offending vehicles. All incidents having been accepted as valid by the verification and QA process will be presented on a list in (configurable) batches on the main screen of the police authorization application. Incidents will be listed for batch creation by their incident date and time, thereby the oldest will be presented the police first.

[0150] Appropriate police personnel will have the ability to view individual incident details by selecting them and clicking an appropriate command button, such as the 'show details' button **904**. They will be presented with a non-editable screen, similar to the verification screen of **FIG. 2**. They may accept or reject a single incident from this screen. For data integrity, the police will not have the ability to put an incident on hold, or to view or enter comments.

[0151] The user (police personnel) will assess the incident and may decide to accept, reject or take no action by canceling from the incident. If the user decides to accept the incident, the incident status is updated to "Ready for Notice Processing" in the database **136** and the user is returned to the main list **902**. If the user decides to reject the incident, the incident status is updated to "Killed" and the user is returned to the main list **902**. The incident is logged in the database as having been rejected by police and the reason is recorded for reporting and auditing purposes. No further action will be taken with this incident. If the user decides to cancel, the incident status remains unchanged and the user is returned to the main list.

[0152] It may be possible for the authorizing officer to view each incident on the list and act on each one individually or they will at any stage return to the main list and decide to accept all the remaining incidents listed by selecting an 'Accept All' function.

[0153] Within the police authorization application, the offense viewer module displays incident images for incidents that have been confirmed as violations. This module will also be security protected and only police authorized personnel may access it. The user will use either a notice number, vehicle registration, or incident number as a search filter.

[0154] On entering a search parameter and executing a search, the system will display the four incident images, data block details, and DMV details. Additional searches can be performed from the main display in the same manner as the initial search.

[0155] The police reports module within the police authorization application allows reports to be run for police functions. The police can then use these reports to follow up on delinquent notices, and similar functions. The reports available are presented in a list and can be previewed through a police authorization application user interface.

[0156] The police authorization application can also include a delinquent notices report that lists delinquent reports in a list. An interface dialog can prompt the user for the number of days and then the report will be displayed. The report will include all notices for which payment is overdue by the selected number of days.

[0157] A dismissals report item can also be included in the police authorization application. This report lists all notices that have been cancelled because they were not processed within the time limits or because of a nomination. A nomination occurs when an alleged offender nominates another person as the driver at the time of the incident. In either case, a previously issued notice needs to be cancelled from the court records. This report can be used as a list to send to the court to request dismissal of cancelled notices.

[0158] The police authorization application also includes a notices module that allows the police department to issue and preview the Notices to Appear which are to be issued to the violators.

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[0159] **FIG. 9C** illustrates a police authorization review interface that can be used by police personnel to review the photos and video clip of an incident. As illustrated in screen display **950**, a particular incident can be selected from an incident list **952**. Incidents can be sorted and searched for using the appropriate input functions **954** and **956**. Information regarding the incident is also provided in area **958** of the display screen. The main display area includes four separate windows. Window **960** and **962** show two still photos of the location from different vantage points or at different times, and window **964** displays the license plate or other identification (e.g., driver's face) of the vehicle. Each still image can be a photo provided by each of a number of still cameras at the scene, or they can be images from any one of the cameras taken at different times. Window **966** displays the video clip of the incident recorded by the video camera. The video clip is typically accessed by selecting a view video command **968**. The display screen of **FIG. 9C** is primarily intended to illustrate one possible composition of the police authorization and review screen, and many different layouts are possible. For example, the video window may be provided as a pop-up window over the main screen, or it may be displayed as a full screen to allow the operator to view details in the video clip.

[0160] Court Interface

[0161] The traffic violation monitoring and reporting system **100** also includes a court interface module **110** that allows a user to communicate details of notices to the courts electronically, and subsequently receive updates on notice statuses from the courts. In one embodiment, this process is managed automatically using a third party scheduling program by executing database script files.

[0162] **FIG. 9B** illustrates the court interface screen generated by the court interface module **110**, according to one embodiment of the present invention. Court interface screen **950** includes a display area **952** that lists the notices that have been approved and are ready to be sent to the alleged offenders. The court interface screen **952** also includes a display area **954** that allows access to files or documents received from the court. These may include acknowledged notices and disposition of notices processed by the court. A text display area **956** may be provided to display messages associated with any incidents listed in display area **952**.

[0163] A manual court interface module can also be provided as a backup if the automatic system fails, or if unscheduled activities are required. The manual court interface module allows the following steps to be initiated: generate notice records from newly approved offense incidents, send details of new notices, receive acknowledgment (edit report) of sent files, and receive weekly dispositions. The database packages that are executed for each of these functions can either be initiated manually by clicking the interface selection, or automatically from a third party scheduling program by executing database script stored files. For every function, the details of the function are stored in a time-stamped record in log table with a unique session log id number. The number of records affected or any errors encountered is also stored.

[0164] Notice Creation

[0165] In one embodiment of the present invention, the notice creation function is initiated either by a scheduler program or will occur automatically when the manual court interface screen is selected. Notice records are created by notice printing module **142** for incidents that have been authorized by the police. **FIG. 10** is a flowchart that illustrates the steps of creating a notice, according to one embodiment of the present invention. In step **1002**, all traffic incident records that have a status of 'Ready for Notice Processing' or 'Ready for Warning Processing' are identified.

[0166] For each incident that is found, a check is performed on the age of the incident, step **1004**. If, in step **1006**, it is determined that too much time has elapsed since the incident occurred, the incident be rejected on the grounds that it is too old to issue, step **1008**. This typically occurs because, depending on the jurisdiction, notices must usually be sent to an alleged offender within specified period of time (e.g., 15 days) of the offense date, address details update date, or nomination date.

[0167] For each incident found that is within the allowed time period, an Offense Notice record is created and assigned a citation number, step **1010**. The created notices will now have a status of 'New' if the status was 'Ready for Notice Processing', or 'New Warning Letter' if the status was 'Ready for Warning Processing'. An associated offender and offender address record is created to store the personal details and address of the owner that was selected during the incident verification process.

[0168] After the appropriate notices have been created, the notices may be sent to court. This function can be initiated either by a scheduler program or manually by selecting a 'Create Notices File' selection on the court interface display screen **950**. For this process, the system first searches for all notices with the appropriate status (e.g., New), and excludes all those that are too old. The details of the notices are written to a new export file (with a pre-defined name and location) in a format that is suitable for the court's system. Notices that are too old have their statuses updated to 'Sent to Police for Dismissal'. The other notices will have their statuses updated to 'Sent To Court'. The system may display a count of how many notices were updated to 'Sent To Court' and 'Sent to Police for Dismissal'.

[0169] The export file created may have the text 'EDIT ONLY' in the header to indicate that the file is to be checked for syntax errors by the court system and that an edit report is to be produced by the court system to act as an acknowledgement of receipt. A procedure in the court system to process the file is to be initiated via a modem connection, which may be handled by a scheduler program or manually by an operator.

[0170] If the notice is to be issued to the violator by a third party, non-judicial or non-police agency, the court must acknowledge receipt of a notice before that party can print a hardcopy of it and mail it to alleged violator. The notice printing module of the data processing system **104** provides a user interface screen that lists and displays in preview form, notices to be printed. Such a notice preview form is illustrated in **FIG. 11**.

[0171] In one embodiment of the present invention, printing a notice involves several main steps. First, the current user is saved as the issue user in the notice record, and the notice status is updated to "Notice Printed or Warning

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Letter Printed", as appropriate. Two scene images, a plate zoom image, a face zoom image, a police authorizer signature image, and the issue user's signature image files are copied from the database **136** into a data processing directory as graphic files (such as .jpg files).

[**0172**] Next, the document is previewed on the screen to ensure all images are retrieved, and then the document is printed to the printer. Note that a preview of a document that has not yet been printed may not display the details of the person issuing the notice because it has not yet been issued.

[**0173**] **FIG. 11** illustrates a notice preview displayed in a user interface screen, according to one embodiment of the present invention. The following details appear on each Notice to Appear: the name and address of the alleged offender, details of the incidence, the four incident images as saved by the verification operator, the location of the incident, the time and date of incident, and fine payment information. Also included is a section where an alleged offender may complete details of the person that they may wish to nominate as the driver of the vehicle at the time, as well as information relating to what the alleged offender may do if he or she disagrees with the allegation. The notice may also include a scanned signature of the police officer that authorized the incident for issuing as an offense, and a scanned signature of the person that issued the notice.

[**0174**] Depending upon the computer implementation, the report preview function may also allow the user to manipulate the notice file, such as print to the notice to a selected printer, or export the notice to an HTML or text file.

[**0175**] In one embodiment of the present invention, an alleged offender may claim they are innocent and subsequently nominate another driver. There are two methods whereby a person may do this. First, the Notice to Appear will have a section on it that the person may complete and return to the party that issued the notice, or the person may complete a Certificate of Innocence at a police station and the police will forward it to the issuing party.

[**0176**] The data provided by the traffic violation monitoring and reporting system constitutes legal evidence that can be used to convict a traffic offender for a traffic violation. In one embodiment of the present invention, the evidentiary package consists of a copy of the notice to appear, in addition to other documents, which are not necessarily produced by the system. Such documents could include information supplied by the court, a chain of evidence testifying as to the integrity of the image data, and a statement of technology.

[**0177**] Image Analysis Expert Systems

[**0178**] In one embodiment of the present invention, an image analysis system to automate components of the data processing system is implemented. Image analysis is a process of discovering, identifying and understanding patterns that are relevant to the performance of an image-based task. One such task is the ability to automatically locate and read license plate information in evidentiary images. Here the pattern of interest is license plate shapes and alphanumeric characters. The goal of the image analysis is to automatically locate these objects and perform character recognition with the accuracy of a human operator.

[**0179**] The advantage of an image analysis system in the verification process of the data processing system would be that all vehicle, owner and incident details can be provided for visual verification at a first instance all complete and thus requiring little or no manual data entry.

[**0180**] The elements of image analysis can be categorized into three basic areas, low level processing, intermediate level processing, and high level processing. The categories form the basis of a framework in describing the various processes that are inherent components of an autonomous image analysis system.

[**0181**] Low level processing deals with the functions that may be viewed as automatic reactions that require no intelligence on the part of the image analysis system. This classification would encompass image compression and/or conversion such as the application of a standard set of filters for image processing.

[**0182**] Intermediate level processing deals with the task of extracting and characterizing components or regions in an image for low level processing. This classification encompasses image segmentation and description that is the isolation, extraction and categorizing of objects within an image.

[**0183**] High level processing involves the recognition and interpretation of the extracted objects. The application of intelligent behavior is most apparent in this level as it entails the capacity to learn from example and to generalize this knowledge so that it can be applied in new and different circumstances.

[**0184**] Image analysis systems utilizing Expert Systems technology, can be used to accurately identify, extract, and translate areas of interest imprinted or appearing in images recorded by the enforcement camera system of **FIG. 1A**. In general, the technology requires the acquisition of knowledge through a process of extracting, structuring, and organizing knowledge from one source so it can be used in software. There are three main areas central to knowledge acquisition that requires consideration in the development of the image analysis expert system. First, the domain must be evaluated to determine if the type of knowledge in the domain is suitable for the image analysis expert system. Second, the source of expertise must be identified and evaluated to ensure that the specific level of knowledge required by the image analysis expert system is provided. Third, the specific knowledge acquisition techniques and participants need to be identified.

[**0185**] The objective of the image analysis expert system is to accurately identify, extract and translate optical data appearing in the photographic evidence captured by any type of enforcement camera systems.

[**0186**] Many film based camera systems optically imprint textual information of the offense onto each photograph. For example speed enforcement camera systems imprint onto each image; information such as measured speed and direction the offending vehicle was travelling, the speed zone and location the camera was monitoring, the operator ID supervising the deployment, and the time and date of the offense. The process can also be applied in the identification and extraction of license plate vehicle details that can be used to identify the offending vehicle owner.

[**0187**] The image analysis expert system knowledge base can be derived from a range of sources such as textbooks,

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manuals and simulation models, although the core knowledge is derived from human experts. The human experts themselves may not necessarily be a technical resource, but may include the operators or users of the system that make decisions based upon known business processes rather than technical issues. This type of inferred knowledge obtained indirectly by these experts does provide a useful resource for the knowledge base.

[0188] Knowledge acquisition embodies several processes and methodologies to capture, identify, and extract knowledge. Although fundamentally, knowledge is obtained from human experts which provides the static core or base line, the image analysis expert system can derive it's own dynamic knowledge by establishing trends or common themes, in essence drawn from it's own experience. The system achieves this ability through a unique feedback and tracking mechanism provided by the data processing system **104**. The system has the ability to determine if the information provided is correctly within a relatively short time (in some cases instantly—using any inherent validating features that may be incorporated in the extract data such as a checksum).

[0189] However, with traditional expert systems, information derived is based on a conclusion made from a set of inputs with no mechanism validating the result, thus if the same inputs are feed into the expert systems the same conclusions are made. With either expert system, knowledge acquisition is typically achieved by observing an expert solve real problems, through discussions, by building scenarios with the expert that can be associated with different problem types, developing rules based on interviews and solving the problems with them, and other similar ways. In addition to these methods of knowledge acquisition, the image analysis expert system can also draw knowledge from inferred knowledge obtained by the verification and adjudication processes' audit trail, allowing more than one result for the same set of inputs, accessing external or other indirect sources of inputs available in the problem domain, and other similar methods.

[0190] The image analysis expert system and image computer are the primary components of the image processing system used in the traffic camera office system employing an automatic infringement processing system. The image computer provides the system with all the offense information in electronic form required in issuing an infringement notice.

[0191] For a speed infringement, the image processing system will provide two digital images of each offense, one a low-resolution version representative from a digital version of the original image, the other a high-resolution extraction of the license plate area only. In addition, textual offense details appearing in captured image is extracted using Optical Character Recognition (OCR) processes.

[0192] **FIG. 5** illustrates a typical speed camera offense output provided by the image processing system, according to one embodiment of the present invention. In **FIG. 5**, the output screen **500** includes several different image areas. An image of the offense is displayed in display area **502**. A close-up image of the license plate of the offending vehicle is shown in display area **504**, and the details of the offense are displayed in display area **506**. This information is validated and confirmed by two separate manual processes before the actual infringement is issued. A traffic camera office infringement processing system typically consists of a high-speed film scanner providing images for the image computer to process under the control of a file arbitrator. Infringement information is automatically extracted by the image computer and stored into a database for manual verification and adjudication at the verification station.

[0193] **FIG. 12** illustrates the traffic camera office infringement processing system components, according to one embodiment of the present invention. Also illustrated in **FIG. 12** are the components that are encompassed by the image processing system.

[0194] Raw digital images of the offenses either obtained directly from the field digital cameras or scanned 35 mm wet film converted into a digital form. The file arbitrator **1202** provides serialized access to the raw offense data. The image computer **1214** within the image processing system **1210** performs the primary image analysis tasks and is the primary interface between database **1208** and the raw digital images **1216**. A verification station **1206** provides a mechanism of visual manual adjudication of actual offense and information provided by the image processing system **1210**. If the information provided is correct and the offense complies with all appropriate business rules then the infringement is issued to the vehicle owner.

[0195] The supervisor station **1204** is used to validate any offense that may have been rejected during the verification and adjudication process of the traffic camera office business flow. Database **1208** may be a relational database, such as an Ingress™ Relational Database system running under a UNIX™ operating system under the HP-9000™ platform. It provides the central repository for all data including offense images and data, audit trail and archiving.

[0196] In one embodiment, the image analysis expert system **1220** provides the image processing system **1210** with human expert like behavior, thus endowing the image computer essentially with Artificial Intelligence to solve problems efficiently and effectively.

[0197] Regardless of enforcement type all infringement images are returned to the traffic camera office for processing including all the infringement details in an electronic form as well as a camera set-up and deployment log, which the operator is required to answer. The speed camera setup and deployment log contains useful information concerning the actual deployment conditions and environment, knowledge that can aid the image analysis process.

[0198] A file arbitrator **1202** detects the new image file, and initiates the image computer **1214** to start the image analysis process. The image computer then validates the image file, extracts from the file the area of the image bounding the data block (containing the offense details), segments and represents the characters within the data block, rebuilds missing or broken characters, and translates the character objects in the text by the process of OCR. Next, the license plate of the offending vehicle is searched. Once it is found, the area is extracted for OCR, the license plate details are determined, including jurisdiction. A low resolution JPEG compressed image representing the entire image is then produced, and a high resolution JPEG compressed image crop of the license plate area only is made. The image set and OCR text data is transferred to the database.

[0199] Once the data reaches the database, it is presented to the verification station for visual confirmation and adju

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dication by a trained operator. The normal process of the operator is to simply confirm the offense details automatically extracted by the image computer. Once these details have been confirmed, the vehicle owner details are searched and presented for content and syntax validation. Once the vehicle owner details are confirmed, the offense data is passed onto the quality system for inspection and issuing of an actual infringement notice.

[0200] Analyzing the process or work flow of the traffic camera office infringement processing system reveals several opportunities for the image analysis expert system to acquire and infer knowledge. From the beginning of the enforcement processing cycle, even before the film reaches the traffic camera office, the knowledge acquisition is occurring.

[0201] For instance, the speed camera setup and deployment log provide the image analysis expert system useful dynamic or temporary knowledge about the deployment configuration and environment that can be useful in the license plate extraction and OCR process. Information describing the weather condition, traffic direction and condition, the number of lanes monitored, and the lane the first few offending vehicles were traveling in, all provide useful information for the image processing system. Even though the acquired knowledge is stored temporarily (until the complete deployment has been successfully processed) archival information can also be created/updated about the camera and deployment location to help establish constants or trends (that is a site/camera profile).

[0202] Once the film data is stored into the main database, the image analysis expert system can access this data when each image computer starts processing a new image file. Since the first task of the image computer is to interpolate the data block area, the image analysis expert system can supply the imaging computer with the best data block location in the image. Accompanying this knowledge would also be the best extraction and OCR process to use (including the best performing parameters).

[0203] In the event that the processing scenario provided was unsuccessful, the image analysis expert system can provide information on alternative extraction and OCR processes. Both failures and successes are recorded by the image analysis expert system, improving the knowledge base, and hence the image processing performance and efficiency. Here the success and failure knowledge is known in real time with the aid of the check digit feature of the data block.

[0204] Next the image computer begins the license plate search and extraction process. Again the image analysis expert system can instruct the image computer to perform this process with the best performing algorithms and parameter scenario so far. Here the feedback of success or failure of the process is delayed as no automatic successful/failure mechanism exists (as with the data block check digit feature). Although the license plate location can be confirmed with the aid of the deployment log (for speed offenses) for at least the first few recorded offenses. Here the camera operator is required to record against each frame number which lane the offending vehicle was travelling.

[0205] However, until the offense is viewed at the verification station the actual image analysis performed by the image computer cannot be validated and hence the image analysis expert system cannot acquire the knowledge unless a verification priority is placed on the first few images of each new film or deployment.

[0206] The actual verification process can also influence the knowledge acquiring process of the image analysis expert system by prompting the verification operator with simple questions each time a correction is made to any part of the provided offense data. Alternative knowledge can be inferred by analyzing the corrections and business rule rejection to determine why the selected process for that particular infringement was unsuccessful.

[0207] **FIG. 13** illustrates the functional components of the image analysis expert system **1220**, according to one embodiment of the present invention. The acquiring module **1302** provides the knowledge database with real time knowledge deduced/provided by the image computer, inferred knowledge received directly from the verification station or analyzed from the system audit trail/system, or direct knowledge acquired from the traffic camera office infringement processing database.

[0208] The knowledge provider **1304** is the primary interface to the image computers, and provides the image computers with the necessary information and parameters to perform the required image processing tasks.

[0209] The local database **1306** serves as the central repository for all knowledge, performance statistics, short and long term data and configuration parameters for the image computers. The local database also serves as storage for neural network training set and template characters.

[0210] The knowledge graphical user interface (GUI) provides the user with the ability to display, modify, and delete the knowledge and database data. The knowledge GUI also allows the updating configuration parameters, character templates used by the OCR process and neural net training.

[0211] The image analysis expert system provides the image computer with a predefined scenario or collection of rules to follow to achieve a successful image analysis outcome. Unlike other Expert Systems, the combination of processing scenarios is relatively few since there is only a limited number of ways a data block of an offense image can be extracted. However, the image analysis expert system of the present invention is generally able to make adjustments to the parameters used by each process or rule, and therefore has an adaptive ability. This is achieved by deliberately varying these parameters and tracking or tracing the results through the system.

[0212] This mechanism of fine tuning the scenarios (or in some cases applying different scenarios all together) is called "sampling". Sampling is a mechanism employed by the image analysis expert system to effectively perform tests by deliberately applying different image processing scenarios or parameter adjustments to improve the performance.

[0213] In one embodiment, this type of operation is performed at the beginning of a new deployment or film and randomly through each batch. The changes are tracked through the traffic camera office infringement processing system. Information on the success or failure is analyzed, allowing for real time fine-tuning of the system. Although the knowledge obtained may only be used on a temporary basis (that is only for the current batch), trends can be recorded and if need be the static knowledge can be upgraded.

[0214] In reference to the image processing system, a 'scenario' is a collection of image processing rules by which the image computer follows to produce a successful image

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analysis outcome. The mechanism by which these rules are stored and the knowledge endowed to the image computer depends on the level of sophistication employed by the image processing system.

[0215] Performance monitoring is a method of fine-tuning or detecting poor image analysis outcomes. The mechanism used is simply the correlation and analysis of statistics derived from real-time data allowing for the fine-tuning that may be required due to small differences or abnormal deployment conditions which were not catered for as part of the fundamental knowledge. Scenario statistics are a second type of statistical data that can be correlated based upon direct scenario outcomes and scenario variants with different parameter values.

[0216] A primary component of the knowledge acquiring module of the image analysis expert system is an expert system that infers knowledge from the verification station. Knowledge such as commonly made OCR mistakes (that is, characters which a regularly incorrectly recognized), invalid license plate selection, incorrect dynamic extraction thresh hold, and other such information is used in deducing as a result of sampling.

[0217] An important requirement of this module, particularly when tracing sampling mode images, is the correct identification of the image itself. A common theme or key must be employed by the verification module, audit system, database, image computer and image analysis expert subsystems.

[0218] Access to main traffic camera office infringement processing database can provide indirect knowledge to the image analysis expert system that cannot be obtained directly from the images or verification process. For example, deployment log information and other additional film and location information provide useable knowledge for the image analysis expert system and image computers.

[0219] The core of the image analysis expert system contains all the image processing knowledge and image computer configurational/operational parameters. The local database encompasses both static and dynamic data. The structure of the database may vary depending on the form of the knowledge and data. Character templates and Neural Network training sets may also be stored on this database.

[0220] Although embodiments of the present invention have been described as deployed in traffic environments involving red light or stop sign offenses at intersections, it is to be noted that alternative embodiments can be deployed in other traffic environments. For example, the traffic violation monitoring and reporting system can be deployed and used along a stretch of road to determine if vehicles are speeding.

[0221] Moreover, embodiments may include facilities for issuing multiple offenses for a single incident. For example, a red light camera with speed tracking can detect and record a speeding vehicle running a red light. The multiple notice may be in the form of separate notices, one for the red light offense and one for the speeding offense, or one notice recording all offenses.

[0222] Image Security

[0223] Embodiments of the present invention incorporate various methods to ensure the security and integrity of the digital images obtained at the target intersection. In one embodiment of the present invention, public key cryptography methods are utilized in the functionality of the digital camera imaging system. The original violation evidence is encrypted at the point of capture in the digital camera system **102** of **FIG. 1A**. As each pixel within the CCD is discharged outside the module, they are converted into a digital stream and encrypted in real time preserving its original raw form. Applying this process at this early stage eliminates the need for special purpose peripheral devices for the storage, transfer, and handling of data.

[0224] In one embodiment of the present invention, variations of known public-key and secret-key encryption systems are used to implement digital envelope cryptography for the digital traffic camera system. Each camera system is assigned a unique digital certificate that is recreated whenever there is any alteration to the system. The certificate nominates relevant system details including the camera's serial number and supplies an identifiable public key for the particular camera system. Later, this public key is used to identify the specific source for each set of evidence reaching the data processing system.

[0225] As each offense occurs, the camera system collects relevant evidence which is comprised of a number of elements or 'properties', including the various image files, the speed data, the time of offense and so on. The camera system then uses all the details of its current, unique digital certificate to build a hash function by applying recognized public key cryptography 'hashing' algorithms. The hash function is a one-way equation that is used to 'sign' each property of the offense as it occurs with its own, unique digital signature.

[0226] The camera system then places each of the signed properties for an offense into an offense database and places this in the system's server outbox (using, for example, the Microsoft™ Message Queue server outbox). The outbox server then breaks all the information in the offense database into smaller, more easily transportable packets, or 'mini-envelopes', of information. It then applies another unique digital signature to each packet (using the public key techniques above).

[0227] Where there are remote communications such as telephone, ISDN, fiber optic, and so on, between the camera site and the data processing system, the signed packets can be electronically transferred over the Internet for processing using a Virtual Private Network. In one embodiment, the data processing system server secures the transmission process by using IP SEC, a standard Internet protocol that is widely used to protect electronic transmissions over unprotected public networks.

[0228] Where there is no remote communication to the camera site, the signed packets may be either downloaded to removable media (e.g., disks), for physical transport to the data processing system, or downloaded to a camera operator's mobile computer for transfer to the system.

[0229] Each signed packet is received at the data processing system by the data processing system's outbox server, which decrypts the mini-envelope packets and automatically checks the authenticity of their signatures. The original offense database is then reassembled from its various signed properties to recreate the original offense file.

[0230] The unique digital signature on each property is then authenticated to identify the source of the property (thus defining the camera that originally captured the evidence), and verify the integrity of that property (by confirming that its original digital signature is intact and unaltered). The original properties with their intact,

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authenticated digital signatures are then stored as the original database (i.e., primary evidence) for the offense.

[0231] The data processing system then selects the data and image items required for citation processing, copies these, and works on the duplicates. The original files with their intact, authenticated, digital signatures are stored separately as the protected primary evidence for the offense. From then, every access or attempted access is logged to an audit chain so the life of the offense is completely accountable.

[0232] Any files with scrambled signatures alerting corruption or alteration of evidence are not sent for processing. Processing can only proceed on evidence that has been confirmed as authentic. Such an encryption and authorization system is useful for deployment in jurisdictions that allow the introduction of digital evidence.

[0233] The application of digital signatures for traffic law enforcement for the purposes of offense authentication provides for a method of securing data integrity that is independent of the media that it is stored and/or transmitted on. The process provides for mechanism of identifying the capture source (that is the camera system) and legitimacy.

[0234] As illustrated in the figures of the present application and described herein, aspects of the present invention may be implemented on one or more computers executing software instructions. According to one embodiment of the present invention, server and client computer systems transmit and receive data over a computer network or standard telephone line. The steps of accessing, downloading, and manipulating the data, as well as other aspects of the present invention are implemented by central processing units (CPU) in the server and client computers executing sequences of instructions stored in a memory. The memory may be a random access memory (RAM), read-only memory (ROM), a persistent store, such as a mass storage device, or any combination of these devices. Execution of the sequences of instructions causes the CPU to perform steps according to embodiments of the present invention.

[0235] The instructions may be loaded into the memory of the server or client computers from a storage device or from one or more other computer systems over a network connection. For example, a client computer may transmit a sequence of instructions to the server computer in response to a message transmitted to the client over a network by the server. As the server receives the instructions over the network connection, it stores the instructions in memory. The server may store the instructions for later execution, or it may execute the instructions as they arrive over the network connection. In some cases, the downloaded instructions may be directly supported by the CPU. In other cases, the instructions may not be directly executable by the CPU, and may instead be executed by an interpreter that interprets the instructions. In other embodiments, hardwired circuitry may be used in place of, or in combination with, software instructions to implement the present invention. Thus, the present invention is not limited to any specific combination of hardware circuitry and software, nor to any particular source for the instructions executed by the server or client computers.

[0236] In the foregoing, a system has been described for automatically monitoring and reporting instances of traffic violations that incorporates both still photo and video data. Although the present invention has been described with reference to specific exemplary embodiments, it will be evident that various modifications and changes may be made to these embodiments without departing from the broader spirit and scope of the invention as set forth in the claims. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense.

What is claimed is:

1. A camera system for monitoring and reporting a potential traffic violation, comprising:

one or more digital still cameras mounted at a fixed traffic location;

one or more digital video cameras mounted at the fixed traffic location;

a detection system configured to detect when a vehicle has improperly crossed a reference point at the fixed traffic location;

a buffer memory for storing video data recorded by the one or more digital video cameras

a data processing system coupled to the enforcement camera system, the data processing system comprising an image processor for compiling vehicle and scene images produced by the one or more digital still cameras, an integration system for combining the vehicle and scene images with a portion of the video data recorded by the one or more digital video cameras.

2. The system of claim 1 further comprising a timer coupled to the detection system, and wherein the enforcement camera system is configured to start the timer upon a detection by the detection system of a potential traffic violation by the vehicle.

3. The system of claim 2 further comprising a video clip recorder configured to extract from the buffer a video clip of the potential traffic violation.

4. The system of claim 3 further wherein the video clip comprises a first portion corresponding to a first predetermined number of seconds prior to the occurrence of the potential traffic violation and a second portion corresponding to a second predetermined number of seconds from the occurrence of the potential traffic violation to the end of the timer period.

5. The system of claim 1 wherein the detection system comprises one or more inductive loops embedded in the road surface proximate the fixed location, the inductive loops operable to sense the presence of the vehicle through a change in magnetic field.

6. The system of claim 6 further comprising one or more piezo-electric strips placed adjacent to the one or more inductive loops, the piezo-electric strips operable to sense the presence of the vehicle through pressure exerted by the weight of the vehicle.

7. The system of claim 1 wherein the detection system comprises a virtual loop digital signal processing module, wherein a virtual loop is defined in the field of view recorded by the one or more video cameras, and the module is operable to sense the presence of the vehicle when it is at least partially present in an area defined by the virtual loop at an improper time.

8. The system of claim 2 wherein the data processing system further comprises a frame editor process operable to separate the frames of the portion of the video data recorded by the one or more digital video cameras into one or more

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individual frames, and to stamp each of the individual frames with data regarding the potential traffic violation.

9. A method of producing primary evidence of a traffic violation at a traffic location, comprising the steps of:

generating a plurality of digital still images of the traffic violation;

storing the still images in a primary image database;

generating a video clip of the traffic violation comprising a first period of time prior to the traffic violation and a second period of time during and after the traffic violation;

storing the video clip in a secondary image database; and

associating the video clip with the still images for on-line review by law enforcement personnel.

10. The method of claim 9 further comprising the steps of:

obtaining a continuous video loop of the traffic location from the video;

storing the continuous video loop in buffer memory;

detecting the occurrence of the potential traffic violation;

starting a timer upon the detection of the occurrence of the potential traffic violation;

stopping the timer upon completion of the timer period; and

extracting a video clip of the potential traffic violation corresponding to a predetermined time period prior to detection of the occurrence of the traffic violation to the completion of the timer period.

11. The method of claim 9 wherein the detection step comprises the step of detecting the presence of the vehicle in an unlawful position in the fixed traffic location through a change in a magnetic field in a location proximate the fixed traffic location.

12. The method of claim 11 wherein the detection step comprises the step of detecting the presence of the vehicle at an unlawful speed in the fixed traffic location through the use of piezo-electric sensors sensing the weight of the vehicle as its tires pass through the fixed traffic location.

13. The method of claim 9 wherein the detection step comprises the steps of:

defining in the field of view recorded by the one or more video cameras, a virtual loop; and

detecting the presence of the vehicle in an unlawful position in the fixed traffic location through the presence of the vehicle when it is at least partially present in an area defined by the virtual loop at an improper time.

14. The method of claim 10 further comprising the step of incorporating the video clip with the plurality of images for review by law enforcement personnel.

15. The method of claim 9 further comprising the steps of:

separating the video clip into one or more separate frames; and

editing each frame of the one or more separate frames to include data regarding the potential traffic violation.

16. The method of claim 9 wherein the plurality of images are obtained by a digital still camera system located at a fixed traffic location, and wherein the video loop is obtained by a digital video camera system located at the fixed traffic location.

17. The method of claim 10 wherein the plurality of still images and video clip are provided to a user through a web-based display interface, and wherein the video clip is displayed in a sub-window provided in the interface.

18. A camera system for monitoring and reporting a potential traffic violation, comprising:

one or more digital video cameras mounted at the fixed traffic location;

a detection system configured to detect when a vehicle has improperly crossed a reference point at the fixed traffic location;

a buffer memory for storing video data recorded by the one or more digital video cameras;

a video clip recorder configured to extract from the buffer a video clip of the potential traffic violation; and

a data processing system coupled to the enforcement camera system, the data processing system comprising an image processor for compiling vehicle and scene images produced by the one or more digital cameras, and a frame editor process for extracting still photo data from the video data.

19. The system of claim 16 further comprising a timer coupled to the detection system, and wherein the enforcement camera system is configured to start the timer upon a detection by the detection system of a potential traffic violation by the vehicle.

20. The system of claim 19 further wherein the video clip comprises a first portion corresponding to a first predetermined number of seconds prior to the occurrence of the potential traffic violation and a second portion corresponding to a second predetermined number of seconds from the occurrence of the potential traffic violation to the end of the timer period.

21. The system of claim 18 wherein the detection system comprises one or more inductive loops embedded in the road surface proximate the fixed location, the inductive loops operable to sense the presence of the vehicle through a change in magnetic field.

22. The system of claim 21 further comprising one or more piezo-electric strips placed adjacent to the one or more inductive loops, the piezo-electric strips operable to sense the presence of the vehicle through pressure exerted by the weight of the vehicle.

23. The system of claim 18 wherein the detection system comprises a virtual loop digital signal processing module, wherein a virtual loop is defined in the field of view recorded by the one or more video cameras, and the module is operable to sense the presence of the vehicle when it is at least partially present in an area defined by the virtual loop at an improper time.

* * * * *

Appendix M

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(54) **DIGITAL IN-CAR VIDEO SURVEILLANCE SYSTEM**

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(22) Filed: **Sep. 25, 2003**

Related U.S. Application Data

(60) Provisional application No. 60/441,631, filed on Jan. 21, 2003.

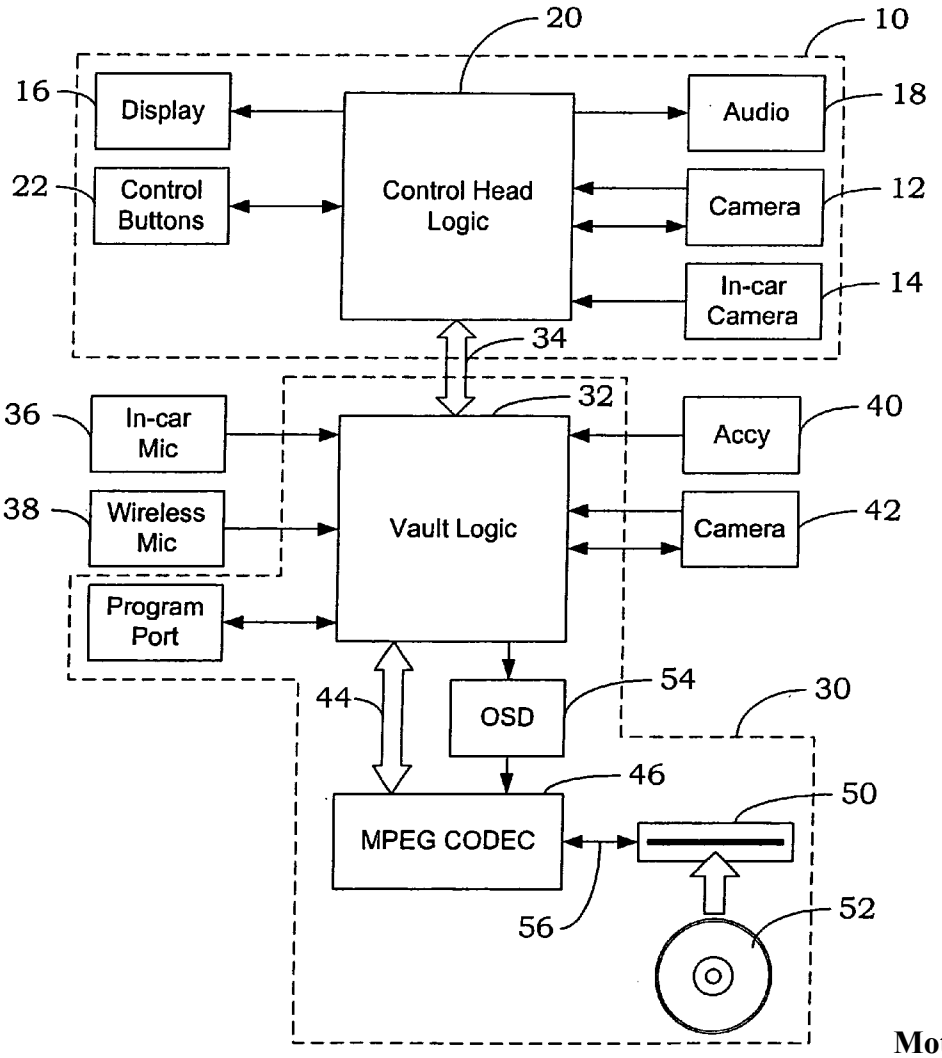
Publication Classification

(51) **Int. Cl.**[7] **H04N 7/18**

(52) **U.S. Cl.** **348/148**; 348/143

(57) **ABSTRACT**

A digital video surveillance system for a law enforcement vehicle comprises a video camera mounted on the law enforcement vehicle and positioned to view an incident. A memory buffer records video signals from the video camera. A controller generates record and playback signals to record and to display the video signals. A digital video recorder is responsive to the record signal to record the video signals from the memory buffer on an optical medium and to the playback signal to reproduce video signals recorded on the optical medium. A vault encloses the digital video recorder. A battery provides backup power to the digital video surveillance system. The optical medium may be a DVD disk. A watermark may be included with the digital recording.



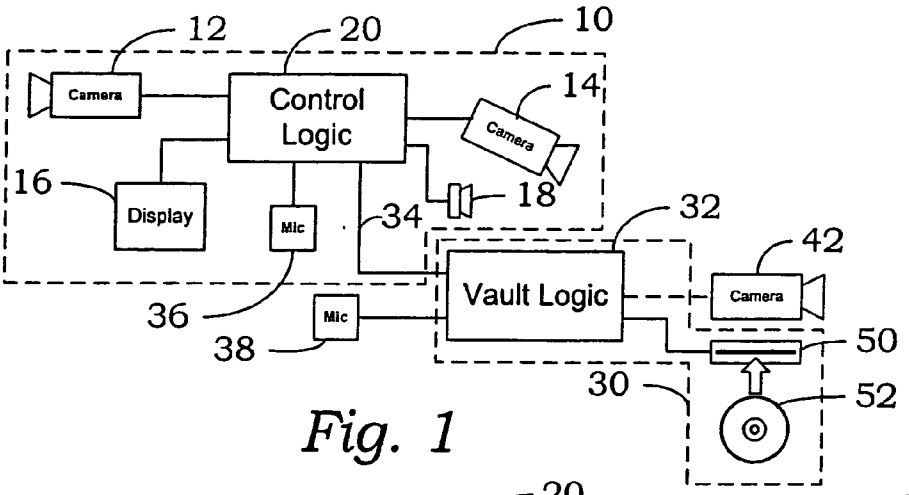

12
20
10
Camera
Control Logic
14
Camera
16
Display
Mic
34
18
32
42
Vault Logic
Camera
36
Mic
38
50
30
52

Fig. 1

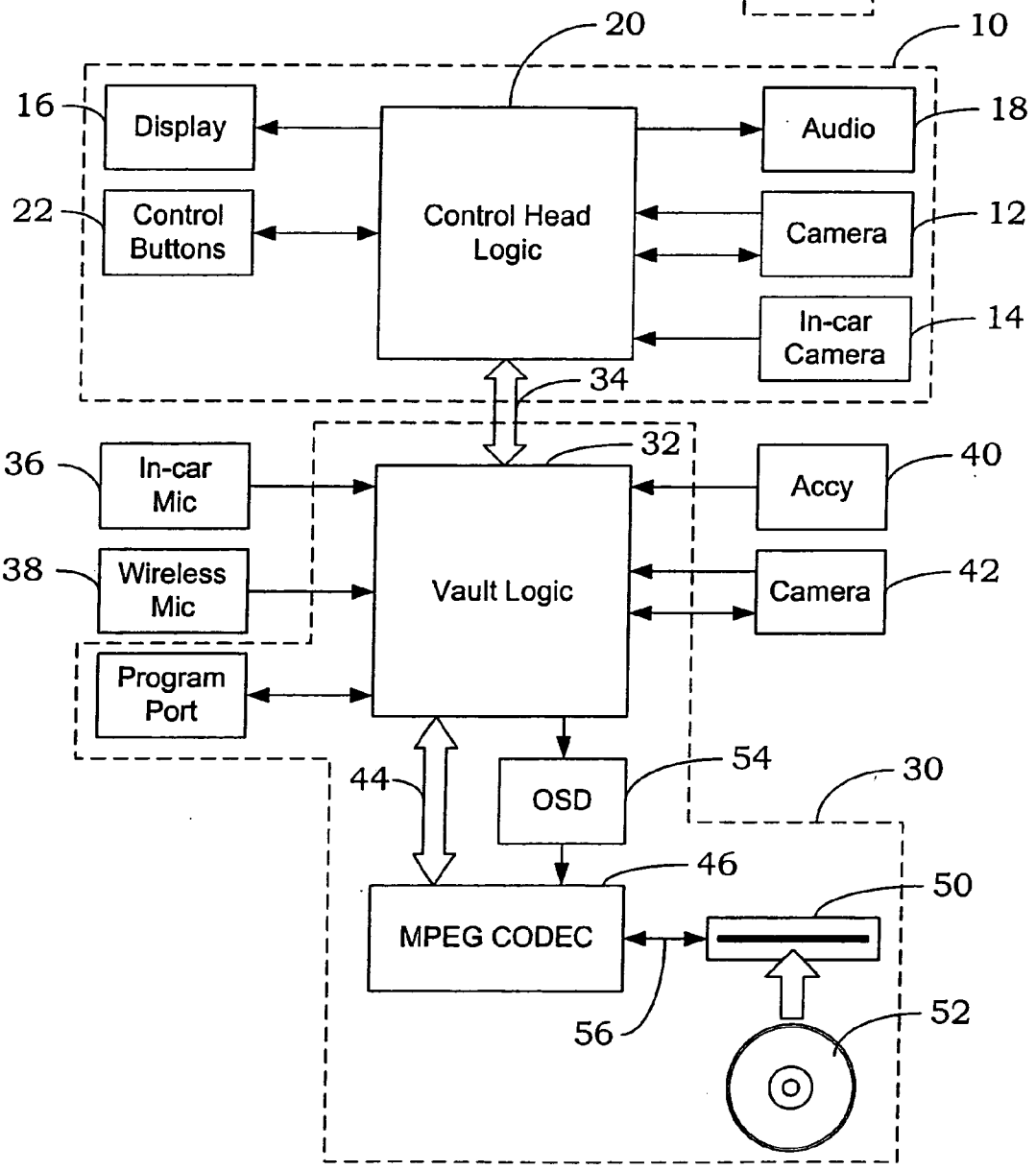

20
10
16
Display
Audio
18
22
Control Buttons
Control Head Logic
Camera
12
In-car Camera
14
34
36
In-car Mic
32
Accy
40
38
Wireless Mic
Vault Logic
Camera
42
Program Port
44
OSD
54
30
46
50
MPEG CODEC
56
52

Fig. 2

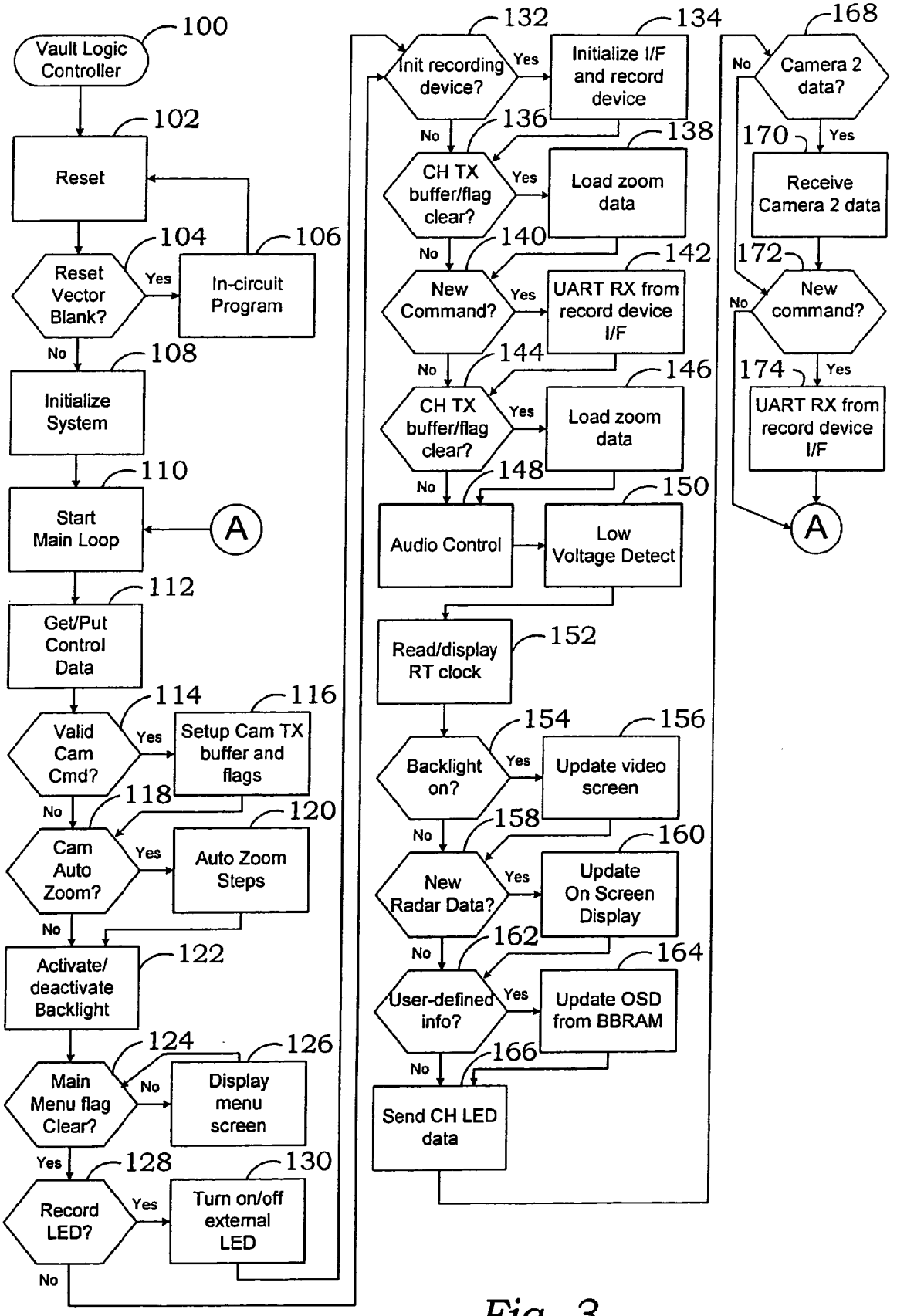

100
Vault Logic Controller
102
Reset
104
Reset Vector Blank?
Yes
106
In-circuit Program
No
108
Initialize System
110
Start Main Loop
A
112
Get/Put Control Data
114
Valid Cam Cmd?
Yes
116
Setup Cam TX buffer and flags
No
118
Cam Auto Zoom?
Yes
120
Auto Zoom Steps
No
122
Activate/ deactivate Backlight
124
Main Menu flag Clear?
No
126
Display menu screen
Yes
128
Record LED?
Yes
130
Turn on/off external LED
No
132
Init recording device?
Yes
134
Initialize I/F and record device
No
136
CH TX buffer/flag clear?
Yes
138
Load zoom data
No
140
New Command?
Yes
142
UART RX from record device I/F
No
144
CH TX buffer/flag clear?
Yes
146
Load zoom data
No
148
Audio Control
150
Low Voltage Detect
152
Read/display RT clock
154
Backlight on?
Yes
156
Update video screen
No
158
New Radar Data?
Yes
160
Update On Screen Display
No
162
User-defined info?
Yes
164
Update OSD from BBRAM
No
166
Send CH LED data
168
No
Camera 2 data?
170
Yes
Receive Camera 2 data
172
No
New command?
174
Yes
UART RX from record device I/F
A

Fig. 3

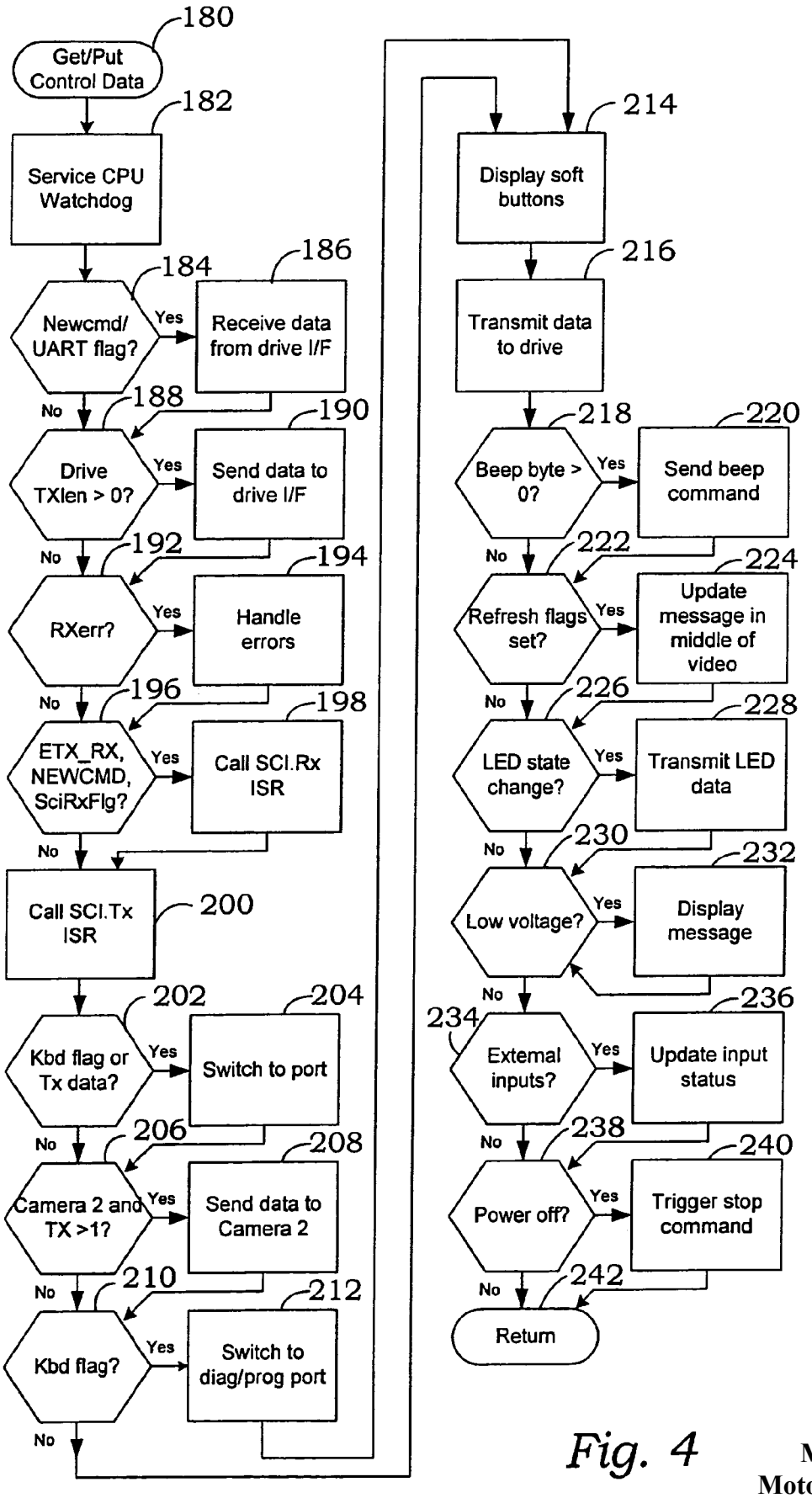

180
Get/Put Control Data
182
Service CPU Watchdog
184
Newcmd/ UART flag?
Yes
186
Receive data from drive I/F
No
188
Drive TXlen > 0?
Yes
190
Send data to drive I/F
No
192
RXerr?
Yes
194
Handle errors
No
196
ETX_RX, NEWCMD, SciRxFlg?
Yes
198
Call SCI.Rx ISR
No
Call SCI.Tx ISR
200
202
Kbd flag or Tx data?
Yes
204
Switch to port
No
206
Camera 2 and TX >1?
Yes
208
Send data to Camera 2
No
210
Kbd flag?
Yes
212
Switch to diag/prog port
No
214
Display soft buttons
216
Transmit data to drive
218
Beep byte > 0?
Yes
220
Send beep command
No
222
Refresh flags set?
Yes
224
Update message in middle of video
No
226
LED state change?
Yes
228
Transmit LED data
No
230
Low voltage?
Yes
232
Display message
No
234
External inputs?
Yes
236
Update input status
No
238
Power off?
Yes
240
Trigger stop command
No
242
Return

Fig. 4

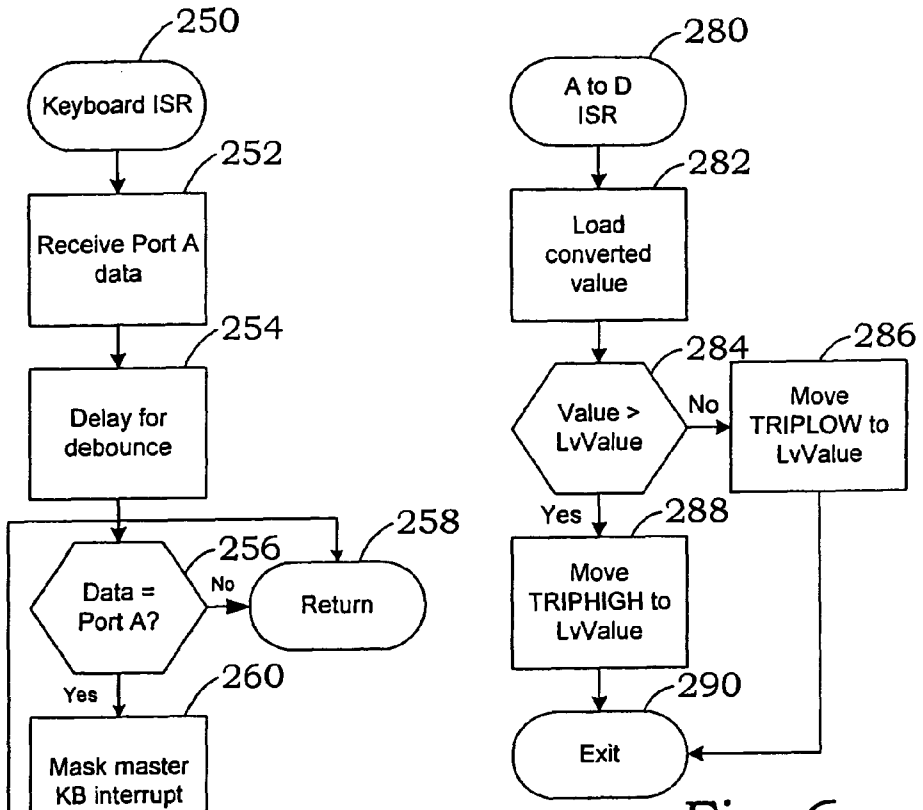

250
Keyboard ISR
252
Receive Port A data
254
Delay for debounce
256
Data = Port A?
No
258
Return
Yes
260
Mask master KB interrupt
280
A to D ISR
282
Load converted value
284
Value > LvValue
No
286
Move TRIPLOW to LvValue
Yes
288
Move TRIPHIGH to LvValue
290
Exit

Fig. 6

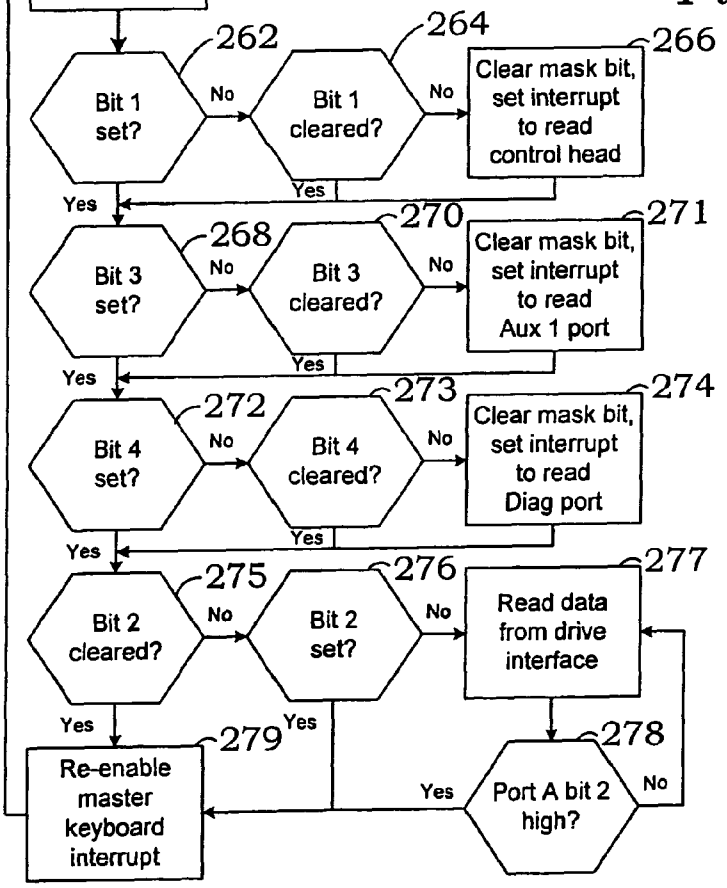

262
Bit 1 set?
No
264
Bit 1 cleared?
No
266
Clear mask bit, set interrupt to read control head
Yes
Yes
268
Bit 3 set?
No
270
Bit 3 cleared?
No
271
Clear mask bit, set interrupt to read Aux 1 port
Yes
Yes
272
Bit 4 set?
No
273
Bit 4 cleared?
No
274
Clear mask bit, set interrupt to read Diag port
Yes
Yes
275
Bit 2 cleared?
No
276
Bit 2 set?
No
277
Read data from drive interface
Yes
Yes
279
Re-enable master keyboard interrupt
Yes
278
Port A bit 2 high?
No

Fig. 5

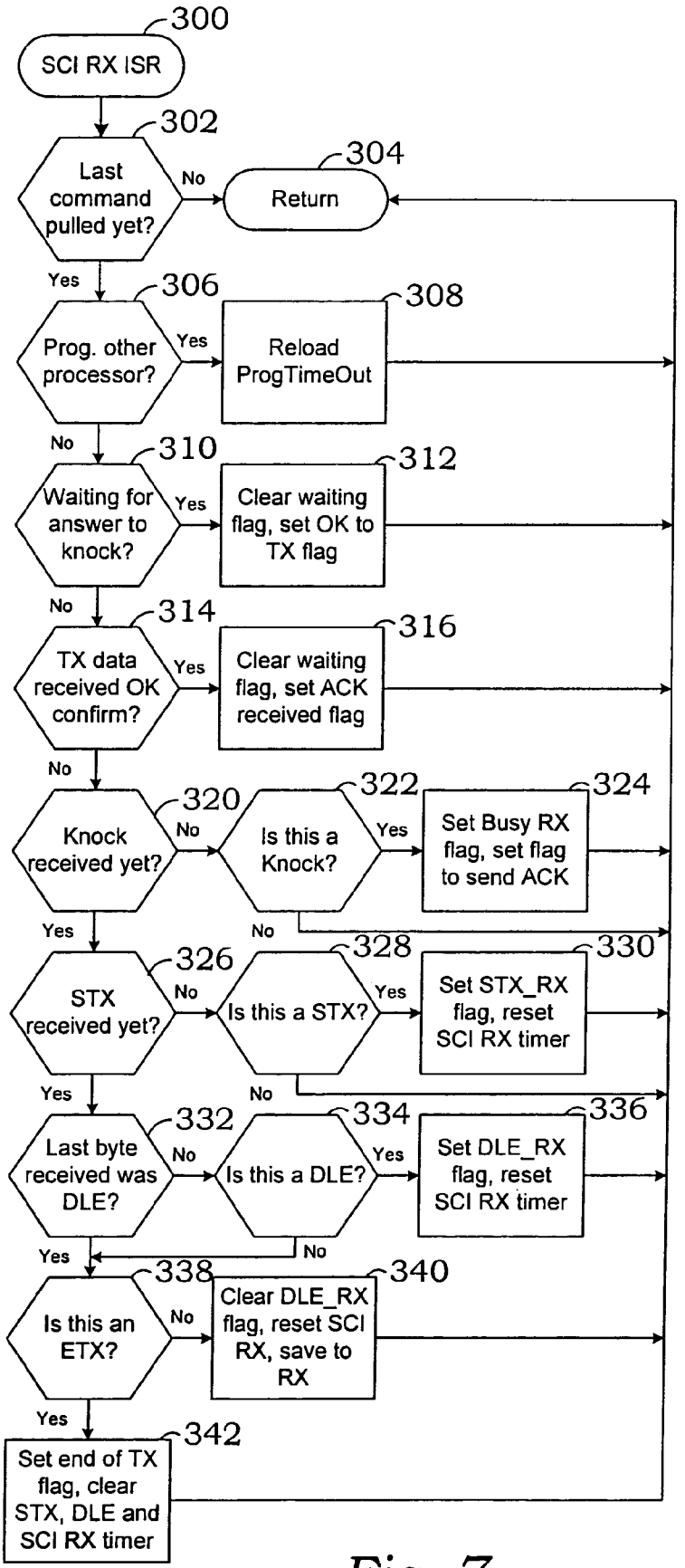

300
SCI RX ISR
302
Last command pulled yet?
No
304
Return
Yes
306
Prog. other processor?
Yes
308
Reload ProgTimeOut
No
310
Waiting for answer to knock?
Yes
312
Clear waiting flag, set OK to TX flag
No
314
TX data received OK confirm?
Yes
316
Clear waiting flag, set ACK received flag
No
320
Knock received yet?
No
322
Is this a Knock?
Yes
324
Set Busy RX flag, set flag to send ACK
Yes
No
326
STX received yet?
No
328
Is this a STX?
Yes
330
Set STX_RX flag, reset SCI RX timer
Yes
No
332
Last byte received was DLE?
No
334
Is this a DLE?
Yes
336
Set DLE_RX flag, reset SCI RX timer
Yes
No
338
Is this an ETX?
No
340
Clear DLE_RX flag, reset SCI RX, save to RX
Yes
342
Set end of TX flag, clear STX, DLE and SCI RX timer

Fig. 7

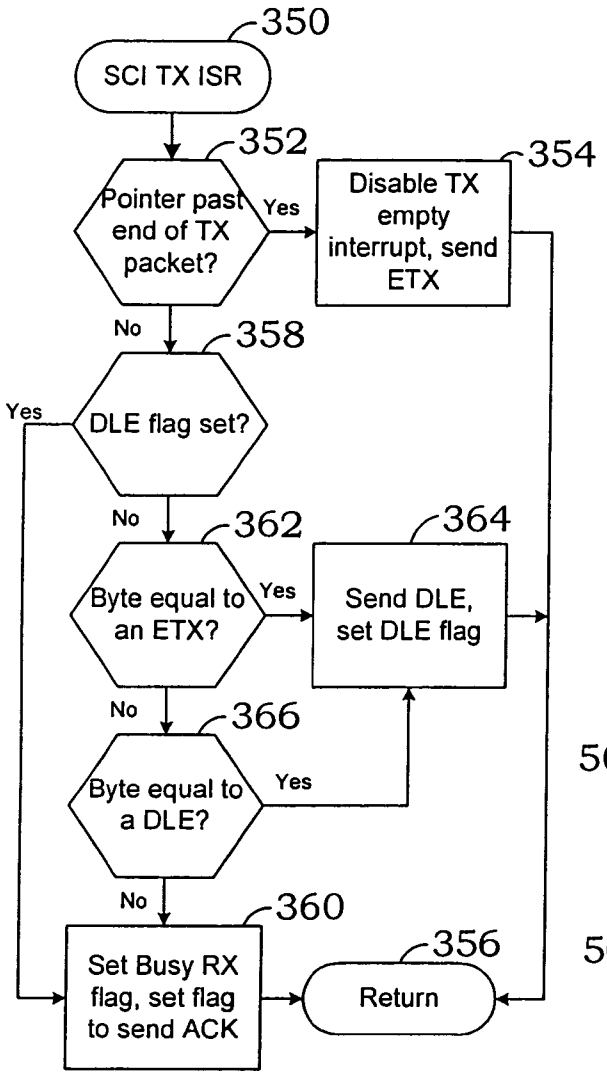

350
SCI TX ISR
352
Pointer past end of TX packet?
Yes
354
Disable TX empty interrupt, send ETX
No
358
DLE flag set?
Yes
No
362
Byte equal to an ETX?
Yes
364
Send DLE, set DLE flag
No
366
Byte equal to a DLE?
Yes
No
360
Set Busy RX flag, set flag to send ACK
356
Return

Fig. 8

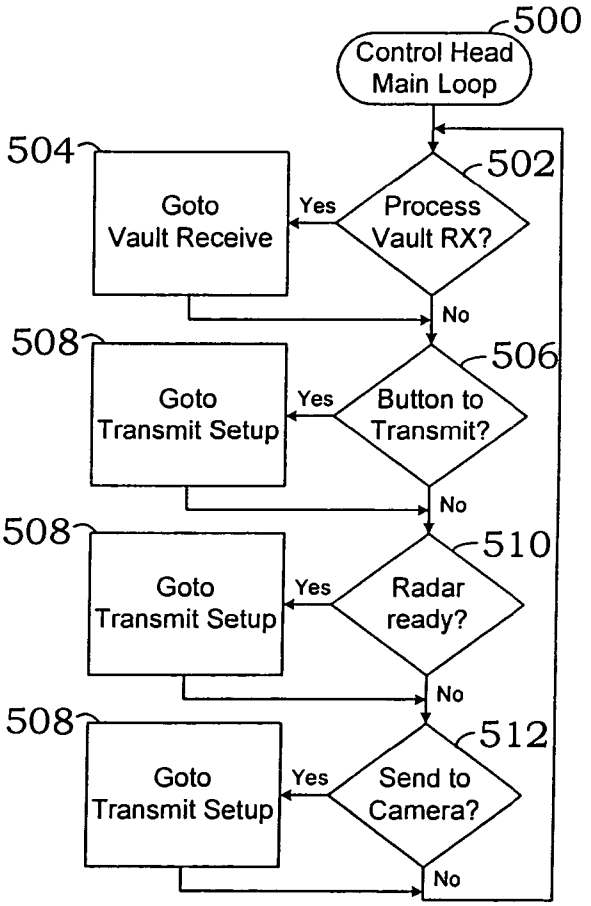

500
Control Head Main Loop
502
Process Vault RX?
Yes
504
Goto Vault Receive
No
506
Button to Transmit?
Yes
508
Goto Transmit Setup
No
510
Radar ready?
Yes
508
Goto Transmit Setup
No
512
Send to Camera?
Yes
508
Goto Transmit Setup
No

Fig. 9

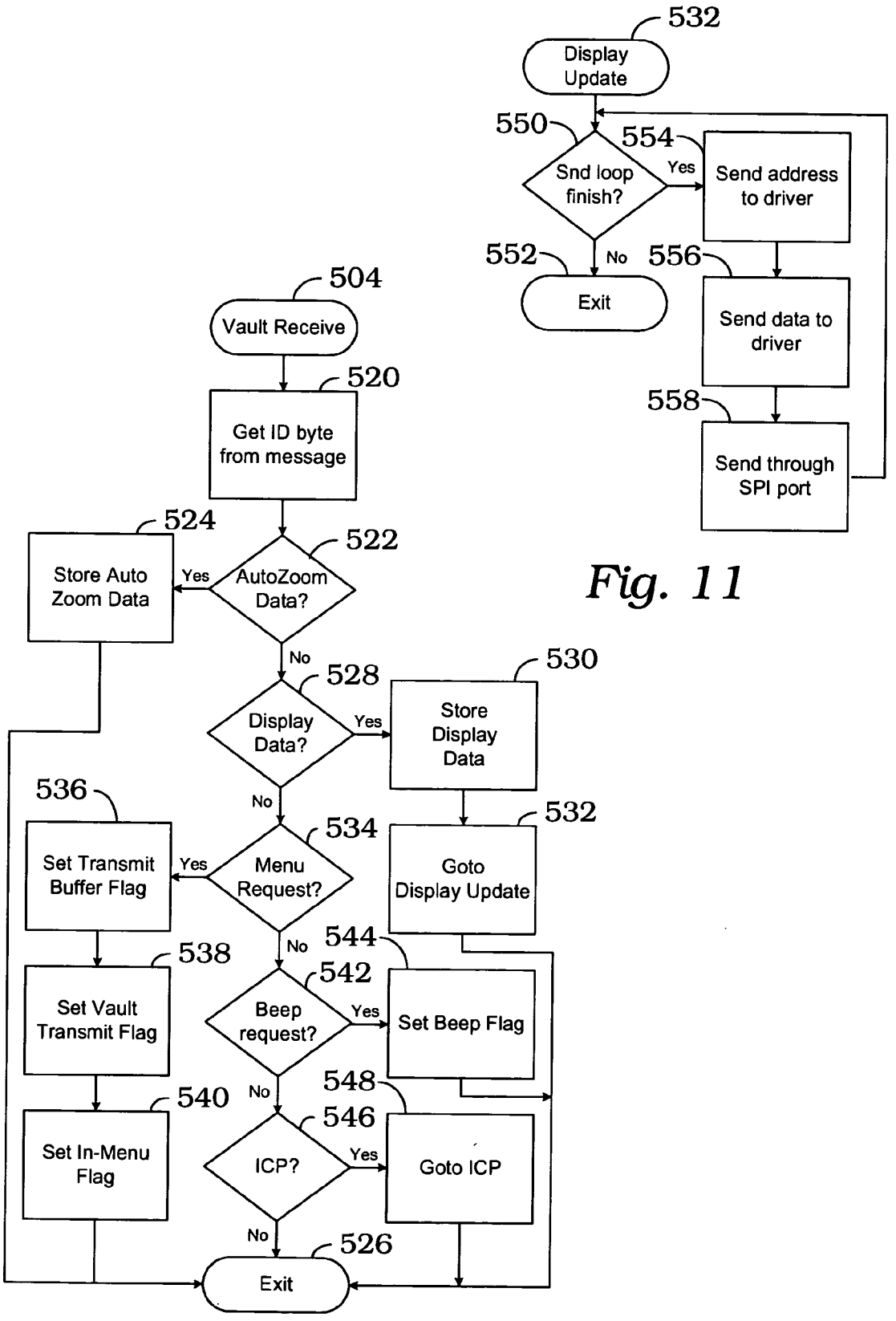

504
Vault Receive
520
Get ID byte from message
524
Store Auto Zoom Data
Yes
522
AutoZoom Data?
No
528
Display Data?
Yes
530
Store Display Data
No
536
Set Transmit Buffer Flag
Yes
534
Menu Request?
532
Goto Display Update
No
538
Set Vault Transmit Flag
542
Beep request?
Yes
544
Set Beep Flag
No
540
Set In-Menu Flag
546
ICP?
Yes
548
Goto ICP
No
526
Exit
532
Display Update
550
Snd loop finish?
Yes
554
Send address to driver
No
552
Exit
556
Send data to driver
558
Send through SPI port

Fig. 11

Fig. 10

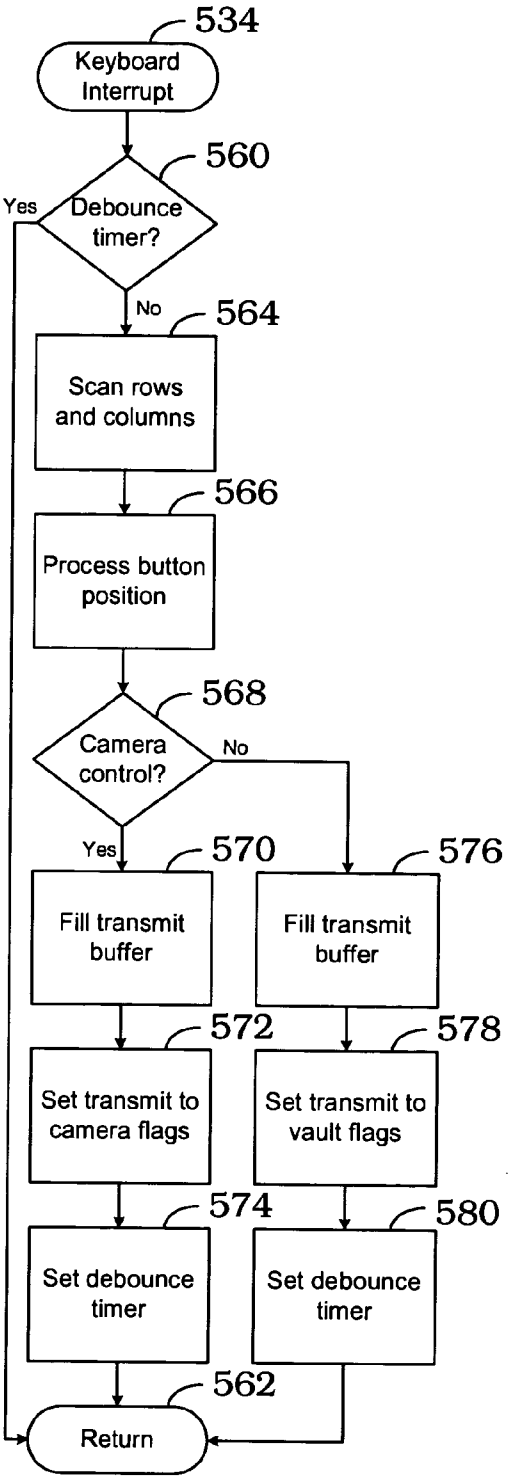

534
Keyboard Interrupt
560
Debounce timer?
Yes
No
564
Scan rows and columns
566
Process button position
568
Camera control?
No
Yes
570
Fill transmit buffer
576
Fill transmit buffer
572
Set transmit to camera flags
578
Set transmit to vault flags
574
Set debounce timer
580
Set debounce timer
562
Return

Fig. 12

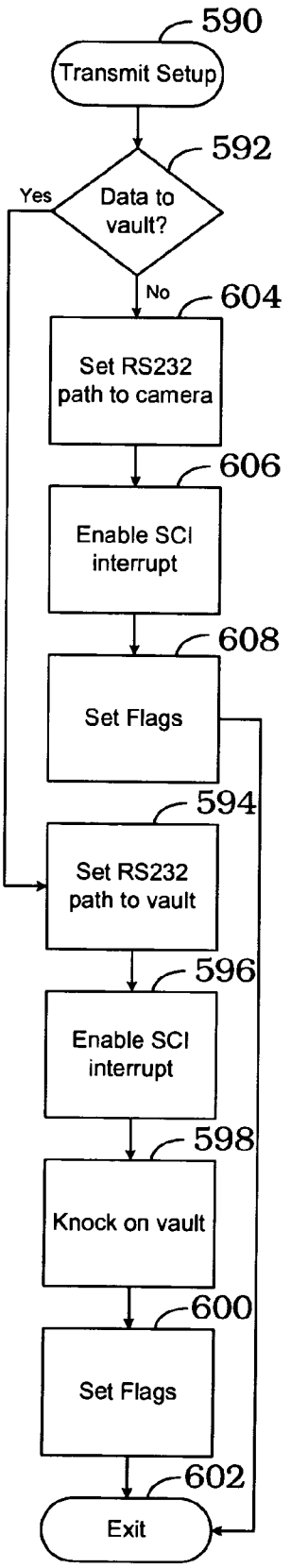

590
Transmit Setup
592
Data to vault?
Yes
No
604
Set RS232 path to camera
606
Enable SCI interrupt
608
Set Flags
594
Set RS232 path to vault
596
Enable SCI interrupt
598
Knock on vault
600
Set Flags
602
Exit

Fig. 13

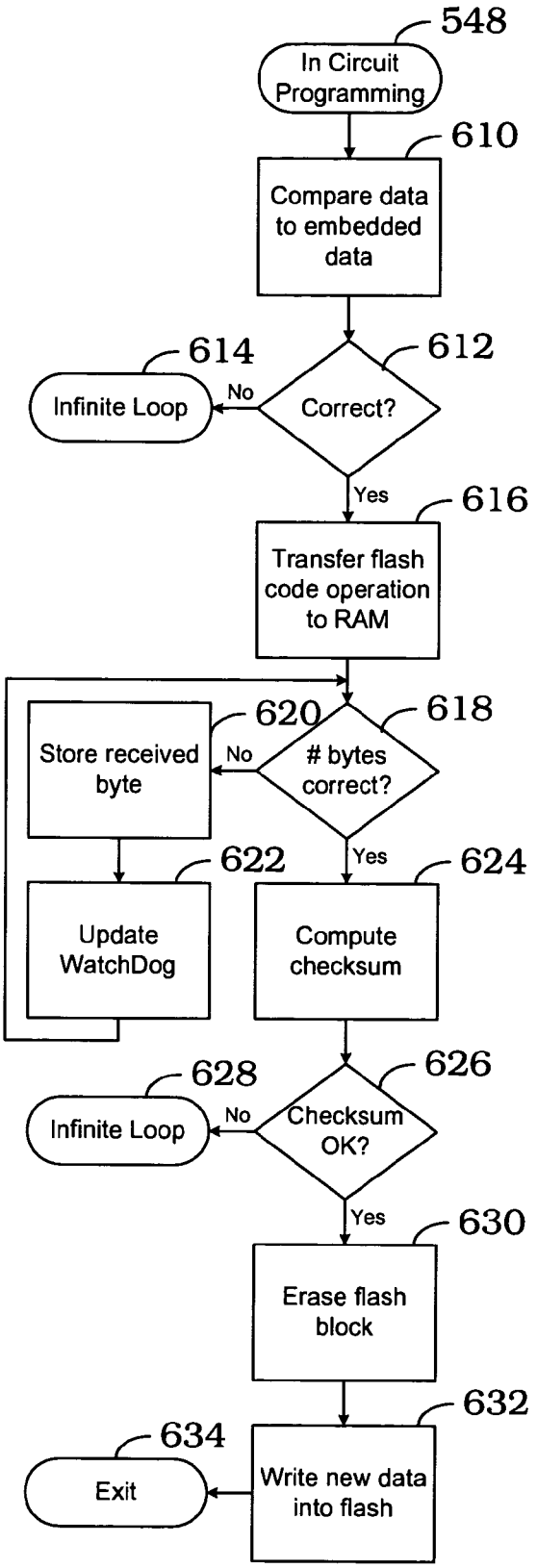

548
In Circuit Programming
610
Compare data to embedded data
614
Infinite Loop
No
612
Correct?
Yes
616
Transfer flash code operation to RAM
620
Store received byte
No
618
bytes correct?
Yes
622
Update WatchDog
624
Compute checksum
628
Infinite Loop
No
626
Checksum OK?
Yes
630
Erase flash block
632
Write new data into flash
634
Exit

Fig. 14

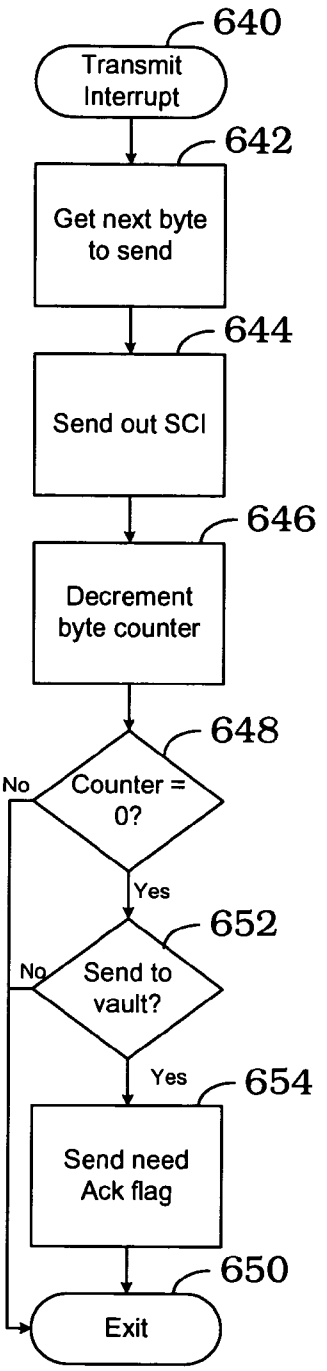

640
Transmit Interrupt
642
Get next byte to send
644
Send out SCI
646
Decrement byte counter
648
Counter = 0?
No
Yes
652
Send to vault?
No
Yes
654
Send need Ack flag
650
Exit

Fig. 15

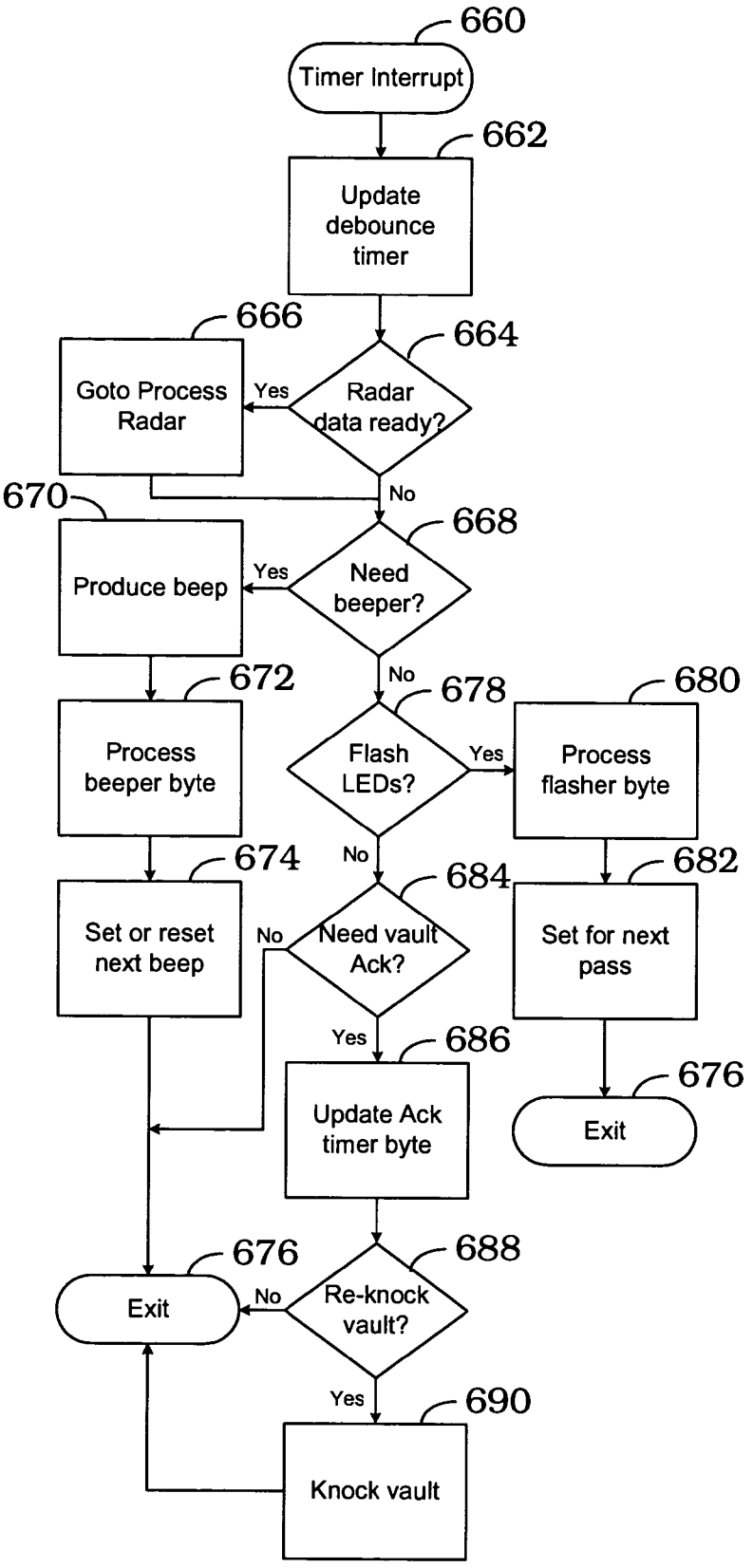

660
Timer Interrupt
662
Update debounce timer
666
Goto Process Radar
Yes
664
Radar data ready?
No
670
Produce beep
Yes
668
Need beeper?
No
672
Process beeper byte
678
Flash LEDs?
Yes
680
Process flasher byte
No
674
Set or reset next beep
No
684
Need vault Ack?
682
Set for next pass
Yes
686
Update Ack timer byte
676
Exit
676
Exit
No
688
Re-knock vault?
Yes
690
Knock vault

Fig. 16

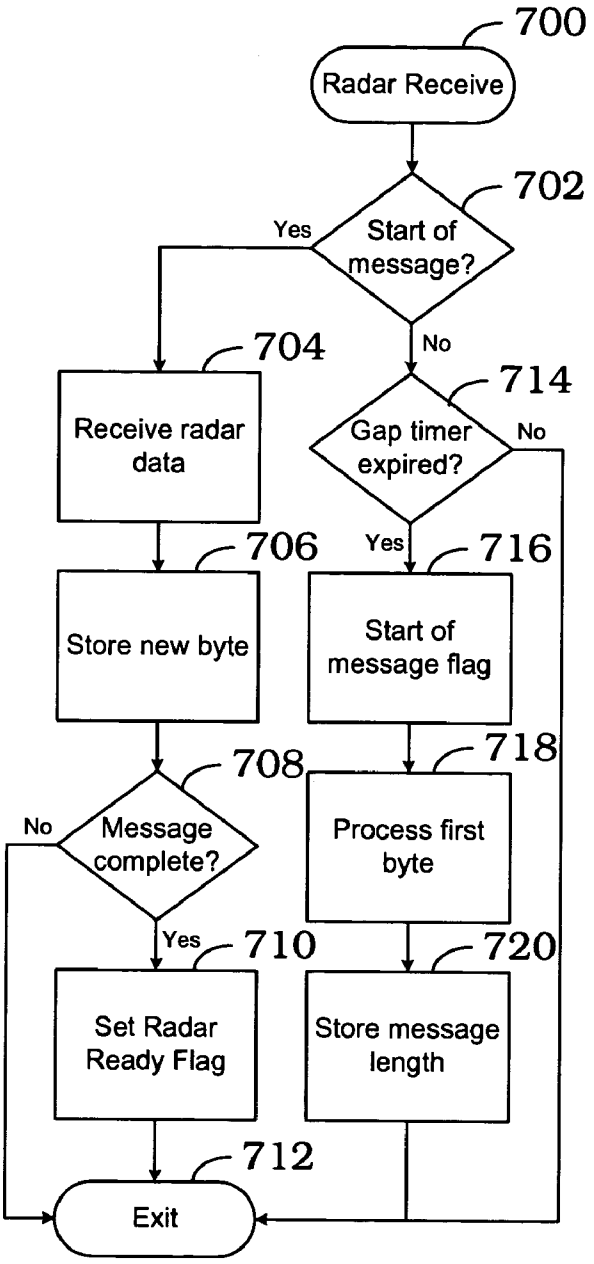


Fig. 17

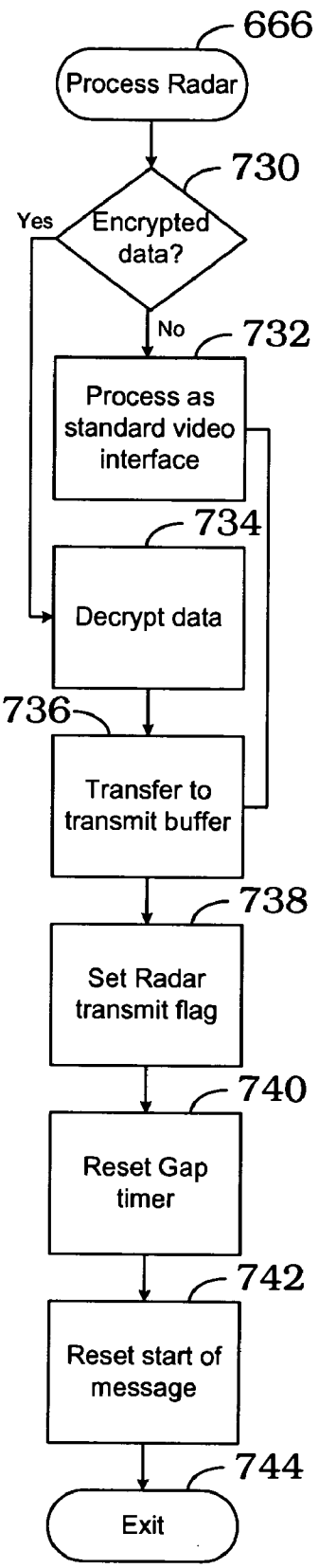


Fig. 18

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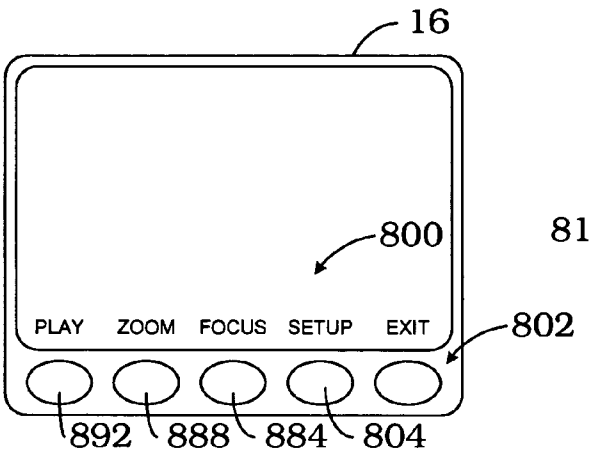


Fig. 19

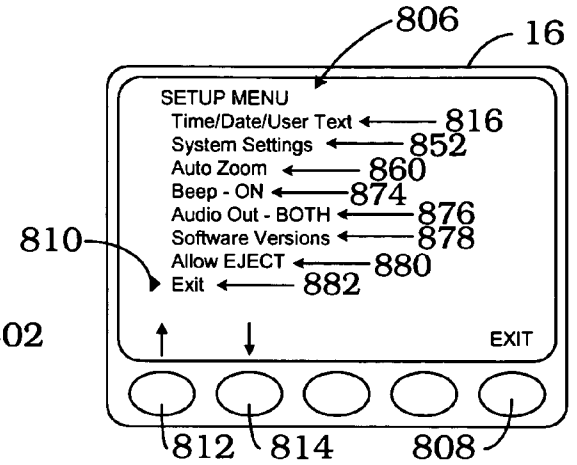


Fig. 20

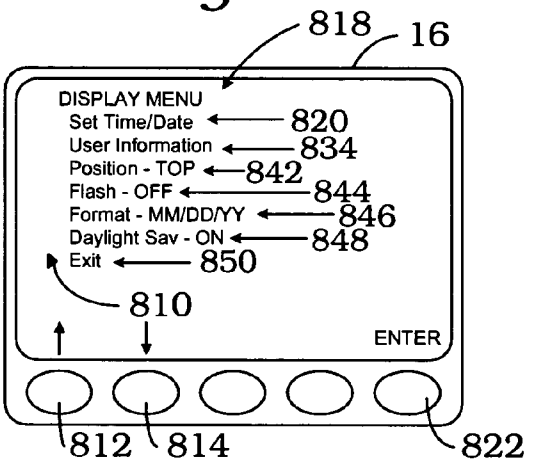


Fig. 21

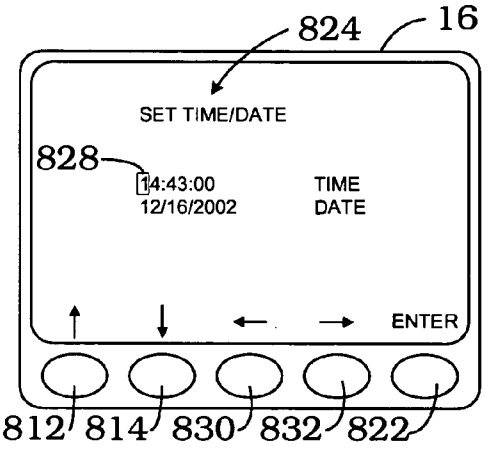


Fig. 22

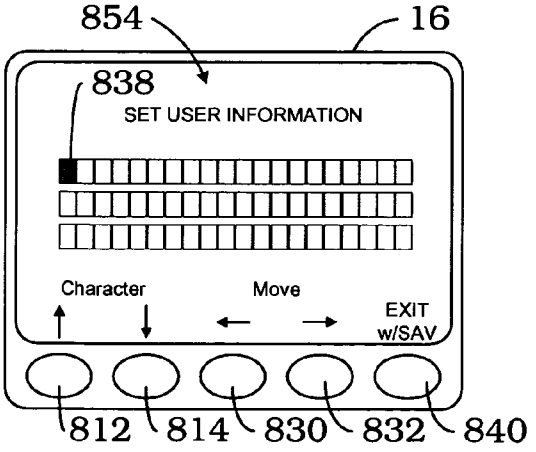


Fig. 23

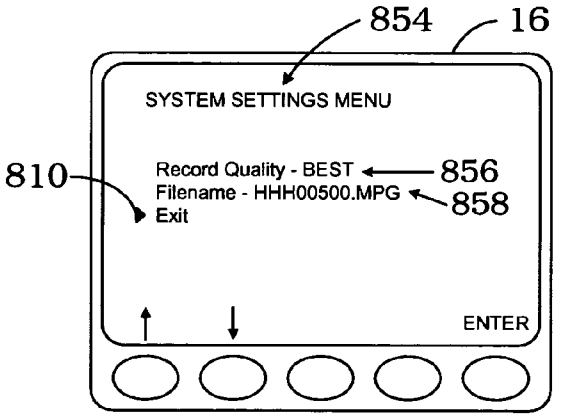


Fig. 24

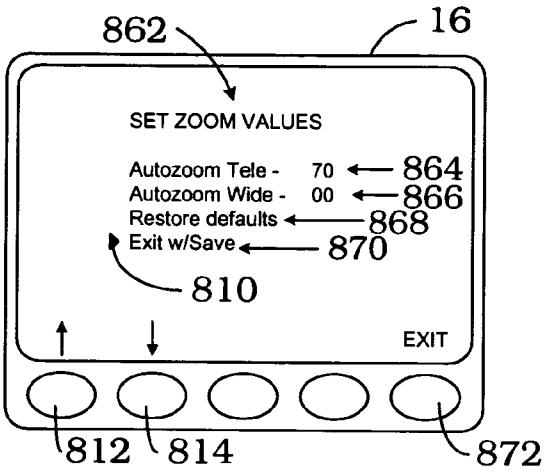


Fig. 25

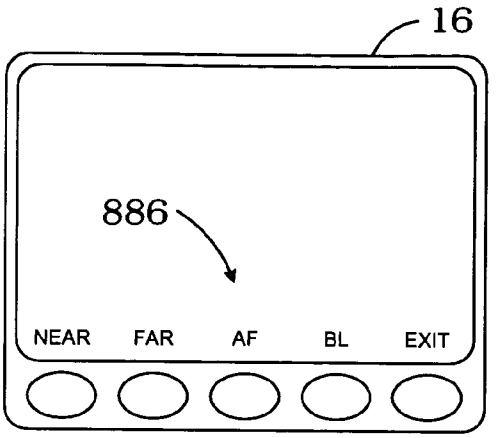


Fig. 26

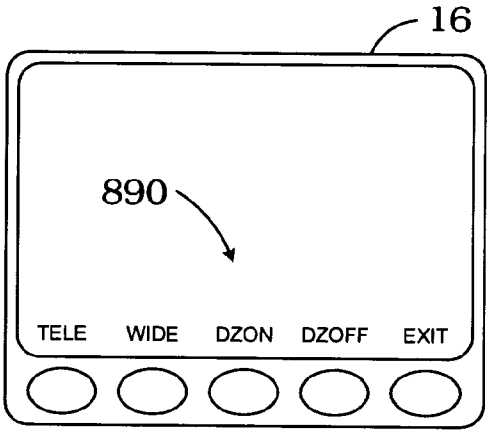


Fig. 27

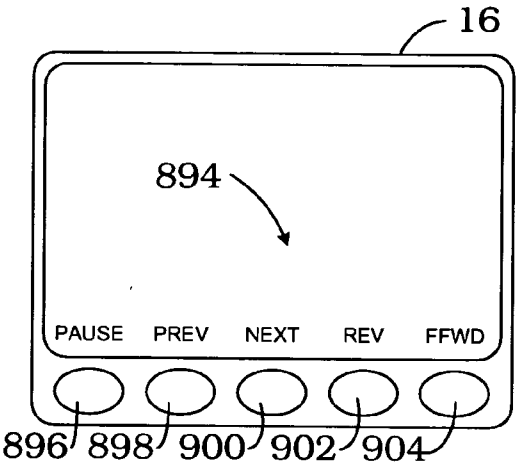


Fig. 28

DIGITAL IN-CAR VIDEO SURVEILLANCE SYSTEM

BACKGROUND OF THE INVENTION

[0001] This invention is directed to a video surveillance system, and in particular to a video surveillance system mounted in a law enforcement vehicle for producing a permanent digital evidentiary record, on a multi-media disk, of a traffic stop or other event and incidents occurring after the suspect's vehicle has been stopped.

[0002] In law enforcement, a reliable witness that is incapable of perjury is needed to substantiate the actions taken by the law enforcement officer and to protect the officer against false allegations by the persons involved in the incident. An excellent witness of this type is a video recording of the incident, now widely used in traffic stops and criminal interdictions, which can be reviewed after the incident and archived. By recording the incident first-hand as it actually happened, video recordings eliminate conflicting individual interpretations of the incident and facilitate effective and efficient law enforcement.

[0003] Vehicle mounted video cameras to make video records of an incident or scene external to the law enforcement vehicle are well known in the art. For example, U.S. Pat. No. 4,949,186 to Peterson discloses a vehicle mounted system in which a video cassette recorder is housed in a vault located in the trunk of a patrol car. U.S. Pat. No. 5,677,979 to Squicciarini et al discloses a video surveillance system which integrates the outputs of a video camera, a radar unit, a wireless microphone, a remote control and a wireless microphone to produce a comprehensive video recording of an incident from its beginning to the end. This system also uses a video cassette recorder to capture the incident on videotape. However, VHS and digital video tapes are bulky, requiring considerable space for storage, are susceptible to damage, and degrade over time. Additionally, the data on tapes may only be accessed sequentially.

[0004] (Docket 3000)

SUMMARY OF THE INVENTION

[0005] The digital video surveillance system of the present invention includes a video server in a law enforcement vehicle which allows recording to various digital optical media including DVD RAM disks. Recording to these media in a moving vehicle and in all-weather conditions is possible by shock-mounting the drives and providing environmental assistance for heating and cooling a lockable protective enclosure in which the drives are encased. This system includes a memory buffer that is recording at all times. When the recorder is activated, the memory buffer contents, including video and audio, will be recorded onto the DVD RAM disk. This ensures that the activity occurring just prior to the activation of the system is recorded as well. The system further provides a method to capture or receive snapshots and output them to or receive them from a wireless transmitter such as a cellular modem for missing persons or suspect identification, for example. Forward-facing and interior cameras are mounted inside an overhead console to reduce the obstruction to the driver and to eliminate the chance of interfering with a passenger side air bag.

[0006] Other advantages of this invention will become apparent from the following description taken in connection with the accompanying drawings, wherein is set forth by way of illustration and example, a preferred embodiment of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] **FIG. 1** is a block diagram showing the basic components of the digital video surveillance system;

[0008] **FIG. 2** is a functional block diagram of the hardware components of the digital video surveillance system;

[0009] **FIG. 3** is a software flow chart for the vault logic controller;

[0010] **FIG. 4** is a software flow chart for the get/put control data routine;

[0011] **FIG. 5** is a software flow chart for the keyboard interrupt service routine;

[0012] **FIG. 6** is a software flow chart for the analog-to-digital interrupt service routine;

[0013] **FIGS. 7*a*-7*b*** are a software flow chart for the serial communications interface receive interrupt service routine;

[0014] **FIG. 8** is a software flow chart for the serial communications interface transmit interrupt service routine;

[0015] **FIG. 9** is a software flow chart for the control head logic main loop;

[0016] **FIG. 10** is a software flow chart for the vault receive routine;

[0017] **FIG. 11** is a software flow chart for the display update routine;

[0018] **FIG. 12** is a software flow chart for the keyboard interrupt routine;

[0019] **FIG. 13** is a software flow chart for the transmit setup routine;

[0020] **FIG. 14** is a software flow chart for the in-circuit programming routine;

[0021] **FIG. 15** is a software flow chart for the transmit interrupt routine;

[0022] **FIG. 16** is a software flow chart for the timer interrupt routine;

[0023] **FIG. 17** is a software flow chart for the radar receive routine; and

[0024] **FIG. 18** is a software flow chart for the process radar routine.

[0025] **FIG. 19** is an illustration of the main menu display.

[0026] **FIG. 20** is an illustration of the setup submenu display.

[0027] **FIG. 21** is an illustration of the display submenu display.

[0028] **FIG. 22** is an illustration of the set time/date submenu display.

[0029] **FIG. 23** is an illustration of the set user information submenu display.

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[0030] **FIG. 24** is an illustration of the system settings submenu display.

[0031] **FIG. 25** is an illustration of the set zoom values submenu display.

[0032] **FIG. 26** is an illustration of the focus submenu display.

[0033] **FIG. 27** is an illustration of the zoom submenu display.

[0034] **FIG. 28** is an illustration of the play submenu display.

DETAILED DESCRIPTION

[0035] **FIG. 1** is a block diagram showing the basic components of the digital video surveillance system. The system is preferably mounted in a law enforcement vehicle, such as a patrol car. An overhead console **10** is mounted inside the passenger compartment of the vehicle above the rearview mirror. The overhead console **10** includes a color video camera **12**, which is pointed in a forward direction to capture images through the windshield. The color video camera **12** may be mounted within the overhead console **10** above the vehicle's internal rearview mirror with a view through the windshield so as not to obstruct the forward view of the driver of a passenger of the vehicle. The video camera **12** includes a wide-angle motorized zoom lens, which allows the operator to easily adjust from a wide angle to a telephoto position and a motorized auto iris, which adjusts the light level from day to night and in varying light conditions to increase the operating light range of the video camera.

[0036] A second video camera **14** may be mounted inside overhead console **10** and may be pointed in a rearward direction to view the interior and occupants of the vehicle. The video captured by cameras **12** and **14** may be displayed on monitor **16** and the audio output through speaker **18**.

[0037] Monitor **16** is preferably a 3.5" color LCD monitor. The monitor **16** is designed to monitor video and audio signals, and is used to focus and adjust the camera **12**, and review recorded segments. The monitor **16** is not required for the rest of the system to operate, and can be turned off if it is distracting to the operator. Information displayed on the monitor **16** may include time, date, emergency lights indicator, siren indicator (where applicable), brake indicator (where applicable), microphone indicator, additional identifier (**60** spaces available) and backlight compensation indicator, for example. In addition, optional interfaces to compatible Kustom Signals radar units and GPS modules may be available. When these optional features are used, radar speed data and/or patrol location coordinates may be recorded on the DVD RAM disk **52** and displayed on the monitor **16**. Live video from the camera **12** or **14** may be viewed through the monitor **16** whether or not the system is recording.

[0038] The monitor also includes five buttons at the bottom of the screen (see FIGS. **19-28**), which have functions dynamically assigned depending on the menu or display selection. In normal operation, these buttons may be assigned to the functions PLAY, FOCUS, ZOOM, SETUP and EXIT, for example. All of these buttons activate submenus within that category, except EXIT, which allows the user to get out of the menu mode, and hides the menu selection bar. The PLAY button plays the last video file recorded, and activates a submenu for reviewing previously recorded video. The FOCUS button is for manual or automatic focus, and for the activation of the Backlight function on the camera **12**. The ZOOM button allows the user to manually operate the camera **12** zoom functions. The SETUP button selects the main menu screen. When the SETUP button is depressed, the five buttons are reassigned to serve the main SETUP menu screen. When one of the sub menus is selected, the five buttons are re-assigned a function according to that sub menu.

[0039] The software menus and associated submenus (see FIGS. **19-28**), which allow the operator to select or change system options and controls, are similar to state of the art systems in present use. Items that may be included on the set-up menu are time/date, display options, camera options, record length, beep control and audio-out control. The time/date submenu includes setting the time and date, the time/date position on the recording and screen (top or bottom), flash preference (on or off) and date format. The display submenu includes settings for an identification generator such as badge number, car number, precinct number, etc., for example. The camera submenu may include settings for auto zoom telephoto, auto zoom wide, and default settings. These menus are accessed using software controlled buttons located below the display screen **16** (see FIGS. **19-28**).

[0040] Referring to **FIGS. 1 and 2**, the above-described components (camera **12**, camera **14**, display or monitor **16** and speaker **18**) are all controlled through the control head logic **20** by inputs from control panel **22**. Control panel or center **22** includes switches, push buttons and other hardware controls to control power to the system, the record and playback function of recorder **50**, and a time-left display (not shown) to display recording time left on the DVD RAM disk **52**. Control head logic **20** includes an 8-bit microprocessor such as the MC68HC908GP32CFB microprocessor available from Motorola.

[0041] The Control Center **22** allows the officer to manually turn the unit ON and OFF and START or STOP the recorder **50** at his or her discretion. A solid LED on the Record button (not shown) and a blinking colon in the time display (not shown) indicates that the system is recording. The recorder **50** may be activated with the emergency lights, siren (if applicable) or microphone, and is turned off at the Control Center **22**. Turning off the lights, siren, or microphone does not stop the recorder **50**. This feature ensures that once activated, the recorder **50** will continue recording even if the light bar or siren malfunctions, or if there is interference on the microphone's **38** frequency. When the emergency lights, siren, or microphone are used to start the recorder **50**, an "L", "S", or "M" will appear recorded on the DVD RAM disk **52** near the time display.

[0042] The time left on disk is displayed in hours and minutes. When approximately ten minutes of disk space for recording is left, the display will blink and the Control Center **22** beeps once, and continues to beep once per minute. When only five minutes are left, the display blinks faster. When the disk **52** reaches its end, the display stops blinking and reads "END". If no disk **52** in the recorder **50**, the time left display shows three horizontal dashes and the recorder **50** may not be activated until a disk **52** is inserted.

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[0043] The Low Voltage LED (not shown) on the panel **22** lights up whenever the voltage input to the system drops below 10.5 volts. As the voltage drops, the picture quality may deteriorate. Low voltages may also place the system in its STOP mode and cause the Control Center **22** to alert the operator.

[0044] The vault or system enclosure generally indicated by reference numeral **30** includes vault logic **32** which is connected to the control head logic **20** by a vault cable **34**. The vault logic receives data from the in-car microphone **36**, a wireless microphone **38** worn by a police officer, accessories **40** such as the emergency lights, brakes, or radar, and an optional camera **42** which may be directed out of the rear of the vehicle. Video and audio data is transferred over an interface **44** to the MPEG (Moving Pictures Expert Group) CODEC (Coder-decoder) logic or video server **46**, which compresses or decompresses the data in real time for storage or retrieval from a digital video recordable media disk drive **50** and DVD RAM disk **52**. User entered data and/or data from accessories **40** are processed by an on screen display processor **54** to be combined and recorded with the video data. The vault logic **32** includes an 8-bit vault logic microprocessor such as the MC68HC908GP32CFB microprocessor available from Motorola.

[0045] The vault logic **32** includes a connector board, a vertical board and a vault or tray logic board as well as a receiver board for wireless audio reception. The DVD RAM drive **50** is connected through an IDE interface **56** to the video server **46**, which controls all the functions of the DVD RAM drive **50**. The connector board includes the vault cable connector from the overhead console and connectors for another video camera such as a video camera directed out of the rear of the vehicle **42**, the in-car microphone **36**, the receiver input from the wireless microphone **38**, and a connector for the system trigger **40**. The vertical board connects the connector board to the tray logic board. The vertical board also provides a connection between the video server **46** and the tray logic board. The tray logic board receives commands from the overhead console logic board through the user interface.

[0046] The video server board **46** includes from 4 to 512 megabytes of RAM, which is used as a history buffer. The system constantly stores information from the cameras and audio input in the RAM on the video server board **46** which stores seventeen to thirty seconds of video history for a 4 Mb history buffer and up to three minutes or more for a 512 Mb history buffer depending on the resolution of the video recorded, for example. The history buffer is a circular FIFO buffer which allows events to be recorded that occurred prior to the system receiving the record command. When the record function is activated, the history buffer prior to activation is transferred to the DVD RAM drive to record the incident up to the point when the record signal was received. Data in the history buffer is transferred to the DVD RAM disk at a data rate of approximately 2.7 Mb per second. If the history buffer is full when recording starts, this transfer occurs in approximately three minutes, for a 512 Mb history buffer. Thereafter, video and audio data is collected in the history buffer before being transferred to the DVD RAM disk in packets. When the stop recording command is received, the final five to six seconds of data in the history buffer is transferred to the DVD disk and recording on the disk is stopped. Data continues to accumulate in the history buffer after recording stops.

[0047] If external power is removed from the system while recording, an internal battery (not shown) continues to provide power to the system to permit the contents of the buffer to be stored on the DVD disk before shutting down the system. The internal battery may, for example, provide a minimum of three minutes of backup power.

[0048] The tray logic board includes an eight-bit microprocessor, which is responsive to commands received from the overhead console to control the DVD RAM drive **50**. Commands from the console include all the standard commands of a DVD player. The tray logic board, vertical board, connector board, video server board and the DVD RAM drive **50** are all enclosed in the locked protective steel vault **30**. The vault **30** is insulated and resistant to damage. The temperature inside the vault **30** is controlled using a solid state heat pump and air circulation fans (not shown). The heat pump and fans are controlled by a temperature sensor, which senses the ambient temperature inside the steel vault **30**. The tray logic board activates the heat pump to heat or cool the inside of the vault **30** to maintain its internal temperature between approximately 50° F. and 100° F. independent of the ambient external temperatures.

[0049] Five, seven and one-half and nine and one-half hour recording times are available on a DVD-RAM disk, subject to the resolution selected (GOOD, BETTER, or BEST). DVD disks may be reviewed on the in-car monitor **16**. DVD disks are available through Kustom Signals, or can be purchased locally through any electronics store. Preferably, name brand, high quality Type II DVD disks should be used. Low quality DVD disks can shorten the life of the recorder **50**.

[0050] The DVD RAM drive **50** has several advantages over VHS and digital tapes used in prior art in-car video systems. For example, at the same resolution as a VHS tape in SP mode, the DVD RAM drive **50** may record up to eight hours of video data on a single-sided, single-layer DVD disk **52**. DVD disks may be single-sided or double-sided. Double-sided disks hold two-times as much data as a single-sided disk. Thus, a double-sided disk may hold the equivalent of two VHS tapes. DVD disks are much more durable than a VHS or digital tape, require less storage space, are less susceptible to damage by magnetic sources and are not worn by repeated playing. With the DVD disk **52**, each incident captured may be indexed for on-screen selection and immediately accessed without having to rewind or fast-forward as is required by a tape. An incident may be watched over and over again instantly.

[0051] The system may include a watermark applied to the DVD disk **52** to ensure that any attempt at tampering with the original video is easily detectable. Watermarks are bits of digital information woven throughout the entire stream of a digital video. DVD recording and playing devices automatically prevent unauthorized recording and playback of unauthorized copies by means of Copy Control Information (CCI) detected in the digital video content. For example in a one-second stream of video, which has an average size of one megabit per second, a watermark would be about two bytes of data. Because the watermark is part of the video itself, it may not be removed without damaging the video

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image. In this manner, evidence recorded on a DVD RAM disk **52** using a watermark cannot be tampered with without being detected.

[**0052**] Operation of the vault logic will first be discussed with reference to the vault logic controller routine **100** shown in **FIG. 3**. The vault logic controller routine **100** begins with a system reset as indicated in block **102**. In decision block **104**, the microprocessor first inquires if the reset vector is blank. If the reset vector is blank, in-circuit programming **106** of the microprocessor is initiated and the I/O pins of the microprocessor are configured to connect the internal UART to the diagnostic/programming port. Once in-circuit programming is complete, control returns to the reset block **102**. If the reset vectors are present, the vault logic processor proceeds to initialize the system as indicated in block **108**.

[**0053**] The initialization routine at system power-up indicated in block **108** includes initializing the vault logic microprocessor **10** port pins, the phase lock loop, the asynchronous serial ports also referred to as the serial communication interface (SCI), initializing the serial peripheral interface (SPI), the A-D converter, keyboard interrupt and port pins. The vault logic microprocessor RAM is set to zero, the external input devices are initialized, the radar buffer is cleared and ports are initialized along with the internal clock chip. The on-screen display chips are initialized. The transfer rate and other configuration data are sent to the SPI UART and this information is verified to be correctly set. The battery backed RAM is initialized. The vault logic microprocessor will then proceed to turn on the power relays for the control head and drive power. Default flags are set for camera **12**, in-car microphone in the off-state, and setting the wireless microphone **38** to a desired frequency. The vault logic microprocessor also verifies communication between the removable digital storage media and the control head logic.

[**0054**] After the system is initialized, the vault logic microprocessor begins executing the main loop of the software as indicated by block **110**. The main loop runs continuously, checking flags and interrupts to service whatever condition may occur or to react to whatever user input that may occur. To keep the system reacting in near real-time, functions that require more than a few milliseconds to complete will do a portion of the task and then return to the main loop to allow another function to be addressed. This is accomplished by the use of flags and other data that represent function steps. One example of this is the auto-zoom function that must wait on the camera to zoom, activate auto-focus, pause for a few seconds, and then return to the wide zoom position. This also serves to reduce the required depth of the stack for each function.

[**0055**] At the beginning of the main loop the Get/Put Control Data routine is called as indicated by block **112**. The Get/Put Control Data routine is a group of command and control routines, which are discussed with reference to the flow diagram shown in **FIG. 4**. Next the vault logic microprocessor inquires, decision block **114**, if a valid camera command byte is present. If a valid camera command byte is present then the vault logic microprocessor sets up the camera transmit buffer and associated flags, as indicated by block **116**. If auto-zoom for a second camera **14** or **42** is active, decision block **118**, the vault logic microprocessor steps through the stages of auto-zoom as indicated by block **120**. After each individual step of auto-zoom is completed, the system returns to the main loop and continues processing. Auto-zoom is activated by depressing an auto button (not shown) on the overhead console. When this button is pressed, the color cameras lens will zoom to a telephoto position, pause, perform a momentary auto focus, then retract to a wide-angle position. Ideally, when the lens pauses, or somewhere within the travel of zoom, the scene should include a sharp legible license plate image. The auto-zoom feature is also useful at night to zoom in on a reflective license plate. In the wide-angle position, reflective license plates are unlikely to be legible. By zooming in, the camera can react to the bright reflection and produce a readable license plate number.

[**0056**] Next, the vault logic microprocessor determines if the backlight needs to be activated or deactivated **122**. The back light compensation feature improves the quality of recordings when the camera is facing into the sunrise or sunset or any bright light. When facing a bright light, the camera reacts to the predominantly bright scene and closes its iris. This results in the subjects in front of the bright light to be too dark. The vault logic microprocessor compensates for a bright light source in back of the main subject and opens the camera's iris.

[**0057**] The vault logic microprocessor next processes the main menu routine. If the main menu flag is set by the keyboard interrupt routine, described hereinbelow, as indicated by decision block **124**, the main menu screen is displayed as indicated by block **126**. Processing remains in the main menu routine until the main menu flag is cleared. This displays the initial menu screen and subsequent submenus are called from this main routine. Each of the subsequent menus return to the main menu routine. The main menu routine also calls the Get/Put Control Data routine (described hereinbelow) to access the command and control features of the system.

[**0058**] After the main menu flag is cleared, the vault logic microprocessor will inquire as to the status of the record LED, decision block **128**. If the record state of the system has changed, the vault logic microprocessor sets or resets a flag to turn on or turn off an external LED, block **130**. The LED record indicator, which may be positioned on the camera **12**, provides confirmation to the officer when outside the vehicle that the system is recording and the microphone is being received. When the system is recording, the record indicator light will come on and remain steady. This light will blink if, while recording, the system receives a transmission from the wireless microphone.

[**0059**] If the initialize recording device flag is cleared by the video server, decision block **132**, the DVD ram disk **52** is initialized along with its interface, block **134**. If the control head transmit buffer is empty and the control head initialization flag is clear, decision block **136**, zoom data parameters are loaded in the control head transfer buffer, block **138**. If the new command flag is set, for example by the keyboard interrupt routine, decision block **140**, by the transmit interrupt routine, the logic microprocessor takes actions based upon data received from the record device interface, block **142**.

[**0060**] If the control head transfer buffer is empty and the control head initialization flag is clear, decision block **144**,

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the zoom data is loaded into the control head transfer buffer **146**. Periodically, the vault logic microprocessor sets the audio left and right channel playback gates and in-car microphone gate, block **148**. The system includes two audio channels, one for the in car microphone, and the other for the wireless microphone. If the in car mic is turned on, the speakers are muted if a signal is received on the wireless mic.

[**0061**] Next, the system enables the A-D converter routine to measure the low-voltage input, block **150**. If the system voltage drops to approximately 10.5 volts, a low volt detect routine sets the flag to turn on the low voltage LED. Low voltages will also place the system in its stop mode. If the power is removed from the system altogether rather than dropping below the 10.5-volt threshold, the state of the system will be preserved and will be automatically restored once power is returned.

[**0062**] Based upon the output from the real-time clock chip, the vault logic microprocessor reads and displays the real-time clock, block **152**. If the back light function in block **122** has been activated, decision block **154**, the video screen is updated, block **156**, to display the back light icon.

[**0063**] If new radar data is available (see accessories **40**, **FIG. 2**), decision block **158**, the on-screen display radar area is updated, block **160**. If user-defined information, such as officer name, badge number, etc., is present, decision block **162**, the on-screen display is updated from the data in the battery-backed RAM, block **164**. Periodically, the vault logic microprocessor sends LED status data to the control head, block **166**. Next, if camera **14** or **42** data is available decision block **168**, the data is received and sent to the recording device block **170**. The system again checks for any new commands block **172** and responds accordingly **174**. Processing then returns to the main loop block **110**.

[**0064**] Referring to **FIG. 4**, the Get/Put Control Data flow chart is illustrated. The Get/Put Control Data routine is called by several routines including the main loop and the various menu routines. It performs the communication and control routines for the system. When the Get/Put Control Data routine **180** is called, the CPU watchdog is serviced, block **182**. If the CPU watchdog is not periodically serviced, the watchdog process will detect a system error and reset the system.

[**0065**] If the new command and UART transfer flags are set by the Receive Interrupt Service Routine, decision block **184**, the vault logic microprocessor receives data from the drive interface, block **186**, and takes action based upon the data received. If the drive data transfer length is greater than zero, decision block **188**, data is sent to the drive interface via the serial peripheral interface (SPI) UART, block **190**. If the receive error flag is set by the drive interface, decision block **192**, a flag is set by the Timer ISR and the data resent, block **194**. If the new command byte, serial communication interface, receive flag and ETX_RX flag are set, decision block **196**, a check sum is performed to verify the accuracy of the data and then the system branches to port specific data handling, block **198**. The system will send an acknowledge byte (ACK) indicating that the data was properly received or not-acknowledge byte (NACK) indicating that the data was not properly received based upon the flags that are set, block **200**. After the serial transfer flag is set, the system will enable the SCI transfer empty interrupt to send the data to the control head utilizing the on-board UART.

[**0066**] If the control head keyboard interrupt flag is set or transfer data is present in the control head transfer buffer, decision block **202**, the transfer port is prohibited from switching until the transfer or receive is complete, block **204**.

[**0067**] Next, if the system is switched to camera **14** or **42** and the transfer step is greater than the pre-determined value, decision block **206**, control data is transferred to camera **14** or **42**, block **208**. Next, if the keyboard interrupt flag is set by the Keyboard ISR, decision block **210**, the vault logic microprocessor will switch the internal UART to the diagnostic/programming connection, block **212**. The system will remain in the diagnostic/programming function until diagnostics are completed or programming is completed.

[**0068**] The display buttons routine, block **214**, displays the soft button labels on the video screen **16** based on the level byte received from the control head. The soft button labels are software defined and controlled labels to display system setup and control information. Based on the command byte data, the vault logic microprocessor will transmit the proper data based on the menu or control selection to the recording device interface via the SPI UART, block **216**.

[**0069**] The beep byte defines the number of status beeps the system emits. Normally the beep byte is set to zero. If the beep byte is greater than zero, decision block **218**, the beep command and number of beeps is transmitted to the control head **10**, block **220**. Whenever the system starts to record the beep function is activated and the system beeps three times, for example. The system may beep eight times whenever the recording media is nearly full, when there is a low voltage condition or when the temperature inside the vault or recorder's enclosure is out of the operating temperature range.

[**0070**] User-defined or system messages may be displayed in the middle or bottom of the display screen **16**. If either the refresh message **1** or refresh message **2** flags are set, decision block **222**, the message displayed in the middle of the recorded video is updated, block **224**. If the LED state has changed, decision block **226**, the current control head data will be transmitted to the control head from the vault logic microprocessor, block **228**. Next, if a low-voltage condition was detected in block **150**, decision block **230**, a low-voltage message will be placed on the video and the system will remain in the low voltage processing condition until the voltage returns to an acceptable level, block **232**.

[**0071**] Periodically, the vault logic microprocessor examines the external inputs such as the siren, lights, auxiliary video one, brake and microphone inputs, decision block **234**, and sets flags to reflect their status to be displayed on the video, block **236**. When a power off input is received, decision block **238**, the switch is debounced and a stop command is sent to the recording device, block **240**. When the recording device has stopped, the power is turned off. Control then returns to the main routine, block **242**.

[**0072**] Referring to **FIG. 5**, the flow chart for the keyboard interrupt service routine **250** is shown and begins by receiving port A data, block **252**, delaying for debounce, block **254**, then checking the data read in block **252** with the port A data, decision block **256**. If the data is not equal, the routine exits, block **258**. If the data is equal, the keyboard interrupt is masked, block **260**. If bit **1** is not set, decision

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block **262**, and has not been cleared, decision block **264**, the mask bit is cleared, and the interrupt is set to read control head data, block **266**. Next if **3** is not set, decision block **268**, and bit **3** has not been cleared, decision block **270**, the mask bit is cleared and the AUX **1** port interrupt is set, block **271**. Next if bit **4** is not set, decision block **272**, and has not been cleared, decision block **273**, the mask bit is cleared and the diagnostic port interrupt is set, block **374**. If bit **2** has not been cleared, decision block **275**, and has not been set, decision block **276**, data is read from the drive interface, block **277**. If port A bit **2** is returned high, decision block **278**, the master keyboard interrupt is re-enabled, block **279**, and the routine returns, block **258**.

[**0073**] The flow chart for the analog to digital interrupt service routine **280**, which monitors system voltage levels, is shown in **FIG. 6**. The analog to digital interrupt service routine **280** begins by loading the converted value **282** then comparing it to the upper and lower limits, decision block **284**. If the converted value is less than the lower limit (triplow), then triplow is moved to the low voltage (LV) value, block **286**, and the interrupt returns **290**. If the value is greater than the LV value (triphigh), then triphigh value is moved to LV value, block **288** and the interrupt service routine exits **290**.

[**0074**] Referring to **FIGS. 7 and 8**, the SCI RX and SCI TX routines are called by the main loop to send or receive serial transmissions from the main processor to the Control Head, Aux port, or Diagnostic port, for example, when they are needed. The port is determined based on the Keyboard ISR. The Motorola processor used allows auto receiving and transmitting of data.

[**0075**] The SCI RX routine **300** begins by determining if the last command has been pulled yet, decision block **302**. If it has not, the SCI RX routine returns, block **304**. If the last command has been pulled, the system determines if another processor is being programmed, decision block **306**. If yes, the program time out is reloaded, block **308**, and the routine returns, block **306**. If another processor is not being programmed, the system determines if an answer to a command-interrogate "knock," decision block **310**. If waiting for a knock, the waiting flag is cleared, the TX flag is set, block **312**, and the routine exits, block **304**.

[**0076**] If not waiting to answer a knock, the system determines transmitted data was received correctly, decision block **314**. If the transmitted data has been correctly received, the waiting flag is cleared and the ACK received flag is set, block **316**, and the routine returns, block **304**. If the system is not waiting to confirm data received, the routine checks if a knock has been received, decision block **320**. If a knock has not been received yet, the current data is checked to determine if it is a knock, decision block **322**. If it is not, the routine exits, block **304**. If it is, the receive busy flag is set and the send ACK flag is set, block **324**, and the routine exits, block **304**.

[**0077**] If a knock has been received, the serial transmit (STX) is determined, block **326**. If an STX has not been received, the routine determines if the current data is a STX, decision block **328**. If it is, the serial transmit/receive flag is set and the serial receive timer is reset, block **330**, and the routine exits, block **304**. If the last byte received is not the Dynamic Link Escape (DLE) byte, decision block **332**, then the current byte is checked. If the current byte is the DLE byte, decision block **334**, the DLE receive flag and serial receive timer are reset, block **336**, and the routine returns, block **304**. If the last byte received is the DLE, the system determines if this is the end of transmission (ETX), decision block **338**. If it is not, the DLE_RX flag is cleared, the serial receive timer is reset and the data is saved to the receive buffer, block **340**. If this is the end of transmit, the end of transmit flag is set, the serial transmit, DLE and serial receive timers are reset, block **342**, and the routine exits, **304**.

[**0078**] The DLE byte is an ASCII **16** or Hex **10**. This byte is used to receive the next character that is being sent in a transmission on its numerical value only if that character normally might have special significance. For example, a Hex **03** means ETX in normal communications. Thus, if a Hex **03** is sent in a data stream and it does not mean ETX, then the DLE byte is sent before the Hex 03 byte to ensure that the data is received and not misinterpreted as an ETX byte. For example, if the data to be sent is "02 05 A5 03 F6 B0 03," then the following would be sent to ensure that all the data is properly received "02 05 A5 10 03 F6 B0 03."

[**0079**] The Serial Transmit interrupt service routine **350** begins by determining if a pointer used to keep track of data transmission progress is past the end of the transmit packet, decision block **352**. If it is, the transmit empty interrupt is disabled and an end of transmit is sent, block **354**, and the routine exits, block **356**. If the pointer is not past the end, the DLE flag is checked, decision block **358**. If the DLE flag is set, the next data byte is sent, and the transmit pointer is incremented, block **360**, and the routine exits, block **356**. If the DLE flag is not set, the routine determines if this is an end of transmit byte, decision block **362**. If it is, the DLE is sent, the DLE flag is set, block **364**, and the routine returns, block **356**. If it is not, the routine determines if the byte is equal to the DLE, decision block **366**. If it is, he DLE is sent, the DLE flag is set, block **364**, and the routine returns, block **356**. If it is not, the next data byte is sent, the transmit pointer is incremented, block **360**, and the routine exits, block **356**.

[**0080**] Referring to FIGS. **9-18**, the software flow charts for the Control Head microprocessor are shown. It should be understood that the software flow charts illustrate the operation of the Control Head microprocessor, but are not intended to be construed as a literal translation of the code for the Control Head. As with many microprocessor based systems, execution of some routines is interrupt driven, other routines are executed based on a time slice, others may be sequentially processed, while still other routines are concurrently processed. Additionally, the source code language may influence the processing structure. The software flow charts provide one means to disclose the software control of the Control Head microprocessor and are not intended to be limited to the form presented.

[**0081**] Referring to **FIG. 9**, the Control Head Main Loop is illustrated, block **500**. The Control Head Main Loop runs repeatedly until the system is reset. Initially, the Control Head Main Loop determines if video or other data has been received from the vault, decision block **502**. If data has been received, the Vault Receive routine is called, block **504**. If no data has been received from the vault, decision block **502**, the control head microprocessor determines if any of the control buttons have been depressed, block **506**. If a button has been pressed, the Transmit Setup routine is called, block

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508, processes the data, and returns to the next step. If no buttons have been pressed, decision block **506**, the control head microprocessor determines if the radar data is ready to transmit data, decision block **510**. If the radar data is ready, the Transmit Setup routine is called, block **508**, processes the data, and returns to the next step. If no radar data is ready, decision block **510**, the control head microprocessor next determines if there is camera data ready to send, decision block **512**. If camera data is ready, the Transmit Setup routine is called, block **508**, processes the data, and returns to the next step. Processing returns to the start of the Control Head Main Loop and repeats.

[**0082**] Referring to **FIG. 10**, the Vault Receive routine flow chart is illustrated beginning with block **504**. First, the identification byte, which identifies the source and type of data being passed, from the input message is determined, block **520**. If the ID byte indicates that the data is auto zoom data, decision block **522**, the auto zoom data is stored, block **524** and the Vault Receive routine returns to the Control Head Main Loop, block **526**. If the ID byte indicates display data, decision block **528**, the display data is stored, block **530**, and the Display Update routine is called, block **532**. Upon return from the Display Update routine, the Vault Receive routine returns to the Control Head Main Loop, block **526**.

[**0083**] If the ID byte is a menu request, decision block **534**, the transmit buffer flag is set, block **536**, the vault transmit flag is set, block **538**, and the in-menu flag is set, block **540**. These flags are read by other processes and the appropriate action taken. Processing returns to the Control Head Main Loop, block **526**.

[**0084**] If the ID byte is a beep request, decision block **542**, the beep flag is set, block **544**, and control returns to the Control Head Main Loop, block **526**. If the ID byte is a in-circuit programming (ICP) request, decision block **546**, the ICP routine is called, block **548**.

[**0085**] Referring to **FIG. 11**, the Display Update routine, which was called by the Vault Receive routine (**FIG. 10**), begins, block **532**, by determining if the send loop has finished, decision block **550**. If all the display data has not been sent, the Display Update routine exits, block **552**. If all display data has been sent by the vault, the address is sent to the display driver, block **554**, the display data is sent to the display drive, block **556**, and the data is sent to the SPI port, block **558**, to the display. Processing returns to the beginning to process the next available display data.

[**0086**] Referring to **FIG. 12**, Keyboard Interrupt routine, block **534**, begins by determining if the debounce timer is running, decision block **560**. The debounce timer is used to ignore additional or repeating inputs until the first input is processed. If the debounce timer is running, the routine exits, block **562**. If the debounce timer is not running, the rows and columns of the keyboard matrix are scanned, block **564**, and the button position is determined, block **566**. If the button pressed is related to camera control, decision block **568**, camera data is loaded in the transmit buffer, block **570**, the transmit to camera flags are set, block **572**, and the debounce timer is reset, block **574**. If the key pressed is not related to camera control, the data is loaded into the transmit buffer, block **576**, the transmit to vault flags are set, block **578**, and the debounce timer is started again, block **580**.

[**0087**] Referring to **FIG. 13**, the Transmit Setup routine is shown starting with block **590**. If the data in the transmit buffer is to be sent to the vault as indicated by the transmit to vault flags, decision block **592**, the serial path to the vault is set, block **594**, the SCI interrupt is enabled, block **596**, and a knock is sent to the vault, block **600**. Next, flags are set to indicate the source of the data to be sent to the vault, block **600**, and the routine exits, block **602**. If the data is not to be sent to the vault, decision block **592**, the serial path to the camera is set, block **604**, the SCI interrupt is enabled, block **606**, and the flags are set to indicate the source of the data to be sent to the camera, block **608**. The routine then exits, block **602**.

[**0088**] Referring to **FIG. 14**, The In-circuit Programming interrupt routine starting with block **548** is shown. The data from the diagnostic/programming port is compared to the embedded data to determine if reprogramming of the system is proper, decision block **612**. If the data does not match, the system locks-up in an infinite loop, block **614**, until the watch dog timer times out. If the data matches, the flash code is transferred from the diagnostic/programming port to control head RAM, block **616**. The user vectors are erased, block **615**. If the correct number of bytes have not been received, decision block **618**, the received data is stored, block **620**, the watchdog timer is updated, **622**, and another byte of data is checked. If the correct number of bytes have been received, decision block **624**, a checksum of the data is calculated, block **624**, to determine if the data was correctly received. If the checksum calculated does not match the checksum received, decision block **626**, the system locks-up in an infinite loop, block **628**, until the watch dog timer times out. If the checksum is correct, decision block **626**, the flash memory is erased, block **630**, the newly received program is written to flash memory, block **632**, and the ICP interrupt exits, **634**.

[**0089**] Referring to **FIG. 15**, the Transmit interrupt routine, block **640**, begins by getting the next byte of data to send, block **642**. The data is transmitted through the SCI, block **644**, and the counter is decremented, block **646**. If the counter is not zero, which indicates that all data has been sent, decision block **648**, the Transmit Interrupt exits, block **650**. If all data has been sent as indicated by the counter equaling zero, decision block **648**, a flag is checked to determine if the data was sent to the vault, decision block **652**. If no data was sent to the vault, the Transmit Interrupt exits, block **650**. If data was sent to the vault, decision block **652**, the need acknowledgement flag is set, block **654** and the interrupt exits, block **650**.

[**0090**] Referring to **FIG. 16**, the Timer Interrupt starting with block **660** is illustrated. The Timer Interrupt is enabled approximately 256 times per second by an internal clock to service timers and interrupt flags set by other routines. First, the debounce timer is updated, block **662**, then the Timer Interrupt reads the radar ready flag to determine if the radar data is ready to send, decision block **664**. If radar data is ready, the Process Radar routine is called (see **FIG. 17**). Next the Timer Interrupt routine reads the beeper flag. If a status beep is needed, decision block **668**, a beep is output, block **670**, the beeper byte is processed to determine what type of beep, block **672**, and the next beep is set or reset, block **674**. The Timer Interrupt routine then exits, block **676**.

[**0091**] If no beeper is needed, decision block 668, the Timer Interrupt routine reads the Flash LEDs flags. If the LEDs need to be flashed, decision block 678, the flasher byte

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is processed, block **680**, the flasher byte is set for the next pass through this routine, block **682**, and the routine exits, block **676**. If no LED needs to be flashed, the Timer Interrupt routine examines the vault acknowledge flag. If no acknowledgement is needed from the vault, decision block **684**, the routine exits. If acknowledgement is need from the vault, decision block **684**, the acknowledgement timer is updated, block **686**. If an acknowledgement is required from the vault and has been received before the acknowledgement timer has expired, the vault does not need to be re-knocked, decision block **688**, and the interrupt exits, block **676**. If the acknowledgement timer has expired and the vault has not sent an acknowledgement, the vault needs to be re-knocked, decision block **688**, the vault is sent another knock, decision block **690**, and the interrupt exits.

[**0092**] The Radar Receive Interrupt routine is shown in **FIG. 17** starting with block **700**. If it is the start of a radar message, decision block **702**, the radar data is receive, block **704**, and stored, block **706**. If the message is not complete, decision block **708**, the interrupt routine exits, block **712**. If the message is complete, the radar ready flag is set, block **710**, and the interrupt exits, block **712**. If it is not the start of a radar message, decision block **702**, and the gap timer has not expired, decision block **714**, the routine exits, block **712**. If gap timer has expired, decision block **714**, the start of radar message flag is set, block **716**, the first byte of the message is processed to determine the message length, block **718**, and the message length is stored, block **720**. The interrupt routine then exits, block **712**.

[**0093**] The Process Radar routine is shown in **FIG. 18** beginning with block **666**. If the data received from the radar is not encrypted, decision block **730**, the data is processed as standard video data, block **732**, and then transferred to the transmit buffer, block **736**. If the data is encrypted, decision block **730**, the data is first decrypted, block **734**, then sent to the transmit buffer, block **736**. Next the radar transfer flag is set, block **738**, the gap timer is reset, block **740**, and the start of message flag is reset, block **742**. The Process Radar routine then exits.

System Set-Up

[**0094**] Referring to **FIG. 19**, the dynamic button labels generally indicated by reference numeral **800** are normally not displayed on the monitor **16**. The main menu labels **800** are automatically displayed on the monitor **16** when any of the monitor buttons generally indicated by reference numeral **802** are pressed. The main menu includes the option labels Play, Zoom, Focus, Setup and Exit located on the monitor **16** above the dynamic buttons **802**.

[**0095**] Depressing the button **804** under the SETUP selection provides access to the Setup Menu **806** (**FIG. 20**). The system may be configured to restrict access to the setup menu. The DVD disk **52** should be in the recorder **50** to enter some parts of the setup menu system. The system records any changes made in the setup routine that impact recording to later determine if the recording on the DVD disk **52** has been altered. A quick review of the recording will either verify the time was not changed, or prove that it was changed.

[**0096**] The setup menu **806** allows the following options to be easily selected or changed: Time/Date; T/D Position; Flash Preference; Date Format; ID Generator; Daylight Savings Adjustment; Auto Zoom Settings; Record Length; Playback rate (Skiprate); Beep Tone Enable; Audio Out Select; and Eject Enable.

[**0097**] When the SETUP button is depressed (**FIG. 19**), the dynamic button labels **800** are reassigned to the following functions as shown in **FIG. 20**: up arrow **812**, down arrow **814**, and EXIT. The EXIT button **808** is relabeled as the ENTER button as the cursor **810** is positioned or scroll up the menu **806** using the arrow buttons **812** and **814**, in order to make a selection.

[**0098**] From the Setup Menu **806**, selection of Time/Date/User Text **816** displays the submenu Display Menu generally indicated by reference numeral **818** as shown in **FIG. 21**. The monitor's dynamic buttons **802** are assigned up arrow, down arrow, and ENTER.

[**0099**] Using the arrow buttons **812** and **814**, the cursor **810** may be positioned next to the Set Time/Date menu label **820** and the Enter button **822** pressed to access the Set Time/Date submenu generally indicated by reference numeral **824**, **FIG. 22**. This option allows the user to set the time and date that is recorded onto the DVD disk **52**. The system's calendar includes provisions for leap years, and can be set to automatically adjust for daylight saving time. To set the Hour, Minute, Month, Day and Year values, a cursor **828** is moved over the digit to be changed using the left and right arrow buttons **830** and **832** respectively. Once the cursor is placed over the digit to be changed and the up and down arrow buttons **812** and **814** may be used to increase or decrease the value. To set the value, the ENTER button **822** is pressed and the system returns to the Display Menu **818**, **FIG. 21**.

[**0100**] The User Information option **834** allows the operator to add an identifier to the video recordings. Examples include: officer badge number, car number, precinct number, etc. Three lines of **20** spaces each generally indicated by reference numeral **836**, **FIG. 23**, may be used. A cursor **838** may be moved over a character position to be changed using the left and right buttons **830** and **832**, and may be changed using the up and down arrow buttons **812814** to scroll through the alphabet, digits and other characters. Pressing the EXIT w/SAV button **840** saves the information entered and returns to the Display Menu **818**.

[**0101**] The Position option **842** allows the operator to place the time and date at the top or bottom of the screen **16**. Using the up and down arrow buttons **812** and **814** to move the cursor **810** next to the Position option **842**, the position of the time and date may be toggled between bottom of the screen and top of the screen by pressing the ENTER button **822**.

[**0102**] The Flash preference **844** allows the operator to select whether or not the time and date will flash. Flashing the time and date (every 12 second for example) allows objects behind the time and date to be seen intermittently. Using the up and down arrow buttons **812** and **814** to move the cursor **810** next to the Flash option **844**, flashing of the time and date may be toggled between ON (time and date flashes on screen) and OFF (time and date do not flash) by pressing the ENTER button **822**.

[**0103**] The Date Format **846** allows the operator to set how the date is displayed. Using the up and down arrow buttons **812** and **814** to move the cursor **810** next to the

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Format option **846**, the format of the date may be toggled between MM/DD/YY and DD/MM/YY by pressing the ENTER button **822**.

[**0104**] The Daylight Savings Mode option **848** allows the operator to control automatic time adjustment for daylight savings. Using the up and down arrow buttons **812** and **814** to move the cursor **810** next to the Daylight Sav option **848**, automatic adjustment of the time may be toggled between ON (system will automatically adjust for daylight savings) and OFF (system will not automatically adjust for daylight savings) by pressing the ENTER button **822**.

[**0105**] Selecting Exit **850** on the Display Menu **818** will return the system to the Setup Menu display **806** (**FIG. 20**).

[**0106**] The System Settings option **852** allows the operator to set the recording quality and file name of the saved recording. Using the up and down arrow buttons **812** and **814** to move the cursor **810** next to the System Settings option **852** and the ENTER button **808** pressed to access the System Settings menu generally indicated by reference numeral **854**, **FIG. 24**.

[**0107**] Selection of the Record Quality option **856** allows the operator to utilize different recording resolutions and therefore different recording time length. The GOOD setting provides 9 Hrs and 20 minutes of record time; the BETTER setting provides 7 Hrs and 30 minutes of record time and the BEST setting provides 5 Hrs and 20 minutes of record time. The record length may be changed at any time. If this setting is changed in the middle of a DVD disk recording, the time-left display will change accordingly.

[**0108**] Selection of the Filename option **858** allows the operator to change the file name of the recorded file on the DVD disk **52**.

[**0109**] Referring to **FIG. 20**, selection of the Auto Zoom option **860** displays the Set Zoom Values menu generally indicated by reference numeral **862**, **FIG. 25**, and allows the operator to customize the values used for the auto zoom feature described hereinabove. The Tele and Wide values are percentages and may be changed by positioning the cursor **810** next to the value to be changed and using the up and down arrows **812** and **814** to adjust the value. Selecting the Restore defaults option **868** resets the Tele and Wide values to predetermined values. Selecting the Exit w/Save option **870** and pressing the EXIT button **872** saves the values and returns the display to the Setup Menu, **FIG. 20**.

[**0110**] The Beep option **874** allows the operator to select whether audible alert (beep tones) messages are output through speaker **18**. If this feature is ON, three beeps, for example, will be output whenever the system starts to record. Whenever the DVD disk **52** is almost full or there is a low voltage condition detected by the system, eight beeps, for example, will be output.

[**0111**] The Audio Out option **876** is used when the system is equipped with an optional in-car microphone. Audio Out allows the operator to select which audio sources will be played back over the in-car monitor **16**. For example, the in-car microphone may be recorded while simultaneously conducting interviews outside the patrol vehicle with the wireless microphone **38**. The system is equipped with a DVD recorder **50** with two audio tracks. The two microphone sources are recorded on separate tracks and for playback, this menu option allows the operator to easily isolate the track of interest.

[**0112**] The Software Versions option **878** allows the operator to view the software revisions for each of the micro-controllers for diagnostic purposes.

[**0113**] The Allow EJECT option **880** allows the operator to eject the DVD disk **52**. The eject button (not shown) on the DVD drive **50** is disabled during normal operation in order to ensure that the disk is write-protected when it is removed. In this manner, evidence cannot be accidentally erased from the disk when it is removed from the system. The Allow EJECT selection **880** write-protects the disk, and enables the Eject button on the front of the DVD drive **50**.

[**0114**] Selection of Exit **882** returns the system display to the Main Menu, **FIG. 19**. Referring to **FIGS. 19 and 26**, selection of the FOCUS button **884** displays the Focus menu generally indicated by reference numeral **886**. The FOCUS menu **886** allows the user to utilize manual focus functions (NEAR, FAR), activate or disable Autofocus (AF), and activate or disable the Backlight (BL) functions.

[**0115**] Referring to **FIGS. 19 and 27**, selection of the ZOOM button **888** displays the Zoom menu generally indicated by reference numeral **890**. The ZOOM menu **890** allows the operator to utilize manual zoom functions (TELE, WIDE), and to activate or disable Digital Zoom (DZON, DZOFF).

[**0116**] Referring to **FIGS. 19 and 28**, selection of the PLAY button **892** displays the Play menu generally indicated by reference numeral **894**. The PLAY menu **894** allows the user to utilize the system's video playback functions, perform Fast-Forward or Reverse Searches and Pause the video at any time. When the Play menu **894** is initially displayed from the Main Menu, the system automatically plays the last recorded video file.

[**0117**] While in the Play menu **894**, and during the process of playing back the last recorded video file, the operator may select any of the functions displayed on the PLAY menu **894**. Video playback may be paused by pushing the PAUSE menu key **896**. Previously recorded video clips may be viewed by pushing the PREV (Previous) button **898**. This button may be pushed to "scroll back" through previously recorded video files as many times as the operator desires until the beginning of the disk recording is reached. Each time the PREV button **898** is pressed, the file previous to the one currently showing will be played back. This button may be pushed until the first file recorded on the disk is reached. At that point the PREV button **898** will no longer elicit a response from the system, and the first file will play.

[**0118**] When viewing previously recorded video segments, the operator may move forward in the video segments as well, playing back video recorded after the one currently being viewed. This is accomplished by pressing the NEXT button **900**. Each time the NEXT button **900** is pressed, the file recorded after the one currently being viewed is played back. The NEXT button **900** may be pushed until the operator has reached the last video segment recorded, at which time that segment will play.

[**0119**] To reverse search the current video segment being viewed, the operator may press the REV (reverse) button

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902. Likewise, the operator may forward search the current video segment being viewed by depressing the FFWD (fast forward) button **904**.

System Operation

[**0120**] When the system is turned ON, a single audible beep is output on speaker **18**. If the system has been exposed to extreme temperatures for an extended period of time, 20-30 minutes of ignition operation may be required for the environmental system to bring the interior of the enclosure to within the recorder's operating temperature range (necessary to record). If the temperature is above freezing, recording can begin immediately.

[**0121**] When a blank DVD disk **52** is inserted into the recorder **50**, the control center **10** displays the time remaining on the disk **52**. If no disk **52** is in recorder **50**, the Control Center **10** displays three horizontal lines, for example.

[**0122**] The system may automatically start recording when the emergency lights or siren is turned on, or when the wireless microphone **38** is activated.

[**0123**] When the system is turned on, a single beep is output from the Control Center **10** through speaker **18**. Beeps are provided (if activated) to indicate whenever the system receives a record command, when the DVD disk **52** nears its end or when a low voltage condition exists. These beeps are intended to alert the operator to the status of the system without having to look at the Control Center **10** or monitor **16**. For example, when the emergency lights are turned on, the system will automatically initiate the record command. The Control Center **10** will beep three times to confirm that the system recognized the lights and has activated the record command.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent is as follows:

1. A digital video surveillance system for a law enforcement vehicle comprising:

a video camera for generating video signals of an incident, said video camera mounted on said law enforcement vehicle and positioned to view an incident;

a memory buffer for recording said video signals from said video camera;

a controller for selectively generating record and playback signals to record and to display said video signals; and

a digital video recorder responsive to said record signal to record said video signals from said memory buffer on an optical medium, said video recorder responsive to said playback signal to reproduce video signals recorded on said optical medium.

2. The digital video surveillance system as set forth in claim 1 further comprising a vault enclosing said digital video recorder.

3. The digital video surveillance system as set forth in claim 1 further comprising a display selectively responsive to said video signals generated by said video camera and said video signals reproduced by said digital video recorder to display a video image.

4. The digital video surveillance system as set forth in claim 1 further comprising a battery for providing backup power to said digital video surveillance system.

5. The digital video surveillance system as set forth in claim 1 wherein said optical medium is a DVD disk.

6. The digital video surveillance system as set forth in claim 5 further comprising means for combining digital information with said video signals prior to recording on said optical medium to provide a tamper-resistant digital recording.

7. The digital video surveillance system as set forth in claim 6 wherein said digital information is a watermark.

8. The digital video surveillance system as set forth in claim 1 further comprising:

a wireless microphone for generating a radio signal modulated by received audio communications;

a receiver responsive to said radio signal for generating electrical signals corresponding to said audio communications received from said wireless microphone; and

logic circuitry for combining said video signals and said electrical signals into a composite signal;

said memory buffer being responsive to said composite signal to continuously record said composite signal;

said video recorder recording said composite signal on said optical medium in response to receiving said record signal and reproducing said composite signal recorded on said optical medium in response to receiving said playback signal.

9. The digital video surveillance system as set forth in claim 8 further comprising a speaker mounted on said law enforcement vehicle responsive to said electrical signals generated by said receiver and said electrical signals of said composite signal reproduced by said digital video recorder.

10. The digital video surveillance system as set forth in claim 1 further comprising a console mounted on said law enforcement vehicle having user-operable controls coupled to said controller for directing the operation of said system.

11. The digital video surveillance system as set forth in claim 10 wherein said console includes a display responsive to said video signals generated by said video camera and said video signals reproduced by said digital video recorder to display a video image.

12. A digital video incident capture system for a law enforcement vehicle comprising:

a video camera for generating video signals of an incident, said video camera mounted on said law enforcement vehicle and positioned to view said incident;

a wireless microphone adapted to be worn by an operator of said law enforcement vehicle, said wireless microphone generating a radio signal modulated by received audio communications;

a receiver responsive to said radio signal for generating electrical signals corresponding to said audio communications received from said wireless microphone;

a controller for selectively generating record and playback signals to record and playback said video signals and said electrical signals corresponding to said audio communications;

logic circuitry for combining said video signals and said electrical signals into a composite signal;

a memory buffer for continuously storing said composite signal;

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a digital video recorder having a DVD drive and responsive to said record signal from said controller to record said composite signal from said memory buffer on a DVD disk, said recorder responsive to said playback signal to reproduce said composite signal recorded on said DVD disk;

a display selectively responsive to said video signals generated by said video camera and said video signals of said composite signal reproduced by said digital video recorder to display a video image; and

a speaker mounted in said law enforcement vehicle responsive to said electrical signals generated by said receiver and said electrical signals of said composite signal reproduced by said digital video recorder.

13. The digital video surveillance system as set forth in claim 12 further comprising a vault enclosing said digital video recorder.

14. The digital video incident capture system as set forth in claim 12 further comprising a battery for providing backup power to said digital video incident capture system.

15. The digital video incident capture system as set forth in claim 14 further comprising means for combining digital information said video signals prior to recording on said DVD disk to provide a tamper-resistant digital recording.

16. The digital video incident capture system as set forth in claim 15 wherein said digital information is a watermark.

17. The digital video incident capture system as set forth in claim 12 further comprising a console mounted on said law enforcement vehicle having user-operable controls coupled to said controller for directing the operation of said system.

18. The digital video incident capture system as set forth in claim 17 wherein said display is mounted in said console.

19. A digital video surveillance system for a law enforcement vehicle comprising:

a video camera for generating video signals, said video camera being mounted on said law enforcement vehicle and positioned to view an incident;

a history buffer for continuously recording said video signals from said video camera to provide a video history of predetermined duration;

a controller for selectively generating a record signal and a playback signal;

a digital video recorder having a disk drive and responsive to said record signal for receiving and recording said video history on an optical medium and for receiving and recording ensuing video signals from said history buffer, and responsive to said playback signal for reproducing video signals recorded on said medium; and

a display selectively responsive to said video signals from the video camera and said video signals reproduced by said video recorder for displaying a video image.

20. The digital video surveillance system as set forth in claim 19 further comprising a vault enclosing said digital video recorder.

21. The digital video surveillance system as set forth in claim 19, wherein said optical medium is a DVD disk.

22. The digital video surveillance system as set forth in claim 19 further comprising a battery for providing backup power to said digital video surveillance system.

23. The digital video surveillance system as set forth in claim 19 further comprising means for combining digital information with said video signals prior to recording on said optical medium to provide a tamper-resistant digital recording.

24. The digital video surveillance system as set forth in claim 23 wherein said digital information is a watermark.

25. The digital video surveillance system as set forth in claim 19 further comprising:

a wireless microphone adapted to be worn by an operator of said law enforcement vehicle, said wireless microphone generating a radio signal modulated by received audio communications;

a receiver responsive to said radio signal for generating electrical signals corresponding to said audio communications received from said wireless microphone; and

logic circuitry for combining said video signals and said electrical signals into a composite signal;

whereby said memory buffer continuously records said composite signal and said video recorder records said composite signal on said optical medium in response to receiving said record signal and reproduces said composite signal recorded on said optical medium in response to receiving said playback signal.

26. The digital video surveillance system as set forth in claim 25 further comprising a speaker mounted on said law enforcement vehicle responsive to said electrical signals generated by said receiver and said electrical signals of said composite signal reproduced by said digital video recorder.

27. The digital video surveillance system as claimed in claim 25, wherein said digital optical medium is a DVD disk.

28. The digital video surveillance system as set forth in claim 25 further comprising means for combining digital information with said video signals prior to recording on said optical medium to provide a tamper-resistant digital recording.

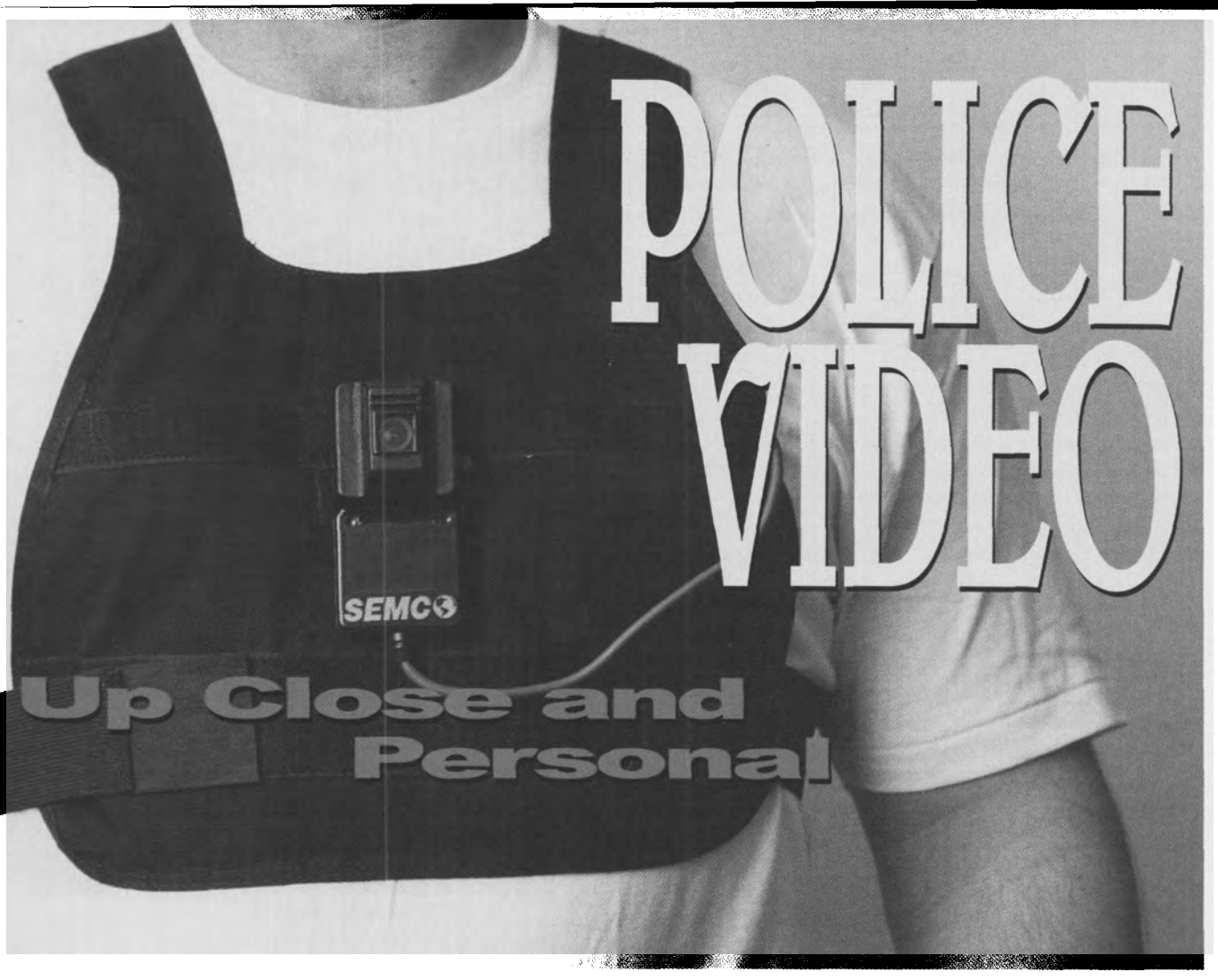
29. The digital video surveillance system as set forth in claim 28 wherein said digital information is a watermark.

30. The digital video surveillance system as set forth in claim 19 further comprising a console mounted on said law enforcement vehicle having user-operable controls coupled to said controller for directing the operation of said system.

31. The digital video surveillance system as set forth in claim 30 wherein said console includes a video display responsive to said video signals generated by said video camera and said video signals reproduced by said digital video recorder.

* * * * *

Appendix N



POLICE VIDEO

Up Close and Personal

By Dale Stockton

During a relatively routine stop for bad driving, the intoxicated driver became uncooperative. She refused to perform the field sobriety tests and later refused to take the blood alcohol test. With only driving and general objective symptom observations, Sgt. Craig Carter, Escondido, CA Police Department, knew this case could be difficult to prove.

From experience, he knew that prosecutors are sometimes reluctant to go to trial relying solely on an officer's testimony. Unlike many cases of this nature, though, this case was on videotape - from the driving observations to the driver's refusal on the blood alcohol test. But while the use of video cameras in police cars is not that unusual, this case had a different twist. Carter was wearing a body-mounted camera, known as a CopCam. The device, working in conjunction with a camera and recording unit in his car, allowed the officer to record the entire scene "up close and personal" with quality audio and video. The tape left no doubt as to the woman's sobriety at the time she was stopped.

"The DA was considering the offer of a plea. Although it was in my report (the use of the videotape), the DA didn't understand how good the video was. After watching it, they went forward with the full charges and she pled guilty. The tape really made a big difference," Carter said.

He explained, "The unit we have has a camera in the car and a camera on the lapel of the officer. The officer can switch between the cameras. The result is, you use the system more often than if it was just in the car. For instance, in a domestic violence situation, you can go into a house and transmit back to the car."

CopCam, manufactured by Semco Corporation, Vista, CA, uses technology developed in military applications. Semco brought the system to law enforcement with the idea of recording not just a car-mounted view but also what the officer was seeing.

Several manufacturers produce miniaturized cameras used by law enforcement agencies in covert surveillance situations around the world. However, Semco is the only one to offer a system designed to be worn on the body of a uniformed police officer in regular patrol operations.

Today's CopCam system bears little resemblance to the prototype introduced in 1994. With input from departments using the device, the system has undergone continual improvements, primarily to increase functionality and wearability in the field. A big change has the size of the recording equipment.

"The equipment in the trunk used to be the size of a large suitcase. It's now much smaller and more secure," Carter said.

The body camera, battery and transmitter have also shrunk. "The camera lens is now attached to the lapel of the shirt, and there's a vest with transmitter and battery worn under the shirt," Carter

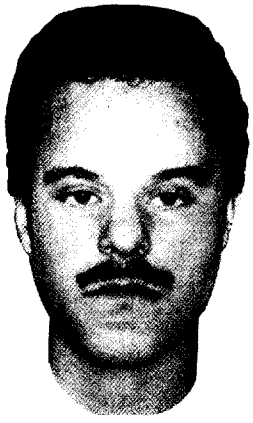
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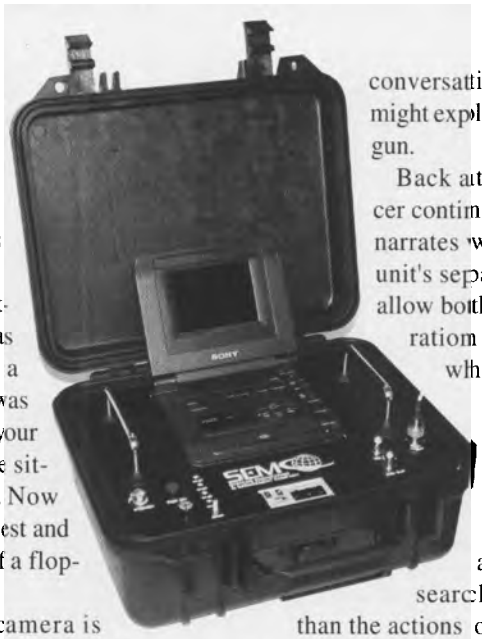
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explained. "The unit is an integral part of your body armor. It's something that no one would ever notice. All the wires are under your shirt.

"The first one I tested, the battery was about the size of a portable radio and it was worn on the back of your gun belt so you were sitting on it in the car. Now the battery is in the vest and it is about the size of a floppy disk," Carter said.



While the body camera is what makes CopCam unique, it's only part of a more comprehensive system. The latest unit provides three cameras; one mounted in the patrol car, one mounted on the officer, and one mounted in a concealed area of the patrol car so as to record the actions of suspects in the back seat. The officer chooses which camera is active and two audio tracks may be recorded simultaneously.

Here's how the new system could work in a real world example. An officer spots a car being operated in an erratic manner. The in-car camera starts to record the driver's actions. As the car stops, the officer taps a button to activate the auto-zoom feature. The unit zooms in, focuses on the vehicle's license plate, and then zooms back out to record the full scene as the officer approaches. As the officer approaches the car, the in-car unit continues to record video while the officer's body unit picks up audio sounds.

At the driver's window, the officer can choose to activate his body camera. If he does so, the recording unit in the patrol car automatically switches to receive the signal of the camera worn by the officer. The camera, worn at roughly chest level, records a clear picture of the faces of vehicle occupants as well as the interior of the car.

Let's assume that the officer obtains consent from the driver to search the car (all recorded on tape) and, as a result, finds a handgun under the front seat which turns out to be stolen. Both subjects are secured in the back of the patrol car. Unknown to the subjects, the officer triggers the concealed camera in the car to records their actions and also their conversation as to how they might explain away the handgun.

Back at the car, the officer continues his search and narrates what he finds. The unit's separate audio tracks allow both the officer's narration and the suspects' whispered conversation to be recorded simultaneously. Should the officer choose to videotape his actions as he searches the car rather than the actions of the suspects, he need only activate his body mounted camera and the recording switches over without the need to return to the police vehicle.

The value of this type of information is obvious. "I had a case where I had a consensual search but the suspect later recanted in court," Carter said. "When you can show it on video, it really helps. The same thing applies to traffic tickets. Once I'm at the window, I have a picture of the driver's face and I have a recording of anything he says."

"The only time I wouldn't have the unit on is when I'm alone in my car," Carter said. "When you turn it on and off, it makes a note of how long you had it on and it has an actual running meter."

How do other officers feel about being taped? What about an officer's actions being taped inadvertently? It hasn't been a problem in Escondido.

"When I come on a scene, the other officers know that I'm wearing it," Carter said. "I've gotten numerous requests where an officer with a touchy situation calls me to the scene to capture it on video.

"For instance, we had a subject trying to commit suicide. When we arrived he had a knife to his neck. We negotiated about 45 minutes before we took the action of using a beanbag round. The tape showed our efforts before we used the beanbag gun, and also showed his state of mind. That was valuable in showing the mental health people what the subject was like in the field in contrast to the way he acted at their facility."

In a situation that was broadcast across the country, an Escondido patrol car

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with a CopCam system captured an officer-involved shooting. The camera showed an officer backing up as a crazed suspect ran at him with a barbecue tool raised in a stabbing position. The officer fired his weapon, killing the suspect. The tape provided details as to exactly what happened at the scene.

Did the tape make a difference? The shooting was cleared by the DA's office shortly after the tape was viewed, an action that often takes more than a month of review. The tone of the media changed when the tape showed just how threatening and fast moving the suspect was at the time.

Would the ultimate outcome have been any different? Lt. Rick Bass pointed out that the tape simply confirmed what several witness officers at the scene had already told investigators and supervisors. "The film showed in more detail what actually happened. For instance, the officer who did the shooting had actually backed up over 25 feet. He hadn't realized how far he had retreated trying to get out of this guy's way.

"In a single officer situation the tape could make a real difference," Bass acknowledged. "Whatever it shows is going to help establish the truth. And on a routine basis, the officer knows they are being recorded and this can make a big difference in officer complaints. To me, that's important. There are a lot of complaints generated from drunk driving arrests because people are under the influence. The tape really helps in those cases," Bass said.

While supportive of new technology, like CopCam, Bass raised some thought provoking issues. "The camera is there to document whatever happens. Some people now feel that we have to have a tape to prove something occurred. I don't want to see the day come when we have to have a camera in every car and on every shirt to prove something," he said.

Then there is the issue of privacy. "We want to make sure that if we go into someone's house we're not recording areas which would be embarrassing to citizens who aren't committing criminal activity," Bass said. "If we go into a house looking for a suspect, as in the service of a search warrant, that's different and the videotape can be invaluable."

Another concern is storage. "A department needs to consider a procedure that's



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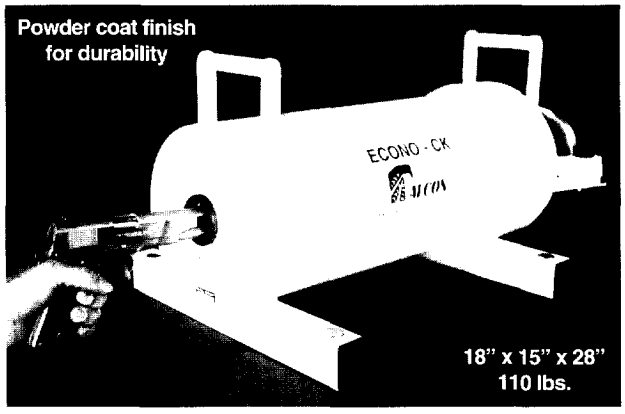
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fair to the public in terms of recording and retaining potential evidence," Bass said. "What if evidence issues are raised after a tape is destroyed? The obvious implication is that it was destroyed to cover something up." He pointed out that tapes add up quickly and storage and retention issues should be part of a well thought-out policy.

Technology continues to change the way officers work. Officers now take advantage of lasers, computers, miniaturized recorders and video transmitters. High-tech equipment, originally developed for specialized military or space applications, is being offered and agencies are identifying practical law enforcement uses for such equipment.

The challenge is to balance the capabilities of these new tools with the foresight to proactively address training and policy issues. Through proper planning, department administrators can ensure high tech equipment purchases effectively enhance an officer's capabilities. L&O

If you would like to learn more about this new crime fighting tool, contact the Semco Corporation, 1430 Vantage Ct, Vista, CA 92083. Phone - 760-727-7800 or 1-800-995-0636, Fax 760-727-5200, or visit the company's web site at www.semco.com.

Dale Stockton is a supervisor with the Carlsbad Police Department, CA and he teaches law enforcement classes to college students.

Versatile Law Enforcement Flashlights

By Tony Lesce

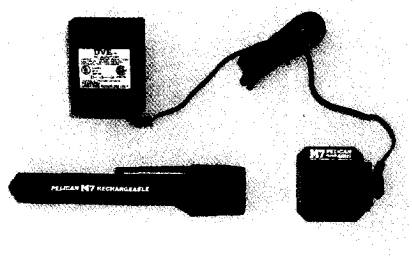
Four new Black Knight rechargeable flashlights by Pelican Products are technically advanced models that provide definite advantages over older models.

The smallest, the M7, is pocket-sized measuring 6 ¼" overall, with a ¾" diameter body and a 1¼" diameter head. It operates on two nicad (nickel-cadmium) rechargeable batteries, and with a xenon bulb. The bulb is part of a prefocused lamp module, and provides a bright spot.

The three-ounce M7 has a hexagonal section thermoplastic rubber shroud around the head to prevent rolling away on an inclined surface. Likewise, the black Xenoy flashlight body has a hexagonal shape. At the rear is a two-function push button switch, for blinking the light and working as an on/off switch with a firmer push. The flashlight's lens is sturdy polycarbonate.

The M7 comes with a charger that can mount either horizontally or vertically. It's impossible to seat the flashlight incorrectly in the charger because the pocket clip acts as a key, fitting only one way. Spring-loaded plungers ensure a secure connection.

Testing showed the 16,000 candlepower spot is bright enough to illuminate objects at several dozen yards, and that battery life is as claimed. Charging time is eight hours from "empty," and the flashlight delivers a full



The rechargeable pocket-size Pelican M7 is slightly over 6" long, has a pocket clip, and delivers 16,000 candlepower for 1 ½ hours on a full charge.

1½ hours continuous light before the bulb becomes dim.

Batteries resist developing a "memory" effect, making it practical to recharge the flashlight before the batteries become depleted. This is an improvement over traditional nickel-cadmium batteries, which have a tendency to develop a "memory" when charged after being only partly discharged.

The larger 20,000 candlepower M9 measures 7 1/8" long, 1 1/8" wide at the body, and 1 ½" at the hexagonal head. The M9 body is made of black ABS plastic, and has a chemical-resisting thermoplastic rubber sheath for a non-slip grip. Again, the beam can be focused.

The M9 comes with a "Smart Charger," which provides a 3-4 hour charge for the three "C" nicad batteries. Batteries can take over 1,000 charges. Weight is eight oz. with batteries. The on/off and blinker switch is located on the body behind the head, for easy thumb operation.

The full-size M11 measures 11" long, with a 1 3/8" black ABS body and a 1 ½" hexagonal head. The lens is unbreakable polycarbonate, and the lamp module is pre-focused. Like the M9, this model has a side-mounted on/off and blinker push button switch. A Smart Charger powers this 40,000 candlepower flashlight, which uses four "C" size nicad batteries. Total full-burn time is 1½ hours per charge. Weight is 1 lb. 2 oz. with batteries.

The "LaserPro" M13, a king-size 80,000 candlepower spotlight, is for heavy-duty use, including underwater operation. It is watertight to 500 feet, sealed with an O-ring, and provides two hours and 15 minutes continuous burn time per charge. The dual-filament bulb carries its own back-up. Each filament provides 80,000 candlepower, and provides 30 hours of operation.

The M13 is 8" long, and the body is 4 ¾" wide at the head, with a carrying handle on top. A wire stand is fitted, and is adjustable to several positions, folding away when not needed. Total weight is 4 lb. with batteries.

Burn time for these and all flashlights is variable (the times given are for uninterrupted illumination). Using the flashlights intermittently, the most realistic way of using them, provides somewhat longer use on a single charge. For extended use, all lights are available with optional 12-volt plug in the charger cord, or a direct wiring rig that allows connecting the charger to the vehicle's electrical system.

All Pelican Black Knight Flashlights come with an unconditional lifetime guarantee. L&O

Available from:
Pelican Products, Inc.
23215 Early Avenue
Torrance, CA 90505
Phone: (800) 4-Pelican
Fax: (310) 326-3311
Web site: http://www.pelican.com
E-mail: jsandoval@pelican.com

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Appendix O

County DIGEST

MARCH 2000 COUNTY OF LOS ANGELES

Linda Estrada

"This recognition has been an overwhelming experience."



Linda Estrada, the February 2000 County Employee of the Month, has been a County employee for 32 years and is presently a Contract Program Monitor for the Office of Administrative Services in the Sheriff's Department.

"This award is a great honor for me as well as my family and co-workers. Initially, my friends and co-workers were more excited than I was. It took a few days for everything to sink in, but February 18th turned out to be an amazing day for me. I was recognized as County Employee of the Month on the County's 150th birthday; that was awesome."

Estrada's current assignment is with Department-wide contract development and administration. She is responsible for such tasks as solicitation, contract development and amendments, purchase order conversions to contracts, and contract administration. She seeks to improve departmental productivity with activities and insights that have Countywide impacts, e.g. she stepped into a project when a less experienced colleague ran into time constraint difficulties on a contract to manage the Custody Jail Store System. Her intervention prevented the Department from possible shut down of the inmate cash-less buying system, which could have resulted in inmate riots and serious Countywide consequences.

"The Sheriff's Department is currently embracing new technology at a rapid pace and the innovations we are working on will set an example for other law enforcement agencies throughout the world. The Contracts Unit works together as a team, and I consider myself very fortunate to work in such an energetic and dynamic department. As exciting as receiving this recognition was for me, the good wishes and support I received from the Sheriff's Department, my co-workers, and friends throughout the County, was a humbling experience. I consider myself very lucky to have the opportunity to work with these truly extraordinary people."

Estrada was one of the founding members of the Minority and Women Owned Business Enterprise Coordinators Council, which was formed to implement a Board directive to determine ways to improve and increase opportunities for

see Estrada on page three

WalkAmerica 2000!

March of Dimes
Saving babies, together



Pictured are the 1999 County WalkAmerica Chair Supervisor Don Knabe and Nancy O'Dell of "Access Hollywood" as they kick-off the 1999 WalkAmerica in Marina Del Rey.

Los Angeles County is stepping into the 21st Century. That's right, the County is once again putting its best foot forward and participating in the March of Dimes annual WalkAmerica event. Celebrating its 30th year, WalkAmerica 2000 will be held on Saturday, April 29, 2000. This

see WalkAmerica on page three

Calendar of Events

Free Property Tax Assessment Seminars
County of Los Angeles
(213) 974-4240

Van Nuys - Bernardi Senior Center
11:00 a.m.
6514 Sylmar Avenue
March 29, 2000 - Wednesday

Noontime Parenting Training Seminars
(213) 893-0355

Dealing With Your Teenager
March 22, 2000
11:45 a.m. to 12:45 p.m.
Kenneth Hahn Hall of Administration
Room 743

Child Care Fair
April 19, 2000
11:30 a.m. to 1:30 p.m.
Civic Center Mall

Petersen Automotive Museum
(323) 930-CARS
www.petersen.org

Discovery Day: Car Sponges
April 1, 2000
2:00 p.m. to 4:00 p.m.



Natural History Museum
of Los Angeles County
(213) 763-DINO
www.nhm.org

The Bahia: World's Largest Cut Gemstone Sculpture
Through September 4, 2000



12th Annual Los Angeles County
Chess Tournament
(626) 458-7188 or (213) 738-2456
April 27, 2000 and every Thursday
thereafter until June 1, 2000

6:00 p.m. to 10:00 p.m.
Public Works Building, Alhambra

Performing Arts Center of
Los Angeles County
(213) 250-ARTS

pARTy!*
May 20, 2000
10:00 a.m. to 4:00 p.m.

*A free outdoors arts festival to celebrate the 20th anniversary of the nationally-acclaimed Education Division of the Performing Arts Center.

Skirball Cultural Center
(310) 440-4500
www.skirball.org

Sigmund Freud: Conflict and Culture
April 4, 2000 through July 25, 2000

Ahmanson Theatre
(213) 628-2772

Martin Guerre
Through April 8, 2000

The Scarlet Pimpernel
April 25, 2000 through June 18, 2000

Page Museum
(323) 934-PAGE
www.tarpits.org

Mammothfest
March 18 & 19, 2000
10:00 a.m. to 4:00 p.m.

Los Angeles Opera
(213) 972-8001
www.laopera.org/

La Rondine
April 15, 2000 to May 5, 2000

Los Angeles County Museum of Art
(323) 857-6512

Lectures at LACMA
Through May 21, 2000

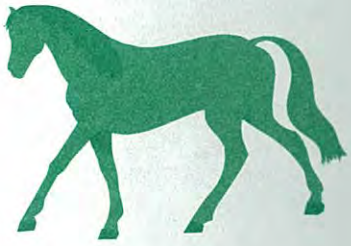
William S. Hart Museum
(661) 254-4584
www.hartmuseum.org

Wyatt Earp
April 1, 2000 - 4:00 p.m. to 5:30 p.m.

Simon Wiesenthal Center
Museum of Tolerance
(310) 475-5738
www.wiesenthal.com

California State Forum:
A Preview of the Mayoral Campaign
March 30, 2000
5:30 p.m.

Minority Images in Film & Television
April 6, 2000 - 6:30 p.m.



Estrada

continued from front page

minority and women owned businesses to compete for County purchases and contracts. She played a critical and influential role in formulating the County's leadership position in the use of alternative fuels in County vehicles.

She routinely participates in the Contracting Connections Workshops, sponsored by each Supervisor's District, and speaks at numerous small business gatherings, e.g. at meetings for the Women Construction Owners and Executives, and the Greater Los Angeles Vendor Fair, which is co-sponsored by the City and County of Los Angeles and the Metropolitan Transportation Authority. Her efforts help support the Board's Small Business Program, and her activities have contributed toward the County's improved cost-benefit equation. She is also the Vice President of the Los Angeles County Contracting and Purchasing Council.

"My most rewarding experience on a personal level is my recent completion of a B.S. Degree in Business Management from the University of Phoenix. It took 13 long and arduous years, but it will all be worthwhile when I attend my graduation ceremony this coming June."

Now that Estrada has completed her school work, she looks forward to spending time traveling, catching up on recreational reading, and taking classes for fun, e.g. creative writing. She plans to spend more time watching her two sons' respective high school baseball teams in action. Her favorite pastime is cooking for family and friends.

She will be donating her time to the collection of private funds for the National World War II Memorial.

"My father, Eloy Trujillo, was a veteran of World War II... I'm sorry that in my father's lifetime there was not a memorial commemorating the bravery and honor of World War II veterans. I hope that this will be rectified in my lifetime and I intend to contribute my time and energy to make this memorial a reality."

Congratulations, Linda!

Yaroslavsky Announces Wedding Ceremonies to be Available at Beverly Hills Registrar-Recorder's Office

Supervisor Zev Yaroslavsky has announced that effective February 17, the Los Angeles County Registrar-Recorder/County Clerk's Beverly Hills branch office will be performing marriage ceremonies. Since



August 5, 1997, the Beverly Hills office has been processing requests for marriage licenses. Adding marriage ceremonies will afford couples the convenience of scheduling an appointment for a civil ceremony following receipt of their marriage license. Yaroslavsky said a Deputy Commissioner of Marriage would perform the ceremonies by appointment on Thursdays only. The R-R/CC Beverly Hills office is located in the courthouse at 9355 Burton Way, First Floor. The office is open Tu-Thur, 8:30 a.m.-4:30 p.m. For appointments, contact the branch office at (310) 288-1261. The fee is $25.00.

Applicants must also obtain a license prior to scheduling an appointment; the license fee is either $67.00 or $69.00 depending on the type. Multilingual assistance is available by calling (800)481-8683.



WalkAmerica

continued from front page

year, the County's primary walk-site will be at El Dorado Park in Long Beach. Employees are encouraged to walk in Long Beach with the County team but can participate at any of the other walk-sites as well.

Supervisor Don Knabe, County WalkAmerica Chair, will lead the Long Beach Walk event. An exciting event has been planned with entertainment and children's activities. It's going to be a great day for employees and their families and friends to have fun, get some exercise and most importantly, help the March of Dimes in their fight against birth defects.

If you would like to join the County's WalkAmerica team, please contact your departmental WalkAmerica Team Captain or Craig Hirakawa, Countywide WalkAmerica Coordinator, at (213) 974-2523. If you can't participate, you can still do your part by sponsoring a walker or by purchasing a WalkAmerica t-shirt or cap. See you on April 29!!!

Mailing Address Change

If you have changed your mailing address, please notify your Personnel Office immediately.

County Library Homework Center

The Los Angeles County Public Library Foundation has received a $90,000 grant from the S. Mark Taper Foundation to fund a Homework Center at the West Covina Library, a branch of the County of Los Angeles Public Library. The new center will be named the S. Mark Taper Homework Center. The County Library anticipates opening the center in the spring of 2000. Grant funds will provide four computers and related software, furniture for the center, and books and other study materials in the fields of math, science, social studies, and language arts. In addition, the grant will fund trained Homework Center staff for a three-year period.

A growing County Library service, Homework Centers provide assistance to students and strengthen the library's support of the public education system. Resources combine print materials, CD products, and access to online information via the Internet. Staff help students understand homework assignments and locate materials for completing their work. The S. Mark Taper Homework Center at West Covina Library will bring the total number of County Library centers to 27.

The S. Mark Taper Foundation, founded in 1989, is a private family foundation dedicated to enhancing the quality of peoples' lives by supporting non-profit organizations and their work in our community. The Los Angeles County Public Library Foundation is a major support unit for the County of Los Angeles Public Library. With a focus on literacy and the Homework Center program, the Library Foundation has developed ties with corporations and charitable foundations.

County Librarian Sandra Reuben stated, "Libraries have enormous potential for providing effective literacy and after-school programs. The County Library is very pleased to have the confidence and support of the S. Mark Taper Foundation in establishing a new Homework Center to assist students at the West Covina Library. We are grateful to both the S. Mark Taper Foundation and the County Library Foundation for working together to the benefit of the community."

Department of Health Services Health Advisory

Avoid contact with water near storm drains during and after rain!



Bacteria levels in ocean water close to storm drains generally increase during and after it rains. These levels can remain elevated up to 72 hours following a storm. The Department of Health Services advises people to avoid water discharging from storm drains whether in the ocean or on the beach.

Storm drains carry runoff from cities and wilderness areas, so bacteria can come from a wide variety of sources. Sewage normally is NOT present in storm drain runoff, since the sewer system is separate from the storm drain system. Laboratory analyses of water samples taken from drain discharge points after storms usually show higher bacteria counts than acceptable by State standards. Water on either side of a drain also can register high bacteria counts, depending on such factors as amounts of discharge and ocean currents and tides. Contamination decreases with distance from the drain.

The Department of Health Services samples and analyzes ocean water on a weekly basis around the more active storm drains. When tests indicate a serious or unusual problem, the Department orders the affected area closed to swimmers. For additional information, call the County Beach Closures and Advisory Hotline: (800) 525-5662.

The CalPERS Long Term Care Program

Most people have medical insurance, but they do not realize they are probably not insured for long-term care. Long-term care is expensive, and is something you should plan for before you need it. Here are some long-term care facts:

- Sixty percent of Americans over age 65 will need long-term care.
- One year in a nursing home can cost $47,000 or more.
- Care at home can cost more than $20,000 per year.
- Long-term care can be needed at any age.

CalPERS is concerned about the long-term care dilemma and offers all California public employees, retirees, their spouses, parents, and parents-in-law the CalPERS Long-Term Care Program. The next application period is April 1, 2000 through June 30, 2000. Call CalPERS at (800) 266-1050 or visit their web site at www.calpers.ca.gov to request an application kit.

March Retirees

Congratulations to the following employees who are joining the ranks of the retired after 30 or more years of service to the people of Los Angeles County:

AGRICULTURAL COMMISSIONER/ WEIGHTS & MEASURES: Melvin A. Makos
ASSESSOR: Maxine Mitchell
AUDITOR-CONTROLLER: Rodney W. Ornellas, Alan T. Sasaki
CHIEF ADMINISTRATIVE OFFICE: John H. Clemons, Kenneth R. Miller
CHILDREN & FAMILY SERVICES: Velma Aiken, Bruce H. Cowan, Georgeann T. Kirk, Judith Melton, Janice L. Sheldon, William C. Stephens, Renee E. Windsor
COMMUNITY & SENIOR SERVICES: Mary F. Debaca
COUNTY COUNSEL: S. Robert Ambrose, Frederick R. Bennett, Barbara Chargaff, Edward G. Pozorski
DISTRICT ATTORNEY: Thomas Alexander, Ruth A. Bullock, Richard J. Chrystie, Donald N. Eastman, Richard I. Frankenstein, Sir W. Harper Jr., Rose U. Himrod, Otis L. Hubbard, Thomas E. Miller, Leonard J. Shaffer, Timothy K. Tyson, Shelby A. Washington
FIRE: John A. Bailey, Robert B. Bell, Charles E. Bender, Roy E. Burleson, Michael L. Case, Lon L. Caskey, Lanny R. Cunningham, Steven J. Dahlmeier, John R. Dishaw, Joel K. Fletcher, Don I. Frantz, Elvin J. Hammer, Lloyd O. Helm, Kenneth E. Kelly, Marvin K. Kolstad, Frank J. Marasa, Larry H. Maynard, Morton M. Migita, David E. Moore, Larry L. Muell, Rodney W. Olney, Frederick Paulicano, John S. Robertson, Michael A. Rubick, Gerald W. Smith, Duane R. Swanson, Steven A. Wagner, James L. Williams, Janet Zauneker
HEALTH SERVICES: Victor Arkin, Brenda Ashkar, Spencer Barr, Vicki K. Carlson, Susan J. Carr, Wesley Chang, Suebretta Clay, Tessie S. Cleveland, Debora Eisert, Corazon P. Flores, Carol Fox, Annie C. Geer, Judith H. Hardy, Naomi Harris, Wentien Huang, Karen S. James, Nadine James, Mary L. Johnson, James R. Keane, Nancy J. Lane, Benjamin R. Margolis, David E. McPhan, Harry T. Nishihara, Cynthia Richardson, Conchita G. Soriano, Zelma L. Staples, James A. Stephens
HUMAN RESOURCES/SAFETY POLICE: Edward Barrios, Jeffrey E. Samsom, Frank A. Work
INTERNAL SERVICES: Albert A. Baker Jr., Eddie L. Fluellen, Haskell E. Jackson, Edward E. McCabe II, Leroy J. Meyer, Cornelia G. Nicholson, Leonard S. Nicholson, Jimmye L. Thies, Ival V. West
MENTAL HEALTH: Melba Burks, Koong Y. Yang
MUNICIPAL COURTS: Betty J. Jennings, Carmen L. Lopez.
PARKS & RECREATION: Felix U. Cruz, Charles Disbrow Jr., George A. Ichiyama, Henry C. Olivas, Paul Palmerin
PROBATION: Roxana F. Alford, Marsha M. Dumontier, Joan E. Fujishiro, Floyd W. Gary, Bessie V. Jackson, Michael K. Kaye, Shirley J. Lamothe, Arburnor A. Lenox Jr., Shirley A. McLaughlin, Patricia Patrick, Billy W. Pugh, Samuel R. Racusin, Ralph Willis
PUBLIC DEFENDER: Edith Y. Goya, Keith S. Hart, Alan H. Simon, Raymond Vega
PUBLIC LIBRARY: Daniel A. Gourdeau, Roy V. Hanson
PUBLIC SOCIAL SERVICES: Kay F. Allen, Richard A. Amescua, Dolores V. Bartlett, Lillian D. Black, Joyce Breslin, Gloria J. Carter, Jewell V. Duff, Richard R. Gonzalez, Carolyn Greenwood, Elizabeth Mines, Irma J. Reed, Janice T. Tassin, Gerald R. Webb
PUBLIC WORKS: Lucinda J. Allen, Jeffrey D. Balthis, Robert Desparicio, Robert J. Dochnahl, John B. Guffey, Richard Hearn, Dennis R. Helling, Rodolfo Hilario, Ronald L. Hobbs, Ronald K. Hofmann, Barry Kurtz, Frank H. Lott, Edmund D. Riddle, Larry Sanderson, Howard E. Spencer, John H. Trammell, Kenneth E. Weary, Richard Winters, Hipolito F. Ynfante
REGIONAL PLANNING: Francis X. Giannini, Rudy R. Lackner
REGISTRAR-RECORDER/COUNTY CLERK: Gerald L. Jerome
SHERIFF: Edmund L. Adams, Raymond Arrington, John D. Arthur, Lawrence N. Balich, Eva R. Blackshire, Lamar Bleavins, Larry J. Brakebush, Wiley L. Burrow, Michael R. Dlugos, John A. Eras, Burnett H. Gaston, Adolph J. Geoffrion, Ronald W. Gillespie, Michael E. Graham, Jeffrey E. Hauptman, James A. Hays, Dale F. Johnson, John R. Johnson, Sammy W. Johnson, Frank E. Jones, Paul N. Kayne, Bobbie J. Kelly, John J. Krino, John A. Krueger, Dora B. Landers, Stephen L. Mulcahy, Robert L. Nielsen, Michael J. O'Rourke, Michael I. Quinn, John M. Rahn, Vivian M. Rinehart, Jane Y. Sawai, Durward E. Schrick, William C. Sieber, Toni R. Terrell, Henry J. Villanueva, Michael E. Watner, James J. Wetzel, Stanley A. White, Terrance K. Wiese, Ronald L. Williams
SUPERIOR COURTS: Dennis D. Lewis, Luetta Watson
TREASURER & TAX COLLECTOR: Lillian Beer Burgess

Congratulations to the following employees who are retiring after serving the people of the County of Los Angeles for more than 25 years:

AGRICULTURAL COMMISSIONER/ WEIGHTS & MEASURES: Win T. Swe
ASSESSOR: Mercedez Diez, Katherine Golden, Marianito B. Tuano
AUDITOR-CONTROLLER: Leslie Kornmann
BEACHES & HARBORS: Marvin E. Avery
DISTRICT ATTORNEY: John L. Schimkola
COMMUNITY & SENIOR SERVICES: Lolita B. Manzano

see Retirees on back page



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Michael J. Henry Director of Personnel Department of Human Resources

Michael J. Henry has been the Director of Personnel, Department of Human Resources (DHR) since the Department's 1994 inception. Mike, who is married and the father of two sons and a daughter, attended Gompers Junior High and Locke High School in South Central Los Angeles and earned a bachelor's degree in Political Science from the University of California at Santa Barbara in 1975. His initial foray into the County was in 1976 under the Comprehensive Employment Training Act (CETA) program as an Administrative Analyst Aide with the Chief Administrative Office. There, he held each successive rank up to Senior Assistant Administrative Officer.

Mike is a past or present member of numerous commissions, task forces, committees, and boards: National Forum for Black Public Administrators, International Personnel Management Association, County Personnel Administrators' Association of California, County Emergency Preparedness Commission, and the South Bay Chapter of the American Red Cross. He is previous Chair of Human Resources Task Force, Emergency Management Steering Committee, Courthouse Security Task Force, Sheriff/Marshal Merger Task Force, and Criminal Split Court Session (Night Court) Task Force. The Night Court project was one of the top 10 programs acknowledged by the Productivity Commission and the Board of Supervisors.

"It's my goal to continue to develop a Human Resources Department with a strong central agency responsibility that is pro active, attempts to solve problems, and provides leadership to help the County implement its strategic plan. Another area we're active in is recruitment and retention; working with departments to help them fill vacancies and retain staff."

Mike hopes to meet the Board of Supervisors' directive to get the County on a five-year cycle for its numerous job classifications, and to continue modernizing its classification system. He feels one of the most important programs that DHR has created, with the full support of the Board of Supervisors, is a Training Academy for County employees. The Academy's training has been geared toward specific County needs.



"Our employees are a major and valuable asset to us. We need to invest in their training to help increase productivity and the quality of our service."

One significant challenge in the Training Academy's development has been in providing a Countywide training program to a vast County workforce of approximately 90,000. This program is in partnership with the California State University system, and allows employees access to training at local campuses. The joint effort between DHR and other departments extends to departmental management assisting with classroom instruction and employee training selection.

"It is my hope that the Academy, as it grows and expands, becomes part of our County culture, that it will be the engine to help drive the CAO's strategic planning process and that over time it will help to change the culture of County organization to make it more productive, more streamlined, and more customer service oriented. It is my desire that once we get this fully up and going, every County employee sometime in their career at least once, maybe multiple times, will have some contact with the Academy."

This collaborative effort with the State University system is cost effective and improves participating employees' convenience by providing them with training facilities that are relatively close to their homes or work sites. Educators from the universities used for training and other area campuses also serve as instructors.

Some of the other significant DHR projects that Mike has been involved with are the Human Services Academy, the Community Based Enterprise Education Program (CBEEP), and Community Based Job Fairs. The Human Services Academy provides selected high school juniors paid work experience in participating County departments, which helps facilitate self esteem and work-based learning. CBEEP furnishes junior, senior, and graduate students from six local universities with invaluable volunteer experience in County government while earning credit toward graduation in their fields of study. Community Based Job Fairs focus on presenting County employment opportunities to a broad spectrum of the public.

DHR recently reintroduced the first Countywide employee orientation



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Sheriff Baca Introduces In-Car Video System and "Cop-Cam"

Sheriff Lee Baca was joined by SEMCO Incorporated's top executives in discussing the in-car video system pilot program initiated at Temple Sheriff's Station.

"Our Department continues to move forward with new and useful technology to benefit Department members and the communities we serve," stated Sheriff Baca to reporters who witnessed the system in use.

Manufactured by SEMCO Incorporated, the in-car video system is actually a combination of two separate video systems that interact with each other. The first is the "Car-Cam" system, in which the video camera is mounted in the patrol vehicle, taping the incident through the front windshield. The second is the "Cop-Cam" system, in which the video camera is mounted on the deputy's chest, videotaping the incident from the deputy's viewpoint. When activated, this system has the ability to tape incidents as they happen, regardless of where they occur in relation to the patrol car. The system also includes two audio microphones. One is mounted on the patrol car, while the second is worn on the deputy's uniform and is connected to a transmitter worn on the belt. The "Car-Cam" and "Cop-Cam" systems record the incidents onto VHS tape, using a trunk-mounted VCR. Each tape is bar-coded for tracking purposes.



Deputy Sheriff with the "Cop-Cam " on the front of his uniform. The In-Car Video System is on the front windshield.

SEMCO Incorporated President William Tincup stated, "SEMCO is proud to be part of the Los Angeles County Sheriff's Department team that intends to set the standard for future law enforcement."

Sheriff Baca added, "The purpose of these video systems is to document incidents as they occur. The training and investigatory benefits gained by such systems are invaluable, and also assist in maintaining public trust."

Henry

continued from page six

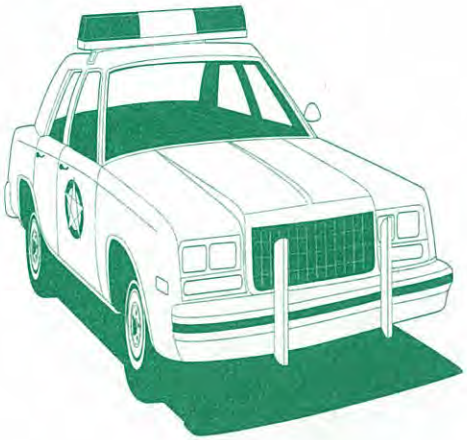
program in some 15 years. New employees from different departments went through a full day orientation that provided them with broad information about County government.

"In 1999 and earlier this year, we rolled out several training programs of significance; one is our Clerical Training Program, the other is a Division Chief Training Program. Later on in the year, we're going to roll out a HR Strategy Training Program and a HR Technical Training Program. These are multi-hour training programs that are aimed at elevating the knowledge of our employees to make them better managers and staff."

Many of the County's senior staff and managers have reached retirement age.

"This is creating opportunities for people in our County system currently and for those joining in the future. I think that working for government is a very worthwhile experience and very fulfilling; it certainly has been for me."

Over the next few months, additional information about the Academy and different types of training opportunities will be included in the *County Digest*, on the Internet, and at department personnel offices.



County DIGEST

Dept. of Human Resources
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continued from page five

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Animal Adoption Reduced to $27

The Los Angeles County Department of Animal Care and Control has reduced the cost of animal adoptions in an effort to curtail the number of animals that end up in overcrowded County shelters. Under the new Save 2000 pet placement program, which is being funded by donations from private agencies, animal welfare foundations and some cities, adoptions that once cost up to $100 or more are now available for the flat rate of $27, including sterilization. The cost will be the same for a dog or cat, male or female, at a County animal shelter. The only additional charge is a $10 to $15 registration fee, required for all dogs over four months old. These adoption rates are significantly lower than those of other, privately operated adoption agencies in Southern California.

The Department is attempting to place more of their shelter animals in private homes, and promote spaying and neutering as a pet population control measure. They plan to keep adoption costs down as long as they can afford to do so. Those interested in supporting the Save 2000 campaign may send tax-deductible donations to the Animal Care Foundation, 11258 S. Garfield Avenue, Downey, CA 90254. For additional information on County pet adoptions, call (310) 523-9566.



Santa Monica Courts Move to New Airport Courthouse

The West District of Los Angeles Superior Court transferred some of its Santa Monica departments to the new courthouse located near LAX airport in February, 2000.

New phone numbers for the departments are as follows:

Criminal Clerk's Office -
(310) 727-6173 and (310) 727-6174
Department A - (310) 727-6106
Department C - (310) 727-6111
Department D - (310) 727-6114





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Appendix P

Deja View Camwear Model 100

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ABSTRACT
Deja View Camwear Model 100 is the first in a family of wearable camcorders designed to free the user from being shackled to his viewfinder. The Model 100 is designed to ensure that the user never misses that important tidbit. While the initial use is for active lifestyles, we are exploring its use in Security, Military, Training, Automotive and sundry other vertical markets.

Categories and Subject Descriptors
B.4.2 [**Input/Output and Data Communications**]: Input/Output Devices
H.3.0 [**Information Storage and Retrieval**]: General

General Terms: Design, Human Factors

Keywords
Camcorder, After-the-fact, wearable, hip pack, clip-on, microphone, lens, SD, flash, memory, ARM, MPEG-4, 1/4" PEL.

1. INTRODUCTION
Deja View, Inc. was founded in September 2002 to offer a wearable camcorder to the consumer electronics market that would solve the age-old dilemma of most amateur photographers who utter the words: "I missed that shot". After nearly two years of research, product design and development, the first Camwear mini-camcorders were scheduled for shipping to retailers in the Fall of 2004.

2. Product Idea
The camera is the brainchild of Sid Reich, Deja View's founder, whose background is in math and in statistics, and has a background which includes writing operating systems. Mr. Reich saw the potential for an always-on camera to prevent users from missing precious footage. He admired Replay TV, or Tivo, which lets users pause and rewind live television. He was further inspired when, while golfing with friends, a squirrel jumped into their parked golf cart. Reich watched from a distance as the squirrel ripped open a bag of bagels, pulled one out and ran to a tree to enjoy it. He said at the time that he wished he could have shown his friends a video instead of just telling them about the squirrel episode.

3. Product Technology
The first Deja View product, called Camwear Model 100, combines the memory of digital cameras, video stream managerment of DVR's and optics of digital camcorders. The device uses a chip developed by Divio (now ESS), a semiconductor company in Sunnyvale California and the NAND Flash SD™ Memory Cards from Toshiba America Electronic Components, Inc. (TEAC). The "engine" for the device is a RISC processor from NeoMagic which is coupled to proprietary firmware.

4. Product Description
The Camwear Model 100 is the world's first wearable mini-camcorder that solves the dreaded problem faced by many amateur photographers/cinematographers each day: "I Missed that Shot!!!"

It does that by allowing the user to press the "record" button AFTER an even has occurred to capture and save up to the 30 seconds of the action that otherwise would be gone forever. The tiny camera/microphone with clip is less than an inch long and smaller than a nickel for easy attachment to eyeglasses or the bill of a hat. It is tethered by a thin wire to a PDA-sized remote unit, or "hip pack" that clips to a belt or waistband, or fits in a pant or coat pocket or handbag.

To operate the Camwear Model 100, users turn on the power and just watch the action as it occurs in front of them. The camcorder's always-on scanning feature feeds a continuous video stream into the control unit. Although users may not have been ready for the action that had just taken place, they can still capture up to 30 seconds of the previous action by hitting the "record" button after-the-fact! Normally, to obtain action footage with a standard handheld video camcorder, the user must anticipate what might happen by keeping the device aimed and ready – before, during and after the event occurs. The Camwear Model 100 eliminated the need to "view the world through a viewfinder." It is completely hands-free.

Key features of the Camwear 100 include:

- Video quality at CIF (320x240) at 30 frames per second
- From 64MB to 1GB memory storage
- Memory-low warning light
- ArcSoft ShowBiz 2 software for editing audio/video clips on a PC and authoring DVD's, VCD's and single frame prints.
- Download clips to PC via USB 1.1 or 2.0 (cable included)
- 110v charger and rechargeable lithium ion battery with a minimum 4 hour operating capacity.
- Direct output to TV, VCRs or DVD burner via RCA jacks
- File viewing with ArcSoft ShowBiz 2 software or Windows Media Player

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CARPE'04, October 15, 2004, New York, New York, USA.
ACM 1-58113-932-2/04/0010.

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5. Product Audience

The Camwear 100 with its "after-the-fact" technology is ideally suited to a variety of applications, including recreation and leisure, travel and tourism, business, education, government, military, law enforcement, medical research and many others where it is important to keep visual documentation of activity. Aimed primarily at the consumer, the product's typical usage would be by parents attempting to capture the precious moments of their son or daughter at such milestone events as school promotions and graduations, Little League or other sports action, weddings, etc.

6. Pricing

The Camwear Model 100 is priced at $399.99 MSRP

7. Distribution

The Camwear 100 will be available through the Deja View website at www.mydejaview.com , and through a network of consumer electronics chain stores, camera stores and major online resellers.







Appendix Q

US 20050088521A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2005/0088521 A1**

Blanco et al. (43) **Pub. Date: Apr. 28, 2005**

(54) **IN-CAR VIDEO SYSTEM USING FLASH MEMORY AS A RECORDING MEDIUM**

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(21) Appl. No.: **10/691,483**

(22) Filed: **Oct. 22, 2003**

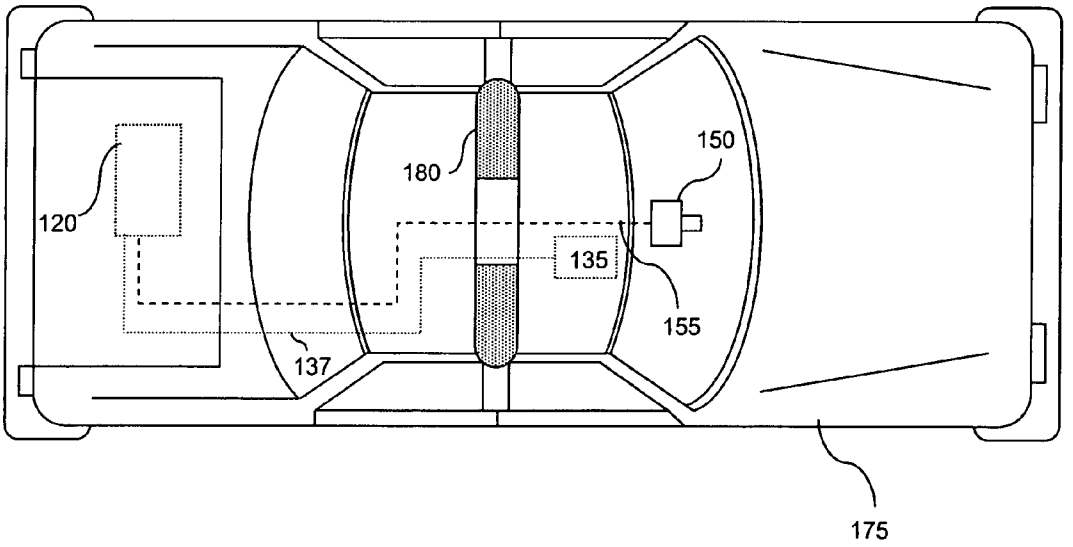
Publication Classification

(51) **Int. Cl.**[7] **H04N 7/18**

(52) **U.S. Cl.** **348/148**

(57) **ABSTRACT**

An inventive system and method is provided by an in-car video system that uses a type of electrically erasable programmable read-only memory known as flash memory to store video of an incident or event. In an illustrative embodiment of the invention, a digital video recorder and video camera are fixably mounted in a vehicle such as a police cruiser. An event of interest is captured by a camera and the resulting video stream is converted into a form that writable to a flash memory. The video recorder writes the video to flash memory to thereby store a record of the event on the flash memory as a storage medium.



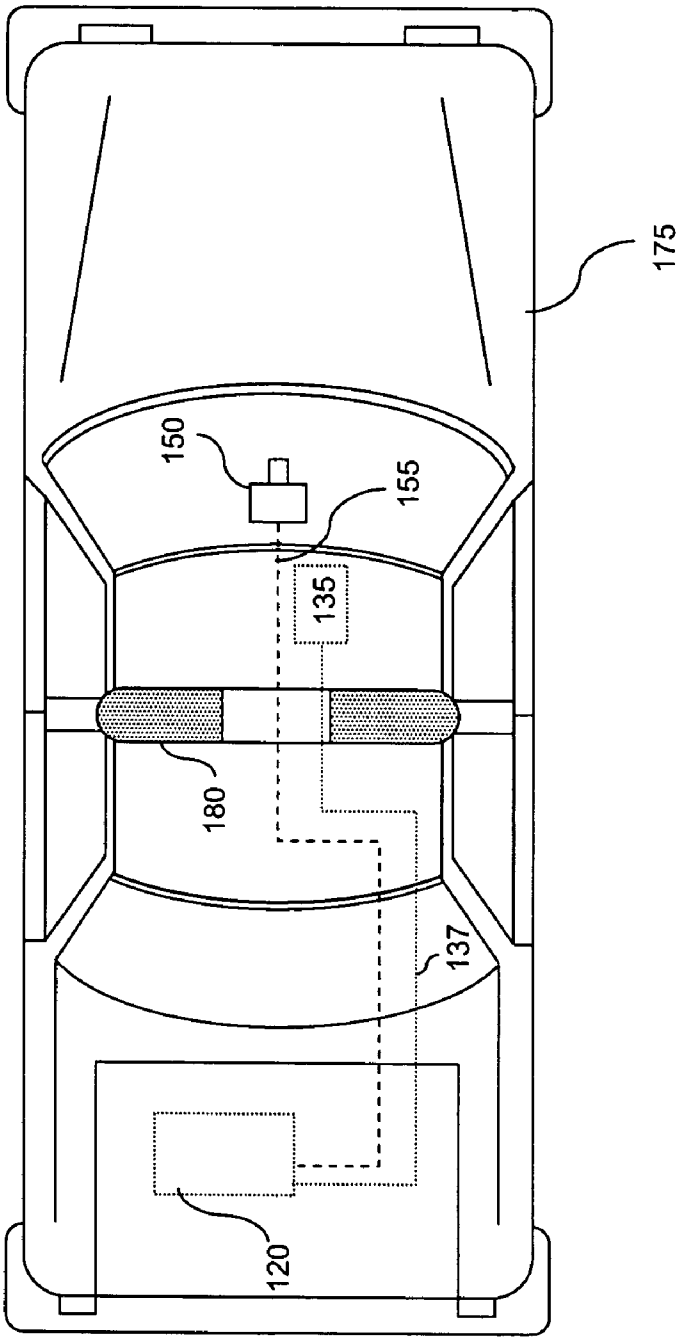


FIG 1

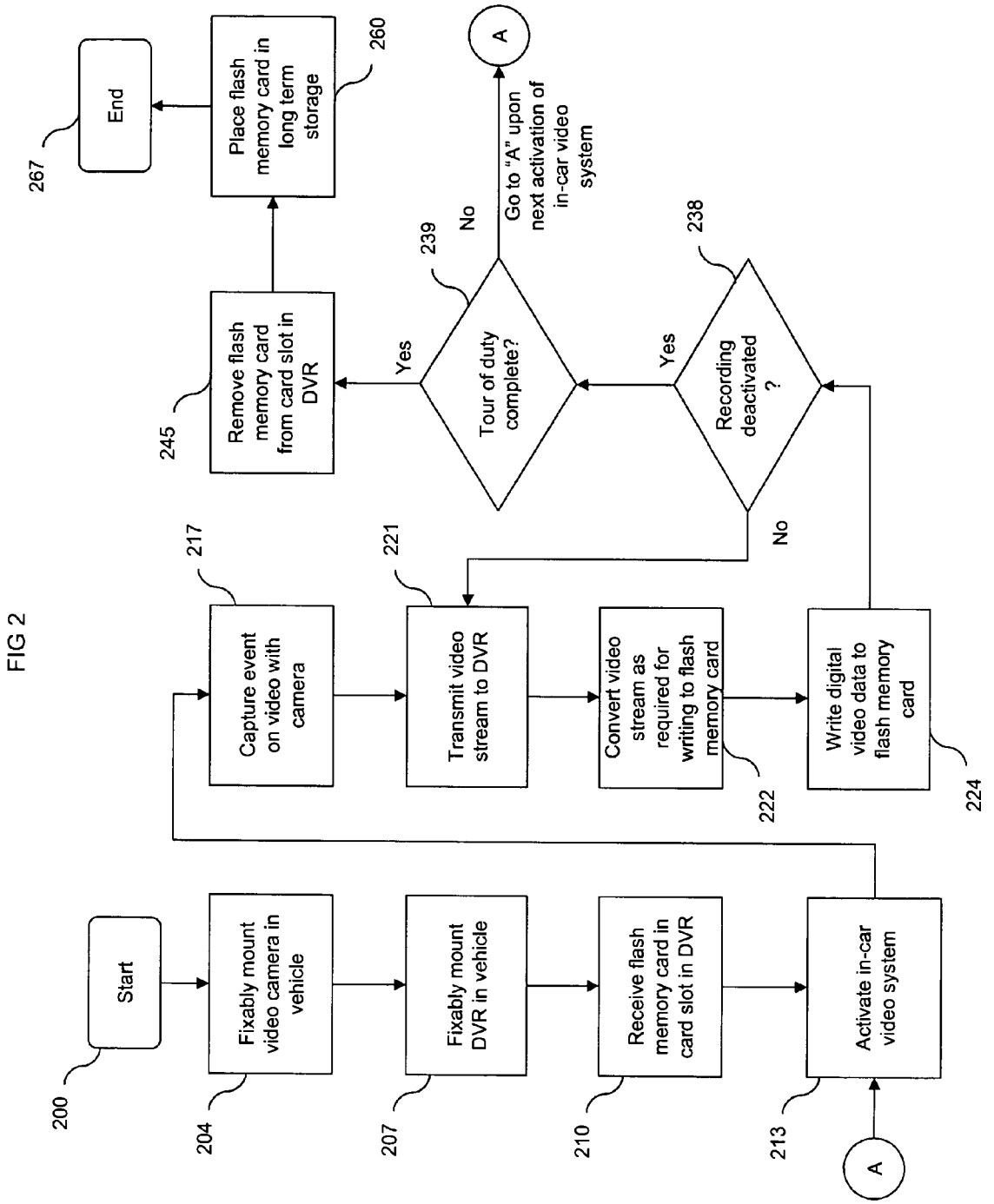

Start
200
Fixably mount video camera in vehicle
204
Fixably mount DVR in vehicle
207
Receive flash memory card in card slot in DVR
210
Activate in-car video system
213
A
Capture event on video with camera
217
Transmit video stream to DVR
221
Convert video stream as required for writing to flash memory card
222
Write digital video data to flash memory card
224
Recording deactivated ?
238
No
Yes
Tour of duty complete?
239
No
Go to "A" upon next activation of in-car video system
A
Yes
Remove flash memory card from card slot in DVR
245
Place flash memory card in long term storage
260
End
267

FIG 2

IN-CAR VIDEO SYSTEM USING FLASH MEMORY AS A RECORDING MEDIUM

BACKGROUND OF THE INVENTION

[0001] This invention is related generally to surveillance systems, and more particularly to an in-car video system using flash memory as a recording medium.

[0002] Vehicle-mounted surveillance systems, also termed in-car video systems, are seeing increased use in the security industry and law enforcement community as an effective means to provide an indisputable video and audio record of encounters involving officers and citizens. In these systems, a video camera is typically mounted on the police car's dashboard or windshield and is generally arranged to have a field of view of the area to the immediate front of the car. The field of view approximately corresponds to what an officer would see when seated in the car's front seat.

[0003] The video camera is operably coupled to a video recorder, such as a video cassette recorder ("VCR") or digital video recorder ("DVR"), mounted in the police car, often in the trunk. A video recording may be started manually by the officer, or in some systems, the video recording is started automatically when, for example, the officer activates the police car's emergency systems (such as overhead lights and/or sirens), or when a vehicle speed-measuring radar unit is operated.

[0004] In-car video systems serve to enhance prosecution of traffic, DWI/DUI and controlled dangerous substances offenses (to name just a few) by contributing detailed graphical and auditory evidence in a time-sequential manner that is inherently unbiased and objective. Such evidence is a valuable adjunct to eyewitness and officer testimony. In addition, as with other quality-improvement initiatives where conduct is surveyed and recorded, in-car video system usage has been shown to assist in the maintenance of high professional standards among law enforcement personnel. Police-community relations have improved and citizen complaints of police misconduct have lessened in many jurisdictions where in-car video systems are used, often as a result of the inherently high-quality evidence provided by such systems. Videos taken with in-car video systems are also valuable training aids to law enforcement personnel.

[0005] Video evidence is protected (and the evidentiary chain of custody readily established) because the video recorder and video recording medium (i.e., videotape or hard disk drive) are typically "locked", often both mechanically and electronically, within a tamperproof security enclosure in the car that is only accessible by law enforcement command personnel. In addition, the in-car systems are configured to prevent erasure or over-recording of a recorded encounter to ensure the integrity of the video evidence. In-car video systems may superimpose time and date stamps on the recorded video image as a further enhancement to the evidentiary strength of the videotape.

[0006] In-car video systems generally employ a wireless microphone carried on the person of a law enforcement officer to record an audio soundtrack that accompanies the visual scene captured on videotape. In some systems, additional wired microphones may be deployed in other locations within the car, such as the rear-seat passenger area, to record sounds and conversations emanating from those locations.

[0007] While current in-car video systems perform very well in many applications, recording media currently used with in-car video systems, including analog video tape and digital storage media like hard disk drives, are bulky and may present storage and other logistical issues in managing the recording media. The size of recording media and associated video recorders can present space utilization issues in some vehicle models as well.

[0008] Current recording media is subject to failure from physical damage to the media or degradation due to environmental factors such as heat, moisture and humidity. For example, hard disk drives can fail in a number of ways but mainly due to mechanical failures relating to the mechanics of the disk such as motor burnout or "stuck" bearings.

[0009] Head and head assembly failures represent another failure mode and include head crashes and read or write errors to the magnetic media. In analog systems, videocassettes can fail if carelessly handled or abused, for example, through tape breakage, stretching or fraying, image dropouts from deteriorated tape base films or magnetic coatings, and failure of tape transports.

SUMMARY OF THE INVENTION

[0010] An inventive system and method is provided by an in-car video system that uses a type of electrically erasable programmable read-only memory known as flash memory to store video of an incident or event.

[0011] In an illustrative embodiment of the invention, a digital video recorder and video camera are fixably mounted in a vehicle such as a police cruiser. An event of interest is captured by a camera and the resulting video stream is converted into a form that is writable to a flash memory. The video recorder writes the video to flash memory to thereby store a record of the event on the flash memory as a storage medium. The type of flash memory preferentially used in the illustrative embodiment of the invention is known as a CompactFlash card.

[0012] Advantageously, the invention creates a robust in-car video system having a large amount of video storage combined with enhanced system packaging that is enabled through the very small form factor of the flash memory. Since flash memory is a solid state device using no moving parts, (i.e., the memory relies on the use of electronics instead of mechanical systems) it is inherently reliable.

[0013] Flash memory may endure extreme temperatures and retains data even without a continuously applied power source. Users may easily insert and remove flash memory from the video recorder and store additional flash memory card in the vehicle in a small amount of space. Because of its extremely small size, flash memory provides efficient and dense storage and is ideal as a removable media for archiving video recordings in a storage area away from the vehicle. The use of flash memory as the recording media may also help to reduce the costs of maintaining in-car video systems because relatively fragile and complex VCRs and DVRs are eliminated from the inventive in-car video system.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] **FIG. 1** is a simplified functional block diagram of an illustrative arrangement of the present invention depict

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ing an in-car video system (including a windshield mounted camera, a control head, and trunk-mounted digital video recorder) in accordance with the invention; and

[0015] **FIG. 2** is a flowchart illustrating a method of operating an in-car video system in accordance with the invention.

DETAILED DESCRIPTION

[0016] Referring to **FIG. 1**, there is depicted a simplified functional block diagram of an illustrative arrangement of the present invention depicting an in-car video system **110** (including a windshield mounted camera **150**, a control head **135** and a trunk-mounted digital video recorder **120**). Vehicle **175** is depicted in **FIG. 1** as a police cruiser with emergency lightbar **180**, however it is emphasized that the features and benefits of the present invention may be equally applicable to a wide variety of vehicle types, and further that the invention is not limited to law enforcement applications. Applications of the invention to the security and the transportation industries may be readily made, for example.

[0017] Camera **150** may be selected from the wide variety of available cameras. Preferably, camera **150** is a compact camera (to reduce the likelihood of obstructing the officer's view out the windshield) with color capabilities such as a solid-state CCD ("charge-coupled device") camera that can operate in low-light environments. Camera **150** may be optionally configured with digital and/or optical zoom capabilities. Camera **150**, in this illustrative arrangement, is mounted to the windshield of vehicle **175**, however other mounting locations may be used in other applications. Camera **150** is operably coupled to digital video recorder **120** via bus **155**.

[0018] A remote control head **135** is located in vehicle **175** near the driver and is operably coupled to digital video recorder **120** via bus **137** to allow the digital video recorder **120** to be conveniently controlled by the officer from within the vehicle. Remote control head **135** may be arranged with typical controls such as "POWER", "RECORD", "STOP", "BACK", "PLAY", and "FORWARD" buttons which operate the digital video recorder **120** accordingly.

[0019] Digital video recorder **120**, as shown in **FIG. 1**, may be located in secure enclosure (i.e., a "vault") contained in the trunk of the car. The enclosure is generally quite rugged, both to provide deterrents against tampering or improper access to the video recording medium and also to protect the medium in the event that the vehicle **175** is involved in a crash. The enclosure may also be environmentally controlled to keep the digital video recorder **120** and recording medium within acceptable operating conditions.

[0020] It is emphasized that digital video recorder **120** may be conveniently located in other areas of the vehicle depending on the requirements of the application of the invention. As described in more detail below, the digital video recorder **120** is adapted to read and write to flash memory (which is has a small physical form factor compare with conventional storage media). Therefore, the invention enables more freedom in packaging the digital video recorder **120** so that it can occupy smaller volumes or be arranged in configurations that are better adapted to available space in the vehicle. For example, many vehicles used in police applications have the radio (i.e., sound system) that is sized for what is commonly called a "double DIN" opening (roughly 4" high by 7" wide). Other vehicles use smaller radios that fit within single DIN or 1.5 DIN openings. In all cases, the digital video recorder of the present invention is contemplated to be small enough to replace the factory radio. This may afford greater ease of operation in many applications and reduce or eliminate the need to place in-car video system components in the trunk of the vehicle. In addition to the digital video recorder **120**, other in-car video system components such as the control head **135** and a video monitor (not shown in **FIG. 1**) may be integrated with the digital video recorder **120** to form a unitary system that is mounted in the space normally reserved for the radio in the vehicle.

[0021] Digital video recorder **120** is specifically adapted, in accordance with the invention, to record to non-volatile memory, including electrically erasable programmable read-only memory. Pronounced "double-e-prom" or "e-e-prom," an EEPROM is a special type of programmable read-only memory ("PROM") that can be erased by exposing it to an electrical charge. Like other types of PROM, EEPROM retains its contents even when the power to it is discontinued. Particular advantage may be realized in many applications of the invention by using "flash memory" which is a special type of EEPROM that can be erased and reprogrammed in blocks instead of one byte at a time. This feature makes flash memory generally "faster" than other types of non-volatile memories. In accordance with the invention, flash memory is well suited to in-car video system applications as a result of this fast speed at which data can be stored and accessed.

[0022] In the present illustrative embodiment of the invention, a flash memory embodied in a card-type format is utilized because such flash memory cards are designed to be conveniently installed and removed from devices that use them. Flash memory cards are typically rugged, durable and long lasting. They can withstand wide temperature ranges as well as high levels of shock and vibration. Many flash memory cards may be configured to provide data access speeds that are as fast or faster than hard disk drives and can support the recording of full motion video. Several types of flash memory cards are in use today including CompactFlash, Smart Media, Secure Digital, Multimedia Card, xD-Picture Card and Memory Stick. While all such flash memory cards can be used successfully to facilitate the practice of the invention, the CompactFlash card provides many significant benefits and is preferred in many applications.

[0023] CompactFlash consists of a small circuit board with flash-memory chips and a dedicated built-in controller chip, all encased in a exterior shell that is several times thicker than other flash memory cards. CompactFlash cards are 43 mm wide and 36 mm long, and come in two thicknesses: Type I cards are 3.3 mm thick, and Type II cards are 5.5 mm thick. CompactFlash cards support dual voltage and will operate at either 3.3 volts or 5 volts. The extra thickness of CompactFlash cards provides enhanced storage capacity over other flash memory cards. Currently, the developer of CompactFlash cards, SanDisk, is producing a Type I CompactFlash card with 4 gigabytes of storage capacity. Such flash memory capacity can provide many hours of full motion video storage per flash memory card (where the exact number of hours of video storage will

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depend on the image size, resolution, frame rate and other factors associated with the video). CompactFlash cards are available in speeds that can provide sustained write performance at a level sufficient to support digital recording of full-motion video. Of course, other lower capacity flash memory cards may also be used with great effect as required by the specific application of the invention.

[0024] Turning now to **FIG. 2**, there is shown a flowchart illustrating a method of operating an in-car video system in accordance with the invention. The method starts at block **200**. At block **204**, a video camera (e.g., **150** in **FIG. 1**) is mounted in a vehicle in which an in-car video system is to be installed. In a similar manner, a digital video recorder is mounted in the vehicle as indicated by block **207**. In some applications of the invention, it may be advantageous to position a digital video recorder having a small form factor package so that it is mounted substantially within a dashboard area of the vehicle. For example, as noted above, this area could be the area of the vehicle's dashboard where a factory-installed radio or sound system would normally be located. Such mounting, which is enabled by the invention as described herein, places the digital video recorder and digital recording medium (i.e., the flash memory card) in a direct operative relationship with a user seated in the front seat of the vehicle.

[0025] The method continues in block **210** in **FIG. 2** where a user places a memory card into a flash memory receiving slot within the digital video recorder. Such a slot is configured to receive a desired flash memory card type and operably couples the flash memory to the digital video recorder. Thus, the flash memory can be accessed as a digital storage medium by the digital video recorder. The slot is typically configured to allow the flash memory card to readily inserted and released with light finger pressure. In some applications of the invention, a plurality of slots may be provided to accommodate different flash memory types (e.g., one slot may accept a CompactFlash card while another slot may accept a Secure Digital card). Alternatively, multiple slots that accept cards of the same format may be provided. In both cases, a digital video recorder configured to be operably coupled to multiple flash memory cards supplies more overall video storage space (where video is written to one flash memory card after another card is filled to capacity in a sequential manner) or allows a redundant (i.e., failsafe) operation where multiple copies of the same video recording are stored on separate flash memory cards.

[0026] At block **213**, upon activation of the in-car video system (via automatic operation through the activation of the vehicle's emergency lights, for example, or via manual activation by a user, video is captured by the video camera and transmitted to the digital video recorder. These steps are indicated in blocks **217** and **221**, respectively, in **FIG. 2**. The incoming video stream is converted to an appropriate format for recording onto the flash memory card at block **222**. In some cases, the video stream is in an analog format and an analog to digital conversion would need to be performed, accordingly. In other cases where the incoming video stream is in digital format, some signal processing or conversion may be desired or required to access and write to the flash memory in an effective manner. The amount and type of signal processing or conversion required is dependent on the specific application of the invention and the necessary implementation of such techniques will be readily appreciated by those skilled in the art.

[0027] At block **224**, digital data that is representative of the event captured by the camera at block **217** is written to the flash memory card. If the in-car video system is still activated, and the digital video recorder still recording, then a decision block **238** control is passed back to block **221** and the above described process of video capture and writing data to the flash memory at blocks **222** and **224** continues in an iterative manner. A video record of the event is thereby created and stored on the flash memory card.

[0028] Once the digital video recorder is deactivated, for example when an event or incident of interest is over, then at decision block **239** the method is paused until such time that another in-car system activation occurs (at block **213**). If the user's tour of duty is over (e.g., a police officer has finished his or her shift), then as indicated by block **245**, the flash memory card would be typically removed from its slot in the digital video recorder. The user then transports the flash memory as a removable digital storage medium and, as indicated by block **260**, the user places the flash memory card into long term storage. At that point, the video recordings can be archived on the same flash memory cards used in the in-car video system, or transferred to other storage media such as CDs or DVDs in a conventional manner. The method ends at block **267** in **FIG. 2**.

[0029] Other features of the invention are contained in the claims that follow.

What is claimed is:

1. An in-car video system, comprising:

a video camera fixably mounted to a vehicle for capturing an image of an event and producing a corresponding video stream;

a digital video recorder fixably mounted to the vehicle, the digital video recorder having a receiving area being adapted to operably couple a flash memory card to the digital video recorder so that the flash memory functions as a digital video storage medium; and

a controller coupled to the video recorder to control writing of data that is representative of the video stream to a flash memory to thereby generate a stored video record of the event.

2. The in-car video system of claim 1 where the receiving area is further adapted so that the flash memory card is removably couplable to the digital video recorder.

3. The in-car video system of claim 1 where the flash memory is a flash memory card selected from the group consisting of Smart Media, Secure Digital, Multimedia Card, xD-Picture Card and Memory Stick.

4. The in-car video system of claim 1 where the flash memory is a CompactFlash card.

5. The in-car video system of claim 1 where the digital video recorder and controller are integrally packaged and sized to fit substantially within a standard single DIN sized radio opening.

6. The in-car video system of claim 1 where the digital video recorder and controller are integrally packaged and sized to fit substantially within a standard 1.5 DIN sized radio opening.

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7. The in-car video system of claim 1 where the digital video recorder and controller are integrally packaged and sized to fit substantially within a standard double DIN sized radio opening.

8. The in-car video system of claim 1 where the digital video recorder and controller are integrally packaged and sized to fit substantially within a factory-sized radio opening of a production vehicle having a police package option.

9. A method of creating a video recording of an event, the method comprising the steps of:

providing a digital video recorder and video camera that are fixably mounted in a vehicle;

capturing video of the event using the car-mounted camera;

transmitting the video to the digital video recorder;

converting the video to a form that is writable to a flash memory, the flash memory being operably coupled to the digital video recorder; and

writing the converted video to the flash memory using the digital video recorder to thereby store a video record of the event on the flash memory.

10. The method of claim 9 including a step of controlling the digital video controller so that video is written to the flash memory automatically upon activation of the vehicle's emergency systems including emergency lights.

11. The method of claim **26** further including a step of providing a plurality of flash memory cards for storage within the vehicle so that when a first flash memory card in the plurality of flash memory cards is filled to capacity, a second flash memory card in the plurality of flash memory cards may be used to replace the first flash memory card.

12. In a vehicle-mounted video system including a car-mounted camera, a method of operating a digital video recorder, the method comprising the steps of:

receiving a flash memory card in a receiving area of the digital video recorder, the receiving area being adapted to operably couple the flash memory card to the digital video recorder so that the flash memory functions as a digital video storage medium;

receiving a video stream of an event captured by the camera;

converting the video stream to a form that is writable to the flash memory;

writing the converted video stream to the flash memory to thereby store a record of the event on the flash memory.

13. The method of claim 12 further including a step of reading the stored record from the flash memory.

14. The method of claim 13 further including a step of transmitting the record read from the flash memory to a remote monitor.

15. The method of claim 12 further including a step of removing the flash memory from the video recorder.

16. The method of claim 15 further including a step of storing the removed flash memory.

17. The method of claim 12 further including a step of fixably positioning the digital video recorder substantially within a dashboard area of the vehicle so that the digital video recorder is in a direct operative relationship with a user seated in the front seat of the vehicle.

18. The method of claim 17 where the dashboard area comprises a dashboard portion that is typically used to house a sound system.

19. The method of claim 18 where the dashboard portion is double DIN sized.

20. The method of claim 12 further including a step of receiving a second flash memory card in a receiving area of the digital video recorder, the receiving area being adapted to operably couple the flash memory card to the digital video recorder so that the second flash memory functions as a second digital video storage medium that automatically stores a portion of the video stream once the other flash memory card becomes full.

* * * * *

Appendix R

US008350907B1

(12) **United States Patent**
Blanco et al.

(10) **Patent No.: US 8,350,907 B1**
(45) **Date of Patent: Jan. 8, 2013**

(54) **METHOD OF STORING DIGITAL VIDEO CAPTURED BY AN IN-CAR VIDEO SYSTEM**

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H04N 7/18 (2006.01)

(52) **U.S. Cl.** **348/143**

(58) **Field of Classification Search** 348/143; 340/539.1; 715/723

See application file for complete search history.

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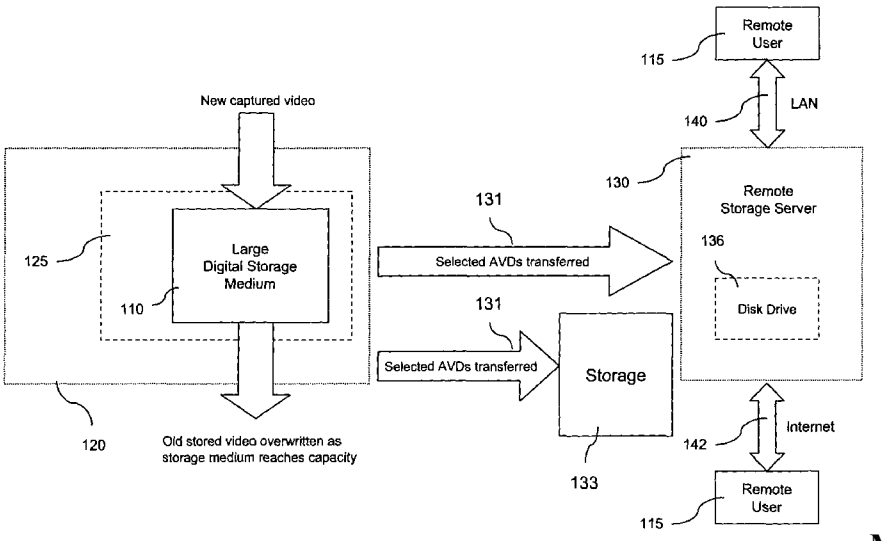
Primary Examiner — Allen Wong

(74) *Attorney, Agent, or Firm* — Mayer & Williams PC; Mark K. Young, Esq.

(57) **ABSTRACT**

A method of storing digital video is provided where an original video clip is selected, according to selection criteria, from video clips stored on a digital storage medium. The frame rate associated with the selected video clip is lowered and a downgraded version of the original video clip is written to a digital storage medium at the lowered frame rate. The original video clip may then be overwritten or erased to thereby reduce the storage space requirements for the downgraded video clip by approximately the percentage reduction in downgraded frame rate.

19 Claims, 4 Drawing Sheets



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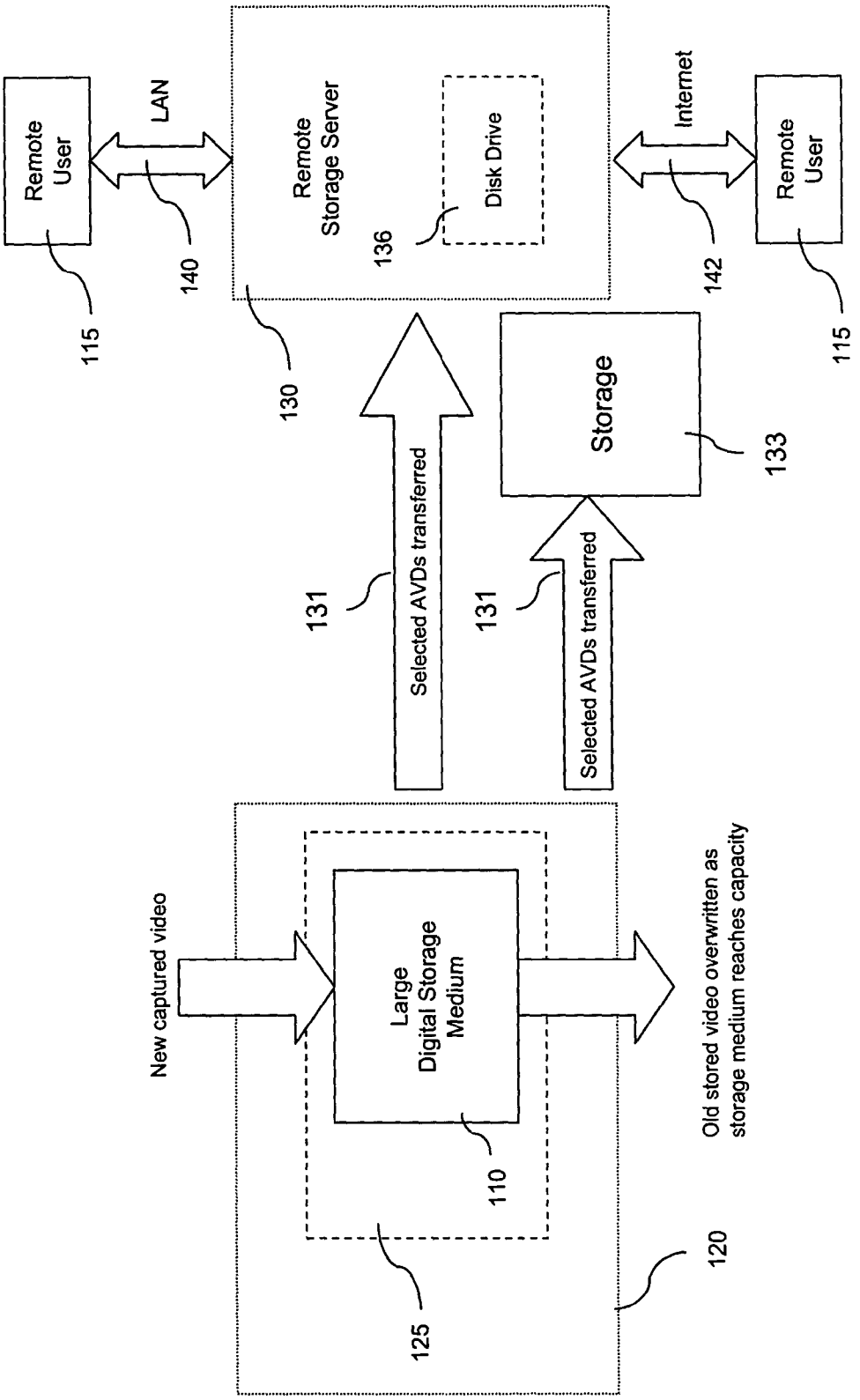

Remote User
LAN
Remote Storage Server
Disk Drive
Internet
Remote User
115
140
136
142
115
130
Storage
133
131
Selected AVDs transferred
131
Selected AVDs transferred
New captured video
Large Digital Storage Medium
Old stored video overwritten as storage medium reaches capacity
110
120
125

FIG 1

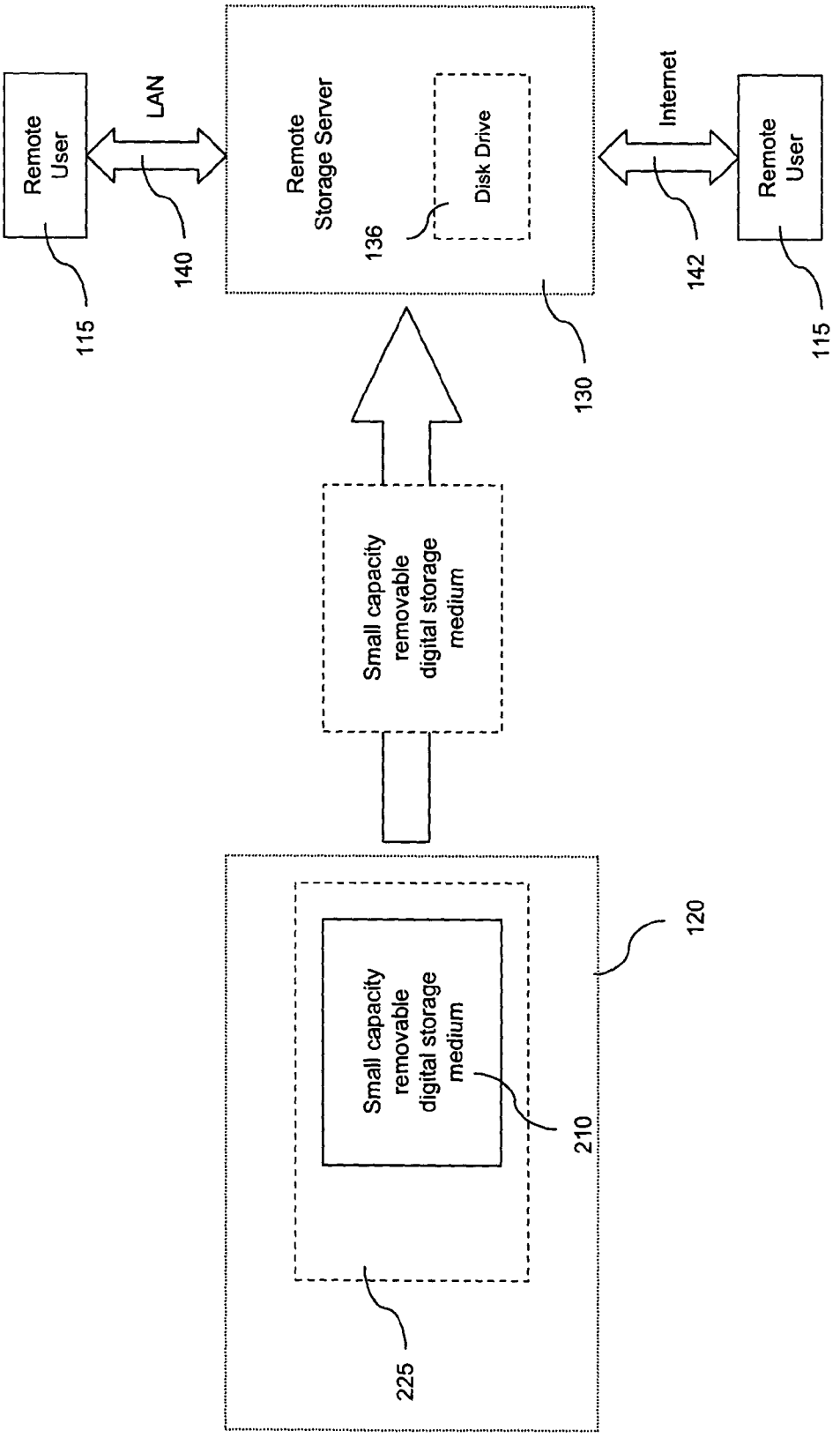

Remote User
LAN
Remote Storage Server
Disk Drive
136
Internet
Remote User
115
140
142
115
130
Small capacity removable digital storage medium
120
Small capacity removable digital storage medium
210
225

FIG 2

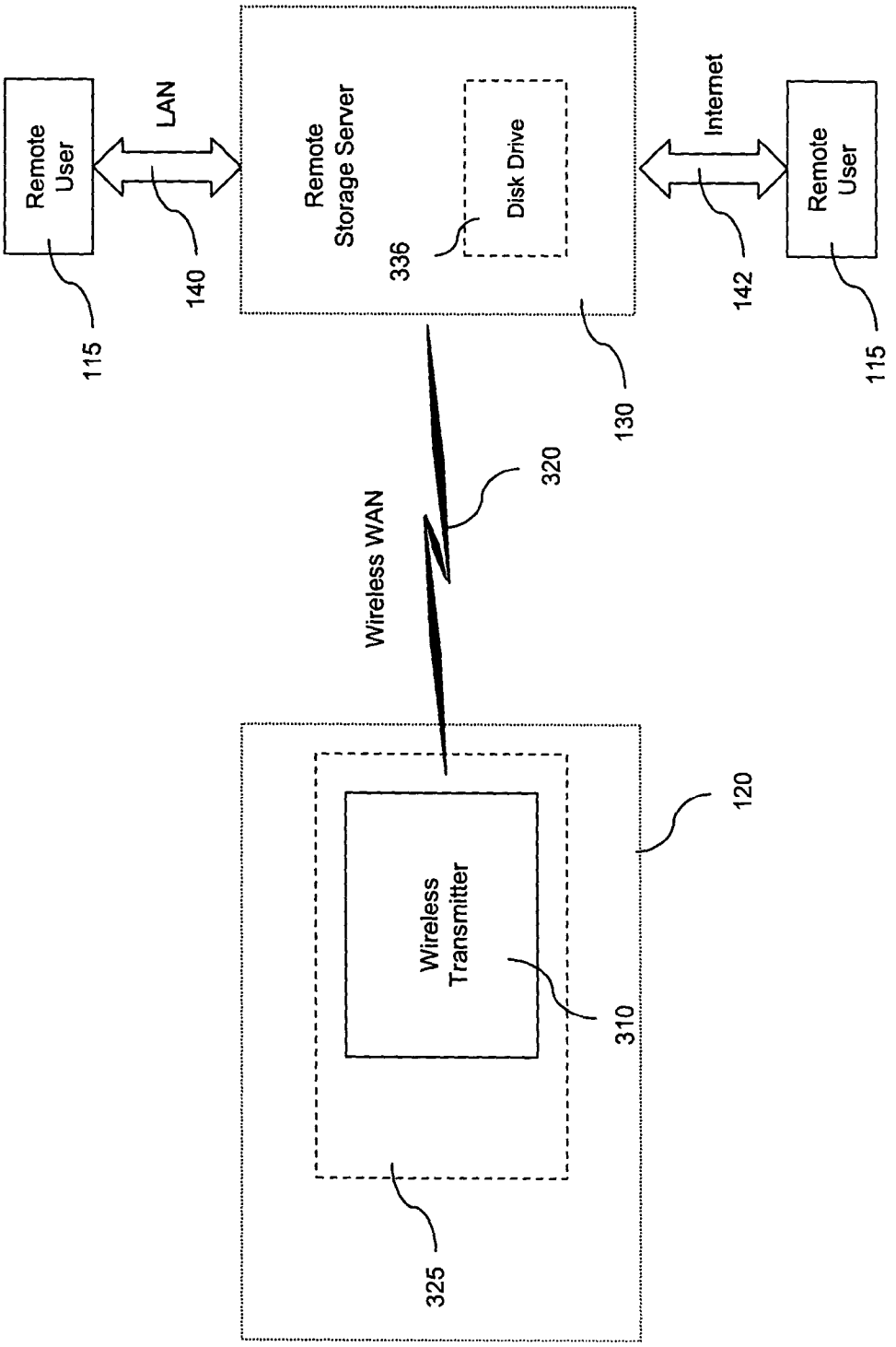

Remote User
LAN
Remote Storage Server
Disk Drive
Internet
Remote User
115
140
336
142
115
130
320
Wireless WAN
120
Wireless Transmitter
310
325

FIG 3

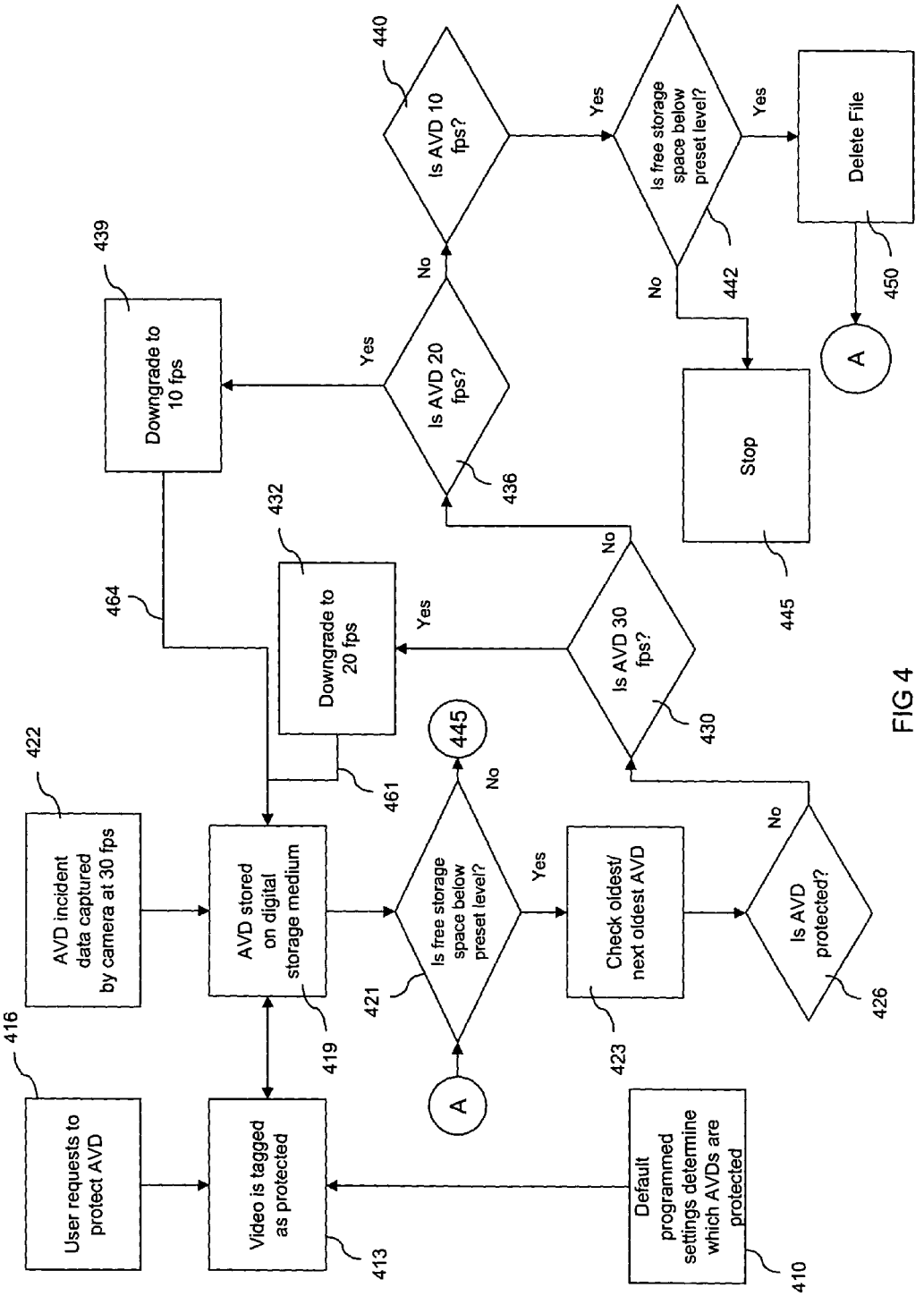

User requests to protect AVD
416
AVD incident data captured by camera at 30 fps
422
Video is tagged as protected
413
AVD stored on digital storage medium
419
Default programmed settings determine which AVDs are protected
410
Is free storage space below preset level?
421
445
No
Yes
A
Check oldest/ next oldest AVD
423
Is AVD protected?
426
No
Is AVD 30 fps?
430
Downgrade to 20 fps
432
461
464
Is AVD 20 fps?
436
Yes
No
Downgrade to 10 fps
439
Is AVD 10 fps?
440
Yes
No
Is free storage space below preset level?
442
Yes
Delete File
450
A
Stop
445

FIG 4

METHOD OF STORING DIGITAL VIDEO CAPTURED BY AN IN-CAR VIDEO SYSTEM

BACKGROUND OF THE INVENTION

This invention is related generally to surveillance systems, and more particularly to a method of storing digital video captured by an in-car video system.

Vehicle-mounted surveillance systems, also termed in-car video systems, are seeing increased use in the security industry and law enforcement community as an effective means to provide an indisputable video and audio record of encounters involving officers and citizens. In these systems, a video camera is typically mounted on the police car's dashboard or windshield and is generally arranged to have a field of view of the area to the immediate front of the car. The field of view approximately corresponds to what an officer would see when seated in the car's front seat. The video camera is operably coupled to a recording device, such as a video cassette recorder ("VCR") or digital video recorder ("DVR"), mounted in the police car, often in the trunk.

In-car video systems generally employ a wireless microphone carried on the person of a law enforcement officer to record an audio soundtrack that accompanies the visual scene captured on the video recording. The audio soundtrack is an extremely valuable complement to the recorded video because it acts as a transcript of what was said, by whom and when. In some cases, the audio soundtrack is more valuable as evidence than the visual record because issues pertaining to consent, admissions, and state-of-mind of the suspect and/or officer (to cite just a few examples) may be resolved more effectively by the audio record. In some systems, additional wired microphones may be deployed in other locations within the car, such as the rear-seat passenger area, to record sounds and conversations emanating from those locations.

A video recording may be started manually by the officer, or in some systems, the video recording is started automatically when, for example, the officer activates the police car's emergency systems (such as overhead lights and/or sirens), vehicle doors are opened, or when a vehicle speed-measuring radar unit is operated. The incident is recorded on video until the system is either manually or automatically switched off.

In-car video systems serve to enhance prosecution of traffic, DWI/DUI and controlled dangerous substances offenses (to name just a few) by contributing detailed graphical and auditory evidence in a time-sequential manner that is inherently unbiased and objective. Such evidence is a valuable adjunct to eyewitness and officer testimony. In addition, as with other quality-improvement initiatives where conduct is surveyed and recorded, in-car video system usage has been shown to assist in the maintenance of high professional standards among law enforcement personnel. Police-community relations have improved and citizen complaints of police misconduct have lessened in many jurisdictions where in-car video systems are used, often as a result of the inherently high-quality evidence provided by such systems. Videos taken with in-car video systems are also valuable training aids to law enforcement personnel.

Video evidence is protected (and the evidentiary chain of custody readily established) because the video recorder and video recording medium are typically "locked", often both mechanically and electronically, within a tamperproof security enclosure in the car (e.g., the trunk) that is only accessible by law enforcement command personnel. In addition, the in-car systems are configured to prevent erasure or over-recording of a recorded incident to ensure the integrity of the video evidence. In-car video systems may superimpose time and date stamps on the recorded video image as a further enhancement to the evidentiary strength of the video recording. In addition to date and time, other data, collectively referred to as "incident markers" such as the indication of the use of emergency lights and sirens, door opening and closures, vehicle speeds and other indicators may be recorded.

In-car video systems have historically been based on analog videotape technology. All video and audio sources (i.e., camera and microphones) are thus recorded on videotape. Once that videotape is full, it is removed and stored for a period of time determined by the requirements of the particular police department. That period may be days, weeks or years. As a result, even a small department may face storing a large number of tapes, perhaps several thousand or more, at any given time. Larger departments face an even larger tape storage problem.

While current videotape-based in-car video systems perform very well in many applications, digital video recording technology—where video is recorded to a computer-type media such as a hard disk drive by a DVR—may be utilized in other applications to realize several potential advantages. These include, for example, the ability to access (and very rapidly) any portion of the recording for incident review, improved reliability of digital media compared to tape mechanisms, better and more consistent image quality, and the lack of degradation of new images and audio when recorded over the top of the old ones.

One of the challenges presented from digital video storage is the amount of long term storage that is typically required in most applications. For example, one hour of VHS quality full motion, 30 frames per second, video requires approximately 1 gigabyte of digital storage. Thus, for each six-hour (i.e., T-120) VHS tape utilized, approximately six gigabytes of digital storage is required. The storage requirements for an agency differ greatly due to the varied length of time the video is required to be held. For example, some agencies save videos for 90 days unless there is an incident associated with the recording. Once the 90 days has elapsed, the videotape is typically erased and reused. Thus, a department with 20 cars producing eight hours of video per day per car would require approximately 14,400 gigabytes of digital storage. Storage requirements of such magnitude have significantly impacted the affordability of digital video recording systems.

SUMMARY OF THE INVENTION

A method of storing digital video is provided where a video clip is selected, according to one or more selection criteria, from video clips stored on a digital storage medium. The frame rate associated with the selected video clip is lowered and a downgraded version of the video clip is written to a digital storage medium at the lowered frame rate.

In an illustrative embodiment of the invention, the video clip is selected according to the length of time the video clip has been stored on the digital storage medium. A downgraded version is created (having a lowered frame rate) and stored to a digital storage medium. The original video clip may then be overwritten or erased to thereby reduce the storage space requirements for the downgraded video clip by approximately the percentage reduction in downgraded frame rate.

The video clips may be downgraded in a chronological sequence to maintain a desired amount of free space on the digital storage medium. Accordingly, the oldest stored video clips are downgraded first, as required, once a predetermined usage threshold is reached and additional new video clips are recorded onto the digital storage medium. The downgrading process may be implemented by an in-car video system or an

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a digital storage device such as a server that is remotely located from the in-car video system, depending on the requirements of the application.

Users may select certain videos (e.g., "important" or otherwise significant recorded incidents) to be exempt from the downgrade process regardless of the video clip's age in some applications. The level of downgrading (i.e., reduction in frame rate) may be selectable by a user in some applications, and the downgrading may also be performed step-wise (for example, first from 30 frames-per-second to 20 fps, and then from 20 fps to 10 fps, as required to maintain the desired level of free space on the digital storage medium). In this illustrative embodiment of the invention, the audio portion of the selected video clip may preferably be kept intact in its entirety in most applications and stored along with the downgraded image.

Advantageously, the inventive method enables the amount of recorded video stored within individual vehicles to be substantially increased. Agencies may be able to store many months of video inside the cars, to thereby negate or lessen the need for expensive storage hardware and complex processes to be implemented within the agency.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a simplified functional block diagram of a first method of long term video storage;

FIG. **2** is a simplified functional block diagram of a second method of long term video storage;

FIG. **3** is a simplified functional block diagram of a third method of long term video storage; and

FIG. **4** is a flow chart of an illustrative process for selectively downgrading the frame rate of selected video clips.

DETAILED DESCRIPTION

Digital video recording systems available today operate in a very similar manner to their videotape counterparts. One or more cameras and one or more microphones feed into a DVR and the recorded video is stored on a digital storage medium. Thus, instead of videotape, a hard disk drive (functionally similar to those used in personal computers) is typically used for storage. Long-term storage can be achieved in several ways.

Referring to FIG. **1**, which provides a simplified block diagram of a first method of long term video storage, a large digital storage medium **110** (for example, a hard disk drive having storage capacity of greater than 50 gigabytes) is utilized in a vehicle **120**, such as a police cruiser, to record and store many hours of video. Typically, the large digital storage medium **110** would be incorporated into an in-car video system, designated by reference number **125** in FIG. **1** which typically includes a DVR, camera, microphone, control unit and monitor (not shown in FIG. **1**). Thus, the digital storage medium **110** functions with regard to the DVR the same way a videotape functions relative to a VCR.

Once the large digital storage medium **110** reaches its maximum capacity, the oldest video is erased (i.e., overwritten) and its space is taken by the newest video as shown in FIG. **1**. All storage is typically maintained in individual vehicles, and not externally at the agency or department. However, selected video recordings, for example those designated as being of interest or of other importance, may be transferred to conventional storage media such as compact disc ("CD") or digital versatile disc ("DVD"), removable hard disk drive or any other removable media (collectively designated by reference numeral **131** in FIG. **1**). The media **131** containing such selected video recordings may be saved by placing the digital storage medium **110** in storage **133**, or the video data may be transferred or copied to a remote storage server **130** as shown in FIG. **1**. In some applications of the invention, the large digital storage medium **110** may be completely removed from the vehicle **120** when full and stored. The full digital storage medium may then be replaced in the vehicle's in-car video system by an empty one.

In this illustrative method as well as the other described below, the storage server **130** may be a stand-alone personal computer with on board storage and a CD or DVD burner (not shown in FIG. **1**). The storage server **130** may also take the form of a network storage unit that allows access by a remote user **115** to the stored video via a local area network **140** ("LAN") or Internet connection **142**. In some applications of the invention, such system access may be controlled down to the individual user and/or the video data such users are allowed to access.

As shown in FIG. **2**, a second method for long term storage utilizes a smaller removable storage medium **210** within in-car video system **225** installed within vehicle **120**. Removable storage medium **210** may be implemented, for example using one to five gigabytes of storage, as provided by such devices as an IBM 1 GB MicroDrive hard drive. Typically, the removable storage medium **210** would be removed from the vehicle **120** at every shift and the video data transferred to a remote storage server **130** that is often located within an agency. Transferring the video data to remote storage server **130** provides easy access to the saved video as well as allowing the removable medium **210** to be put back into field use (i.e., recycled).

Such methodology also allows users located remotely from the vehicle **120** to search for video clips using a number of pointers or search fields. For example, police vehicle number, officer badge or other identifying number, officer name, date, time may be used as search criteria, either individually, or in combination. The occurrence of external triggers or incidents markers such as the emergency Lights, Siren, Car door opening, etc., that may be part of the video record, may also be searched in some applications of the invention.

In a third method of long term video storage depicted in FIG. **3**, the removable media may be replaced with a wireless link, enabled for example, through the use of a wireless transmitter **310** as shown. In such a methodology, the video is transferred whenever the car is within range of an applicable WAN **320**. The video data is transferred to a storage server **130** coupled to the WAN. Accessibility by personnel **115** may be provided via LAN and Internet connections, **140** and **142** respectively, as shown.

The third method described above is often the most advantageous in many applications. It often requires the least amount of interaction from the officer which can be desirable from the viewpoint of training reduction and enhanced evidence preservation. However, it may be a more difficult method to employ in practice due to the large amounts of data required for video storage.

Turning now to FIG. **4**, a flow chart of an illustrative process for selectively downgrading the frame rate of selected video clips is shown. As shown in block **422** of FIG. **4**, AVD pertaining to a particular incident is captured by a camera and associated microphones. The frame rate in most applications will be 30 frames-per-second ("fps") which is the conventionally accepted frame rate for full motion video. "AVD," as the term is used generally means a combination of video images plus audio as typically captured by the cameras and microphones used in most in-car video systems. It is noted, however, that some applications may be suited to the use of either

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video or audio separately. The principles of the invention may be beneficially applied to each of these situations and, accordingly, the term AVD as used herein may mean audio and video data, alone or in combination. A digital storage medium such as a hard disk drive (for example, those identified by reference numerals **110**, **210** or **336** in FIGS. **1-3**, respectively) stores the AVD, as indicated by block **419**.

A typical user of the method described here could be a police officer using an in-car video system incorporating the inventive principles. It may be possible for an officer to feel that a particular video recording of an incident should be saved some reason and tag it as protected and thus exempt from the downgrading process. Such a request to protect the AVD associated with captured incidents is shown in block **416** of FIG. **4**.

An alternative method to protect AVD from being downgraded is indicated by block **410**. In this method, the occurrence of one or more predetermined criteria will determine in advance which AVD is protected. A user of this alternative method of protection could be a command staff member of a police department or administrator. Policy, or other reasons, may dictate for example, that all video recordings of all traffic stops involving the issuance of summons never be downgraded or erased and the individual officer should not be provided discretion regarding AVD meeting such criteria. This "default" exempt status for certain AVD meeting predetermined criteria is indicated by block **410** in FIG. **4**.

As new video clips are captured and written to the hard disk drive in block **419**, the digital storage medium fills until it reaches a predetermined threshold as shown at block **421**. For example, a particular digital storage medium could be set up so that at least 10% free storage space is available at any given time. If the storage of the new captured video does not cause the free storage space to fall below the preset level, then control is passed to block **445** and no action is taken. If the storage does result in less free storage space than desired, at block **423** in FIG. **4**, the oldest video clip stored in the digital storage medium (representing the earliest recorded incident in time) becomes a candidate for downgrading to a lower frame rate.

It is noted that the criteria of age is merely illustrative as some video clips may be candidates for downgrading based on other criteria, depending on the requirements of the application. For example, some agencies may record video as soon as emergency lights on the police cruiser are activated (such as when an officer is in transit to a call under emergency condition). In such circumstances it may be possible that no evidence of any value is recorded because the incident to which the officer was responding occurred out of camera view, for example, a first aid call for a heart attack victim in a hotel room. Therefore, it may be desirable to downgrade video recordings having limited evidentiary value irregardless of age.

To maintain the desired free space on the digital storage medium, in an illustrative example, the oldest video clip is converted from 30 fps to an arbitrary lower rate (for example, 15 fps or less as may be determined by the agency). Alternatively, as shown in FIG. **4** in blocks **423-440**, a step-wise downgrade approach may also be used to convert the video from higher to successively lower frame rates in an iterative manner, for example 30 fps to 20 fps and then to 10 fps. The step-wise approach may be taken to successively downgrade the AVD over some selected time interval. Accordingly, the very oldest AVDs are downgraded and stored at the lowest frame rate, the newest AVDs are stored at the full frame rate, and the AVDs in between the oldest and newest are downgraded and stored at an intermediate frame rate.

Returning back to FIG. **4**, as shown at block **423-426**, if the oldest AVD is not protected (via the tagging process described above), then process control passes to block **430**. If the AVD is currently at 30 fps, then as shown in block **432**, the AVD is downgraded to 20 fps and the downgraded AVD is written to the digital storage medium as indicated by line **461**. The original AVD (i.e., the version on which the downgraded version is based) is then marked as free to be overwritten (for example, by downgraded AVDs or new video recordings) or erased from the digital storage medium as indicated by block **450** if additional space is required to maintain the preset level on the digital storage medium.

As indicated in block **436** of FIG. **4**, if the AVD is currently at 20 fps (having been previously downgraded in an earlier iteration), then it is downgraded again to 10 fps. The downgraded AVD is written to the digital storage medium as indicated by line **464**. The original AVD (i.e., the 20 fps version on which the downgraded version is based) is then marked as free to be overwritten or erased from the digital storage medium. Such overwriting or erasure of the original AVD thus frees up additional storage space on the digital storage medium.

At block **440**, once the AVD is finally downgraded to 10 fps, a check at block **442** is performed to determine if the free storage space is below the preset level. If so, then process control returns to block **421**, as shown, and the process iterates with the next oldest stored AVD. The process continues in an iterative manner until the desired free space on the digital storage medium is achieved.

Other features of the invention are contained in the claims that follow.

What is claimed is:

1. A method of storing a video clip captured using an in-car video system, the video clip having an associated frame rate, the method comprising the steps of:

selecting a video clip from video clips stored on a digital storage medium, where the step of selecting is performed according to a length of time a video clip has been stored on the digital storage medium; and

downgrading the selected video clip so that a frame rate of the downgraded video clip is lower than a frame rate of the selected video clip prior to downgrading; and

storing the downgraded video clip at the lower frame rate.

2. The method of claim **1** where the steps of selecting and downgrading are performed when a determination of current free space on the digital storage medium indicates that the current free space is below a threshold.

3. The method of claim **1** where the downgraded video clip is stored on the digital storage medium.

4. The method of claim **1** where the downgraded video clip is stored on a second digital storage medium.

5. The method of claim **1** where the step of downgrading is performed iteratively.

6. The method of claim **1** where the downgraded video clip is performed step wise.

7. The method of claim **1** where the steps of selecting and downgrading are performed iteratively so that video clips stored on the digital storage medium are downgraded in a chronological sequence.

8. The method of claim **1** where the frame rate of the downgraded video clip is user selectable.

9. The method of claim **1** where the step of downgrading is performed in an in-car video system located in a vehicle.

10. The method of claim **1** where video clips stored on the digital storage medium are exempted from the step of downgrading according to user-defined exemption criteria.

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11. The method of claim 1 where the step of selecting is further performed according to an evidentiary value of a video clip.

12. A method of operating a digital storage medium used to store video clips of scenes captured by a camera, the video clips each having an associated frame rate and being chronologically stored on the digital storage medium from oldest to youngest, the method comprising the steps of:

downgrading the oldest video clip to a lower associated frame rate to thereby reduce the amount of space required to store the oldest video clip; and

storing the downgraded video clip at the lower associated frame rate on the digital storage medium.

13. The method of claim 12 where the step of downgrading is performed when free space on the digital storage medium falls below a threshold.

14. The method of claim 12 further including a step of iteratively performing the downgrading step to maintain a level of free storage of the digital medium.

15. The method of claim 14 where the level of free storage of the digital storage medium is preset.

16. The method of claim 12 further including the step of overwriting the oldest video clip with a new video clip.

17. A digital video storage system, comprising:

a digital storage medium; and

a processor for downgrading digital video clips of scenes captured by an in-car video system camera, the video clips each having an associated frame rate and stored on the digital storage medium so that a frame rate of the downgraded video clips is lower than a frame rate of the selected video clips prior to downgrading,

wherein the video clips selected to be downgraded by said processor are selected according to a length of time a video clip has been stored on said digital storage medium.

18. The digital video storage system of claim 17 further including a user interface for selectively exempting video clips from downgrading by the processor.

19. The digital video storage system of claim 17 further including a user interface for selectively setting the frame rate of the downgraded video clip.

* * * * *

Appendix U

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(54) **MOBILE DIGITAL SURVEILLANCE SYSTEM**

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Publication Classification

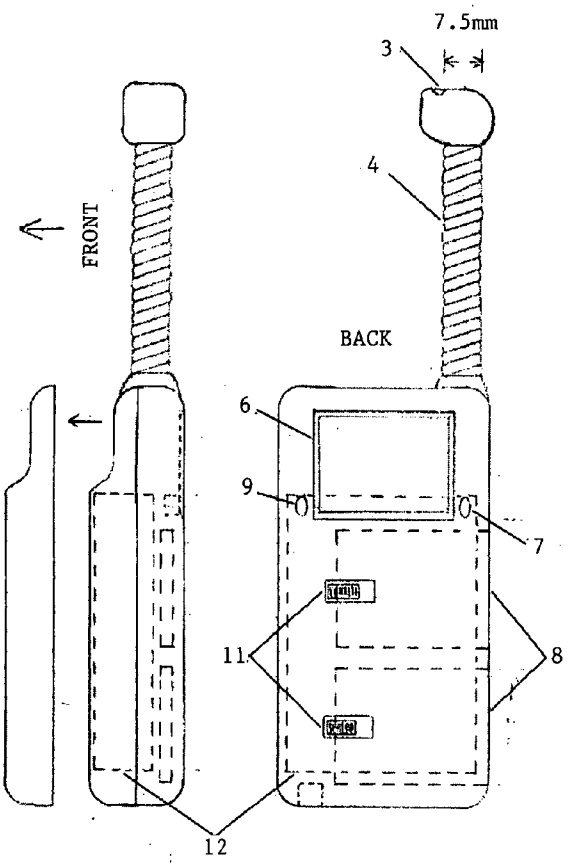
(51) **Int. Cl.**[7] **H04N 7/173**; H04N 5/76; H04N 7/16; H04Q 7/20; H04B 1/38; H04H 1/00; H04M 1/00; H04M 11/00

(52) **U.S. Cl.** **348/231.3**; 725/62; 348/231.7; 348/231.9; 455/403; 455/3.01; 455/414.1; 455/566

(57) **ABSTRACT**

A mobile recording device includes a flexible camera head for capturing video stream data in real time; a microphone for capturing audio data in real time; a position determining module for capturing position data for the mobile recording device; a first and a second replaceable memory modules for storing the video stream data and the audio data, wherein the first replaceable memory module can be replaced when the second replaceable memory module is being used to store the video and audio data and the second replaceable memory module can be replaced when the first replaceable memory module is being used to store the video and audio data.

The mobile recording device may further include a wireless transceiver for wirelessly transmitting the video, the audio, and the position data to a remote location and receiving data from the remote location.



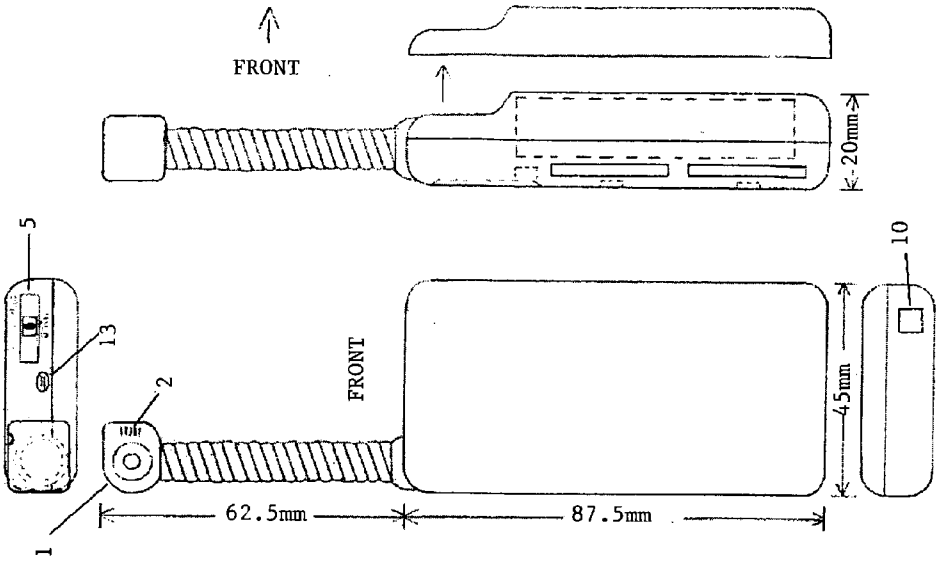

FRONT
20mm
5
13
2
1
FRONT
10
45mm
62.5mm
87.5mm

FIG. 1B

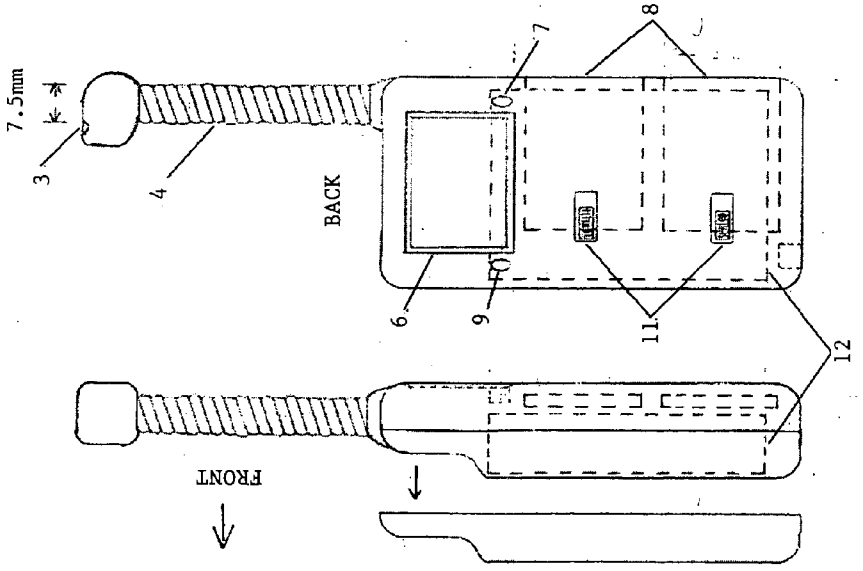

7.5mm
3
4
BACK
7
8
6
9
11
12
FRONT

FIG. 1A

FIG. 2

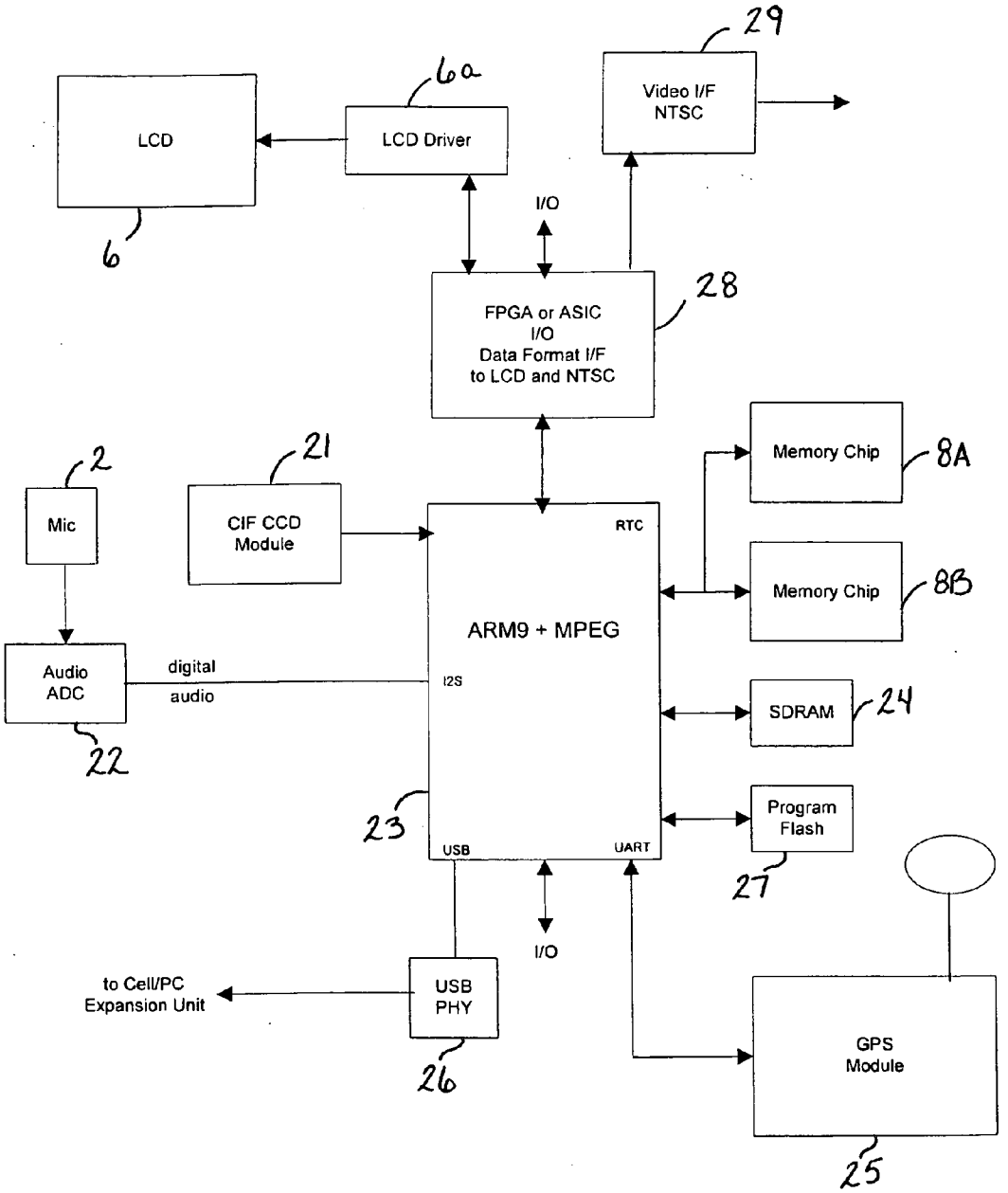
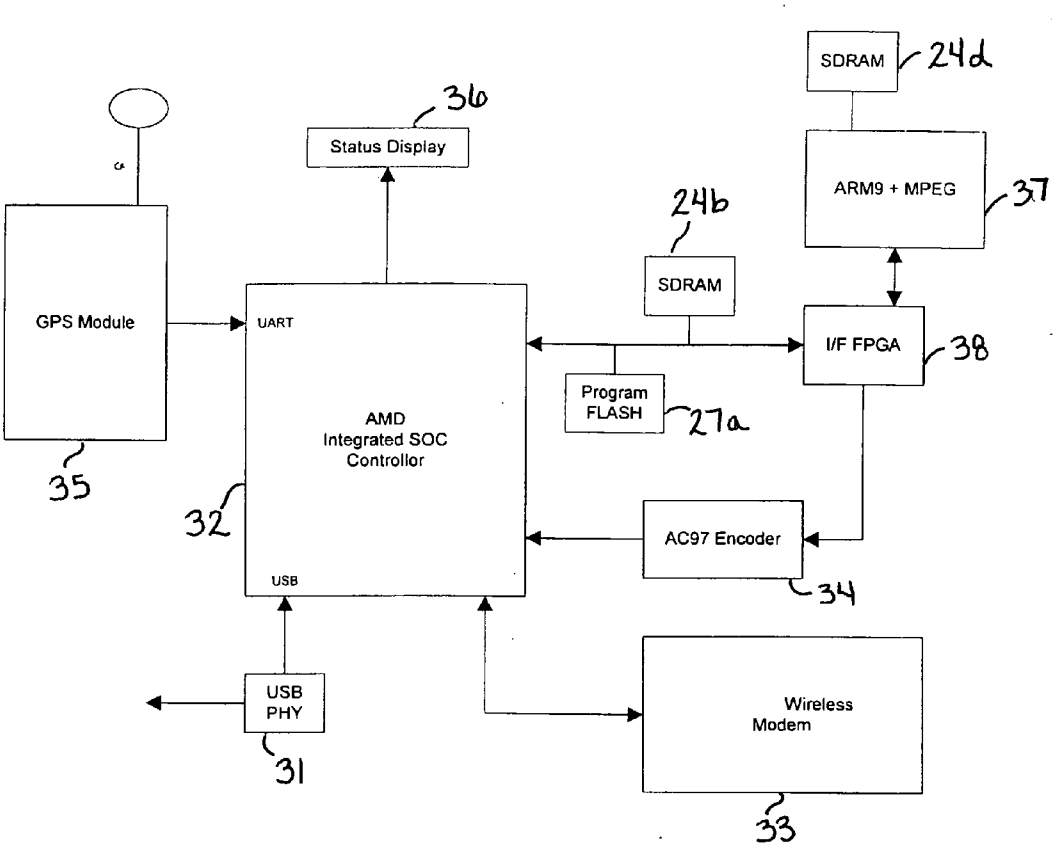

29
Video I/F
NTSC
60a
LCD
LCD Driver
6
I/O
28
FPGA or ASIC
I/O
Data Format I/F
to LCD and NTSC
Memory Chip
8A
2
21
Mic
CIF CCD
Module
RTC
Memory Chip
8B
ARM9 + MPEG
Audio
ADC
digital
audio
I2S
SDRAM
24
22
23
Program
Flash
USB
UART
27
I/O
to Cell/PC
Expansion Unit
USB
PHY
GPS
Module
26
25

FIG. 3


SDRAM
24d
36
Status Display
ARM9 + MPEG
37
24b
SDRAM
GPS Module
UART
I/F FPGA
38
Program FLASH
27a
AMD Integrated SOC Controllor
35
32
AC97 Encoder
USB
34
USB PHY
31
Wireless Modem
33

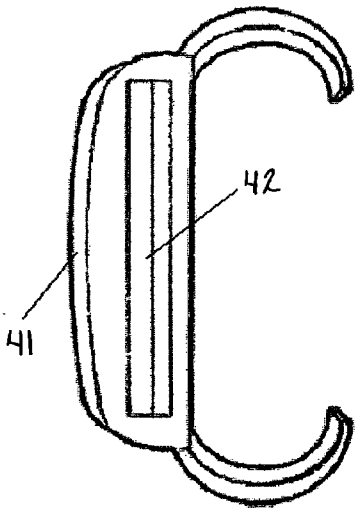


FIG. 4A

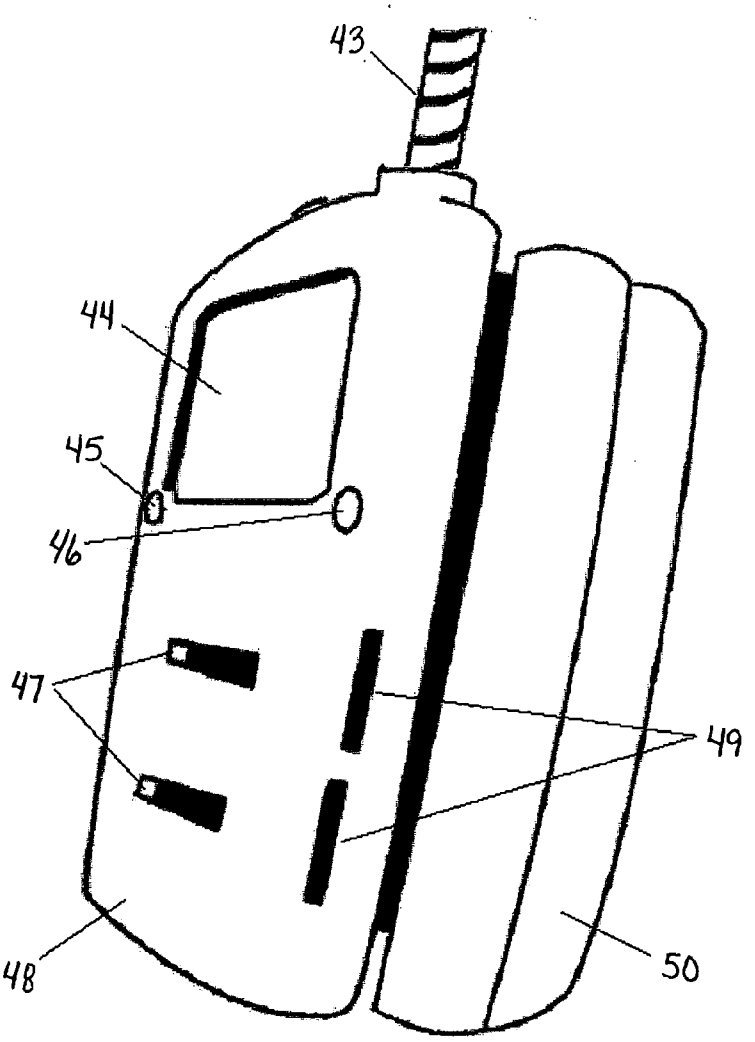
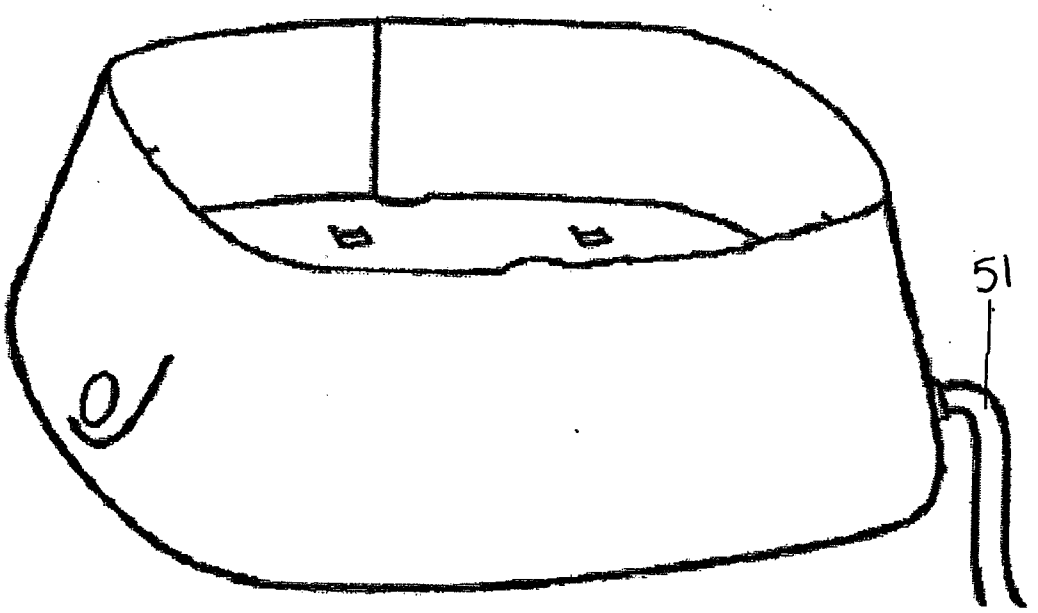


FIG. 4B

FIG. 4C



MOBILE DIGITAL SURVEILLANCE SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This patent application claims the benefit of the filing date of U.S. Provisional Patent Application Ser. No. 60/510,875, filed Oct. 14, 2003, and entitled "MOBILE DIGITAL SURVEILLANCE SYSTEM", the entire contents of which are hereby expressly incorporated by reference.

FIELD OF THE INVENTION

[0002] The present invention relates generally to wireless video/audio devices; and more particularly to a personal mobile digital recording system.

BACKGROUND OF THE INVENTION

[0003] Some of the top complaints from those who use videotape systems are related to reliability, quality, and size. These systems, based on consumer technology, simply aren't designed to operate on a daily basis in rigorous environments. They break often and become a burden, especially to larger departments whose operating requirements tend to worsen as they grow larger. As for quality, consumer based videotape technology has limited quality even in its optimal state. For example, size, cleaning recording heads, replacing tapes with new tapes, SP mode, and cool operating temperatures limit the quality and convenience of using consumer based videotape technology for surveillance purposes. Quality further degrades when any of these variables changes over time.

[0004] Even when an image is recorded under optimal conditions, the quality of the video will degrade over time, for instance, every time the video is reviewed, or when the tape itself is subjected to extreme temperatures. These deficiencies can loom large when, for example, a jury must decide guilt or innocence from seemingly minor details on a videotape. There currently exists a void in the market for a small solid-state video recorder that can be useful for surveillance purposes. Therefore, there is a need for a mobile digital surveillance system with enhanced video recording and video management.

SUMMARY OF THE INVENTION

[0005] The present invention provides an improved method and system for a personal mobile digital recording system (MDRS) to capture activities of, for example, a law enforcement officer.

[0006] In one embodiment, the present invention is a mobile recording device including a flexible camera head for capturing video stream data in real time; a microphone for capturing audio data in real time; a position determining module for capturing position data for the mobile recording device; a first and a second replaceable memory modules for storing the video stream data and the audio data, wherein the first replaceable memory module can be replaced when the second replaceable memory module is being used to store the video and audio data and the second replaceable memory module can be replaced when the first replaceable memory module is being used to store the video and audio data.

[0007] In one embodiment, the mobile recording device further includes a wireless transceiver for wirelessly transmitting the video, the audio, and the position data to a remote location and receiving data from the remote location. For example, the mobile recording device is capable of receiving a command from the remote location to start recording data, and/or to transmit its location data.

[0008] The mobile recording device may include a compass for indicating a direction the camera head is pointing to, a finger print sensor for capturing and transmitting finger print data in real time, and/or a facial scanning module for capturing and transmitting facial profiles in real time.

[0009] In one embodiment, the present invention is a mobile recording device including: a flexible camera head for capturing video stream data in real time; a microphone for capturing audio data in real time; a circular buffer for continuously storing the video stream data and the audio data; and a wireless transceiver for transmitting the video and audio data in real time to a remote location.

[0010] In one embodiment, the present invention is a mobile recording device including: a flexible camera head for capturing video stream data in real time; a microphone for capturing audio data in real time; a finger print sensor for capturing finger print data in real time; and a wireless transceiver for transmitting the video, audio, and finger print data in real time to a remote location and for receiving commands from the remote location.

[0011] These and other-features of the present invention will become readily apparent in view of the accompanying drawings and the detailed description of the embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] **FIGS. 1A and 1B** are exemplary diagrams illustrating an exemplary embodiment of the present invention;

[0013] **FIG. 2** is an exemplary system block diagram, according to one embodiment of the present invention;

[0014] **FIG. 3** is an exemplary system block diagram, according to one embodiment of the present invention depicting a wireless capability; and

[0015] **FIG. 4A** illustrates an exemplary wireless adaptor for a mobile digital recording system, according to one embodiment of the present invention;

[0016] **FIG. 4B** shows a mobile digital recording system next to a wireless adaptor and the general alignment of the two units, according to one embodiment of the present invention; and

[0017] **FIG. 4C** is an exemplary charging base for a mobile digital recording system, according to one embodiment of the present invention.

DETAILED DESCRIPTION

[0018] In one embodiment, the present invention is a personal mobile digital recording system (MDRS) to capture activities of, for example, a law enforcement officer for his entire shift. The MDRS of the present invention is truly mobile as it is smaller than most cell phones and can travel with users wherever they go. The MDRS captures audio/video feeds from user's pocket and provides date, time and GPS location data for an extended period of time.

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[0019] In one embodiment, the present invention is a MDRS that can be placed in a vehicle one moment, or be mobile with its operator in the next. The MDRS knows the location of its operator, the direction that the camera is pointing, and can transmit that location and direction back to a remote operations center. It can also transmit live video back to the operations center. The MDRS is capable of automatically saving the entire shift of a law enforcement officer, for example, for 10-12 hours, or more. It saves compressed video files in an easy to use computer format eliminating the need for vast video tape archives. Additionally, the MDRS of the present invention may be used by accident investigators to review the last several hours of, for example, a school bus's operation. Insurance investigators may use the MDRS to identify all of the vehicles involved in a big rig truck accident, for example.

[0020] In one embodiment, the MDRS provides users with a simple and effective audio and video log of their day activities. The MDRS may be placed in a docking station on the dashboard of a vehicle, clip into a shirt pocket, or attach to the front of a tactical vest. A small LCD screen on the back of the MDRS displays what is being captured by the video recorder.

[0021] **FIGS. 1A and 1B** are exemplary diagrams illustrating an exemplary embodiment of the present invention. **FIG. 1A** depicts a back and a first side view of an exemplary MDRS, while **FIG. 1B** illustrates a front, a second side view, top and bottom views f the MDRS. The measurements indicated in **FIGS. 1A and 1B** are exemplary sizes and may vary in different embodiments of the present invention.

[0022] The MDRS depicted in **FIGS. 1A and 1B** may be changed and redefined to achieve a more aesthetic appearance or to achieve the technological requirements. The MDRS includes the following components: at least two removable Secure Digital (SD) memory cards (or any other replaceable memory modules) **8**, a LCD screen **6**, a camera head **1** with color CCD Sensor that supports replaceable lenses, a microphone **2**, a flexible support **4** for the camera head, a Li-ion battery **12**, one or more video outputs (not shown), and optionally a small speaker (not shown).

[0023] The MDRS also includes cellular support for video and audio transmission, and MPEG (e.g., MPEG4 and/or MPEG2) video and audio capability. The video and audio data are recorded in the alternating SD memory cards.

[0024] The MDRS also includes an On/Off status LED **3**, and On/Hold/Off switch **5**, a LCD On/Off button **7**, a memory/data storage change button **9**, a power connector **10**, a memory/data storage eject **11**, a battery case open latch **13**, a button for establishing cellular data connection with preprogrammed number to transmit video and audio (not shown), a button for disconnecting cellular data connection (not shown), a cellular antenna (not shown), and a battery cover (not shown).

[0025] The camera head supports color CCD and/or CMOS sensors. Camera head also supports user replaceable lens choices of a variety of sizes.

[0026] In one embodiment, the MDRS records in an endless loop using two or four replaceable memory modules. The amount of data recorded is dependent on the capacity of the SD cards. For instance, using the high capacity SD cards enables the unit to capture in excess of 24 hours of video and audio data. SD cards may be "hot" ejected and swapped to secure any video and audio data previously recorded. The MDRS incorporates a GPS (Global Positioning System) chip and antenna. GPS location information is encoded as part of the video and audio data stream. Other position determining modules are also available and may be used in some embodiments of the present invention.

[0027] The MDRS incorporates a wireless data transceiver. This enables the user to manually initiate a live video feed to a remote control center. Additionally, the control center may remotely instruct the unit to initiate a live data and/or video feed.

[0028] In one embodiment, video is captured in color at a resolution of 360×240 at 30 frames per second. The encoding format is MPEG4 and can achieve upwards of 40:1 compression. The video capture device (camera head **1**) is located on the top of a flexible stalk or gooseneck in an enclosed camera head.

[0029] Flexible stalk **4** contains the video camera head as well as microphone **2**. The camera stalk can flex to allow the video camera to be positioned to best capture the scene. The camera stalk attaches to the MDRS body via a plug and is secured by a mounting cap (not shown). Multiple camera stalks and wired accessories may be used to address different field requirements.

[0030] The stalk is stiff enough so that the camera head won't inadvertently move. The camera head can be aimed by rotating it at the end of the stalk, and/or by bending the stalk in the desired direction. The stalk plugs into the MDRS body and is secured by a mounting cap. Some embodiments may not include the stalk. These wired camera heads can be used for remote mounting of the camera head. Wired lengths vary depending on the application. These wired lengths include the video capture device and a microphone enclosed in the camera head, a wire run, a MDRS body plug, and one or more securing mounting cap(s).

[0031] In one embodiment, the MDRS uses a new generation integrated charge couple device (CCD), or CMOS imaging technology, for example, a Sanyom CCD containing anti-blooming, auto-white balance and auto-exposure capabilities. The CCD is preferably low-light capable. Different lenses may be mounted on the camera head. The user choice of the lens determines the field of view captured. Lenses ranging, for example, from 4 mm to 16 mm are currently available and may be changed by the user.

[0032] In one embodiment, the MDRS includes single chip micro-fluxgate compass CMOS technology for "Situational awareness." Compass bearing data will be encoded as part of an "overlay" channel in the MPEG data stream. For example, a Microsystems Design Groups Integrated micro fluxgate sensor may be used.

[0033] In one embodiment, the MDRS uses a micro-fluxgate sensor integrated onto a CMOS IC process. The micro-fluxgate sensor is low noise and low temperature with a sensor response sensitivity. Exemplary micro-fluxgate sensors are described in P. M. Drljaca, P. Kejik, F. Vincent, R. S. Popovic, "*Low Noise CMOS Micro-Fluxgate Magnetometer*", Transducers'03, Boston, Mass., USA, pp. 304-307, Jun. 8-12-4, 2003; and P. M. Drljaca, P. Kejik, F. Vincent, D. Piguet, F. Gueissaz, R. S. Popovic, *Single Core*

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Fully Integrated CMOS Micro-fluxgate magnetometer", EUROSENOSRS XV September 15-18, Prague, Czech Republic; the entire contents of which are fully incorporated herein by reference.

[0034] In one embodiment, audio is recorded in monaural at 16 k bits/second approximately the quality of AM radio. The microphone incorporated into the camera head is sensitive enough to pick up a quiet conversion for example, from more than 5 meters.

[0035] In one embodiment, video, audio, date and time, GPS overlay channel, electronic compass bearing channel, and biometric data overlay channel are encoded in an MPEG data stream. Any attempt to alter the data stream would affect the date and time encoding in the data stream. The MPEG data stream is written and saved on replaceable memory modules. Current measurements indicate that an MPEG data stream containing video+audio+date and time+40 bytes GPS and Compass+120 bytes bio encodes at a rate of 512 bps. The GPS and bio overlay data are preferably encoded in P-Frame data packets and not in every data packet.

[0036] In one embodiment, the MDRS records in two replaceable memory modules alternating between them automatically in an endless loop. Operator's may eject one replaceable memory module and replace it while the MDRS is still recording to the other replaceable memory modules. The replaceable memory modules may be write protected using the "Write Protect" tab on the replaceable memory modules. The MPEG data format is tamper proof eliminating chain of evidence questions. This is because video frames are time stamped frequently.

[0037] In one embodiment, the MDRS includes GPS capability. GPS location data is encoded in the MPEG data stream to track the location of the MDRS. The location may be periodically recorded. The period of the location recordation is programmable by the user. The location data combined with the date and time data give an accurate history of the location of the MDRS.

[0038] In one embodiment, the MDRS includes an electronic compass. Compass bearing data indicates the direction the camera is pointing. This compass bearing data combined with GPS data and the date and time data provide a new level of situational awareness for monitoring facilities or site/area surveys. Compass bearing information is encoded as part of the video and audio data stream. The compass information may also be displayed on the LCD.

[0039] Additional biographical data or text may also be encoded as part of the data stream. This additional data may include the MDRS unit ID, date and time, or any other personnel data stored in the MDRS firmware.

[0040] The MDRS is capable of transmitting live data to a control monitoring system. The monitoring system can plot the location of the MDRS, or provide the location data to another system. The monitoring system can display the real-time video and audio provided by multiple MDRS units. In addition, biographical data may be overlaid on the video image to identify the MDRS's operator. In one embodiment, simple text overlay may be inserted by the operator over video frames. Text may be entered by a plug-in keyboard or by pre-programmed buttons on the MDRS. Live transmission may be initiated by the MDRS's operator, or may be remotely initiated by the control monitoring system.

[0041] In one embodiment, operational controls for the MDRS are basic and simple. When the system is turned on, it starts recording until it is turned off. The operator may turn the LCD screen on and off, and may instruct the MDRS to change recording to the "other" SD card. The operator may eject and replace the SD cards. The operator may initiate or terminate a live transmission.

[0042] In one embodiment, MDRS setup controls are menu driven and much more extensive. Some of the controls include:

[0043] setup of the operator's biographical data.

[0044] enabling or disabling of audio.

[0045] live transmission connection parameters.

[0046] date and time formats.

[0047] automatically start recording on power up.

[0048] In one embodiment, MDRS automatically recharges when placed in its docking station. Clips and vest attachments allow the MDRS to be carried in a shirt pocket or attached to a tactical vest. Docking stations can be mounted on a vehicle dashboard and the MDRS placed into it when the operator returns to the vehicle. This provides for a vehicle based camera while the operator is in the vehicle and a personnel based camera while the operator is away from the vehicle.

[0049] The docking station includes a stable platform for the camera to sit in. The camera platform provides stability in all directions. Preferably, the camera should not be able to be "bounced" out of docking station. The LCD, LCD On/Off button and memory/data storage change button are visible and accessible while camera is docked. Camera is charged while sitting in the docking station. Docking Station will accept AC or DC power and delivers DC power to the camera.

[0050] In one embodiment, the MDRS may be permanently mounted and with the use of the wired camera head, and a longer wire run length, the camera head may be positioned in a more advantageous way. The MDRS can be configured to automatically start recording when power is applied, and to stop recording when power is turned off. An example for this use would be a permanent mounting in a vehicle like a bus. In one embodiment, the start and stop functions are voice activated using a voice recognition module.

[0051] In one embodiment, the docking station is powered and provides a charging port for the unit. A high energy Li-Ion battery powers the MDRS for at least ten hours at a time. By periodic placement into its docking station, the MDRS may be left on indefinitely. The MDRS may be wired directly to a power source for permanent mounting options. Those skilled in art would easily recognize that other forms of providing power to the MDRS and the docking station, such as different battery technologies, or different types of power sources, are possible.

[0052] Other features in some embodiments include:

[0053] PCcard card interface supporting multiple wireless solutions and international standards;

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[0054] finger print sensor to capture and transmit finger prints in real-time,

[0055] facial scanning/identity software to capture and transmit facial profiles in real-time, and

[0056] support for integrated facility control room monitoring software.

[0057] In one embodiment, microphone **2** is integrated into the camera head **1**. Microphone **2** is sensitive enough to pick up a quiet conversion at approximately 5 meters or more.

[0058] In one embodiment, the camera head **1** includes a micro LED. The status LED **3** faces toward the back and top of the camera so that it is not visible from in front of the Camera, as shown in **FIG. 1A**. The LED displays the following colors on the following conditions:

[0059] Green—Camera is recording

[0060] Green Flashing—Camera is transmitting

[0061] Red—Camera is recording, but power level is low

[0062] In one embodiment, the camera head support supports up to 95° (from vertical) change in camera angle in any direction. Camera head support is typically "stiff" enough to prevent unintended change in angle. Camera head can swivel about **450** (from horizontal).

[0063] The camera starts recording when the On/Hold/Off switch **5** is placed into the "On" position. When recording, all other buttons on the Camera will remain functional. When the switch is placed into the "Hold" position, all other buttons on the camera are disabled. Placing the switch into the "Off" position turns the camera off.

[0064] The color LCD **6** (or other small display technologies) displays the CCD image. When the camera is powered "On", the LCD is enabled. In one embodiment, the LCD displays the following information, date and time, battery power level, A/B (A/B/C/D) memory card active, A/B time (HH:MI:SS) of saved data, cellular transmission active, and/or any other needed information.

[0065] "Date and Time" are user selectable: "Battery Power Level" indicates how much recording time is remaining. If the battery **12** is being charged, the recording time indicator will flash. "A/B/C/D memory card active" indicates which SD Memory, card is currently being written to. "A/B HH:MI:SS of saved data indicates the hours, minutes and seconds of recorded data in each SD memory card. The above status are typically for user's information only and are not recorded on video image. However, in one embodiment, selective data may be recorded on the video image or audio data. The LCD On/Off button **7** toggles the LCD on or off. This button only disables the LCD, while the camera is still recording.

[0066] **FIG. 2** is an exemplary system block diagram, according to one embodiment of the present invention, without a wireless capability. **FIG. 3** is an exemplary system block diagram, according to one embodiment of the present invention depicting a wireless capability, either as a separate module connectable to the main module of **FIG. 2**, or integrated with the main module of **FIG. 2**. The wireless capability may be packaged as a expansion module pluggable into the main unit. The wireless capability may be used to transmit video, audio, and/or position data to a remote location and receive data, such as commands from the remote location. For example, the remote location may send a command to the MDRS to start recording and/or to transmit its location data, using a specific identification number for the specific MDRS,

[0067] As shown in **FIG. 2**, images are captured through an integrated lens via the CIF CCD Module **21**. This module coverts light to electronic signals using a CCD. The analog electrical signals from the CCD are digitized by an A to D converter (ADC) located in this component. The output of this module includes pixels of image data at 24 bits/pixel. (8 bits Red, 8 bits Green and 8 bits Blue.) This video stream is made up of a group of "pictures" or frames which are taken at up to 30 times per second. Audio is captured by microphone **2** and digitized by the Audio ADC **22**.

[0068] The output data of the CCD module and the Audio ADC is fed into an encoding device **23**. The encoding device **23** stores each video frame in a SDRAM **25**, and compresses the stream of frames using, for example, the MPEG4 and/or MPEG2 standards. Compressed audio is also multiplexed into the stream at this point. The encoding device does this via software algorithms executed by an internal processor (for example, ARM9 included with the encoding device **23**) and/or hardware acceleration blocks. In addition, the processor reads a GPS device **25** and a real time clock (not shown) and embeds this information in the MPEG stream. The resulting MPEG compressed audio/video stream is stored in the SDRAM **24** as well. The processor is also capable of reading an I/O port (not shown) for received data from a remote location. An LCD driver **6**a provides the video data to be displayed by the LCD **6**.

[0069] The FPGA or ASIC chip **28** manages sensor control, the image path, address generation, the memory chip interface, and also includes other glue logic. This chip's functionality can be upgraded from program FLASH **27**. Real-time video output is available from the Video I/F module **29**.

[0070] The MPEG compressed audio/video stream is then copied to the replaceable memory modules **8**A and **8**B, via a direct memory access (DMA) process. In addition, the compressed audio/video stream can be sent out of the unit through an output interface, for example, a USB interface **26**, again using a DMA process.

[0071] In one embodiment, the cellular capability is provided via an expansion module pluggable to the main unit. In this embodiment, the MPEG stream is received from the main unit via a USB interface **31** (or other interface) by the expansion module, as shown in **FIG. 3**. In this case, a MPEG device **37**, such as, Sanyom MPEG device is used for decoding and returning the video to an integrated SOC controller **32**, and an audio stream encoded by an audio codec **34** to create a lower quality audio/video stream (e.g., sub-sampling) for transmission over the cellular network through a wireless transceiver **33**. For example, a PCMCIA compatible wireless modem may be used to transmit the data. However, other wireless transceivers may be plugged into or be an integral part of the MDRS for transmitting and receiving data.

[0072] The MPEG device **37** and the SOC controller **32** interface through the FPGA **38**. Programming is stored in

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program FLASH **27***a* and can be upgraded as new features become available. Each processor **32** and **37** have their own processing memory areas **24***b* and **24***d* respectively. A text based I/O port is available for status display **36**.

[**0073**] Since the bandwidth of the cellular modem is much lower than the bandwidth which can be stored in the replaceable memory modules **8**A and **8**B, this re-compression step is needed. The quality of the audio/video stored in the main unit is of much higher quality than the stream sent via the cellular network.

[**0074**] Thus, the MDRS of the present invention is capable of simultaneous storing of video on replaceable memory modules and outputting data in real-time for wireless transmission. The MDRS also embeds GPS data in an MPEG stream and converts, in real-time, MPEG format to low bit rate MPEG for wireless transmission.

[**0075**] In one embodiment, a wireless accessory unit, as a standalone wireless tracking unit, is capable of sending a location data stream via a cellular network to a remote location.

[**0076**] In one embodiment, the MDRS is capable of outputting a composite video signal. In one embodiment, the MDRS provides the user with the ability to configure or set the following data: date and time, date format, and audio on/off.

[**0077**] In one embodiment, MPEG4 format is used to facilitate integration of additional features into the MDRS. In this embodiment, the MDRS data includes: audio, video at 15 fps at a minimum of 320×240 pixels, encoded date and time, GPS data encoded on an "overlay" channel in the MPEG4 data stream, compass bearing data encoded on an "overlay" channel in the MPEG4 data stream, and MDRS unit identifier and any user profile information encoded onto an additional "overlay" channel in the MPEG4 data stream.

[**0078**] This gives the MPEG4 Player (playback is preferably PC based) the ability to show these additional graphics as "overlays" onto the video data. Because they are a separate part of the encoded data stream, they do not affect the video quality.

[**0079**] MPEG format allows the data files to be played back on a Windows™ computer. The MDRS is capable of sending the video/audio and other data to a PC via the USB interface **26** and/or via a wireless communication link. MPEG players for Windows™ computers are commercially available. These MPEG players may be used for testing the camera data by ejecting the replaceable memory module and connecting it to a Windows-computer using a memory card reader. The MDRS data file are able to be viewed using several different MPEG players.

[**0080**] In one embodiment, the GPS information is encoded as part of an "overlay" channel in the MPEG-4 data stream. For example, a Motorola™ chip (Same as item **25** in **FIG. 2**), which is a self-contained, single-chip assisted global positioning system (A-GPS) receiver may be used.

[**0081**] In one embodiment, the MDRS is capable of sending live video and audio back to an operations support system. Antenna placement is typically on top, on the opposite side of the camera stalk. MDRS firmware contains preprogrammed callout numbers. Under normal operations, the MDRS may be called by a remote site to initiate transmission of data. In one embodiment, Sandbridge™ SB9600 chipset is used for data transmission. The chip set supports multiple cellular markets by varying the communication protocols on a Software-Defined-Baseband processor chip. This might be accomplished by loading the "A" replaceable memory module with CDMA, GPRS, GSM or 802.11g, and the like programming.

[**0082**] In one embodiment, the MDRS records video and audio in MPEG4 format. This format allows date/time encoding in the data stream. The MDRS provides this Date/Time data to the MPEG4 encoder. When the MDRS is powered "On" the user confirms that all image files will be erased. Once the user has confirmed that all image files can be erased, the MDRS starts recording and creates a new image file in the "A" (top) replaceable memory module. All previous image files on the "A" replaceable memory module are removed and therefore, the entire replaceable memory module is available for recording. When the "A" replaceable memory module is full, the MDRS creates a new image file in the "B" replaceable memory module.

[**0083**] All previous image files on the "B" replaceable memory module are removed and no confirmation of file erasure is required. The entire replaceable memory module is available for recording. When the "B" replaceable memory module is full the MDRS starts recording again on the "A" replaceable memory module and no confirmation of image file erasure is required. The process of switching back and forth between the replaceable memory modules is automatic and is maintained for as long as the camera is "On". More than two replaceable memory module, such as four replaceable memory module, may be used. The "non-active" replaceable memory module may be ejected and replaced at anytime without interrupting the current recording. This provides the MDRS with even a higher storage capacity.

[**0084**] If the MDRS contains only a single replaceable memory module, the MDRS automatically records in the single replaceable memory module. In one embodiment, the MDRS divides the available memory into two image files of equal sections. These sections will represent the "A" and "B" sections as described above. The MDRS alternates between the two image files on the single replaceable memory module. In one embodiment, the single replaceable memory module includes a single image file configured as a circular buffer. The single replaceable memory module is then operated as a circular buffer, in which the video, audio, and other data is being continuously recorded in the single replaceable memory module in a circular manner.

[**0085**] In one embodiment, the image files created on the SD memory card are named according to the following format: YYMMDDHHMI.mp4 (YY=Year, MM=Month, DD=Day, HH=Hour, MI=Minute). The "A" SD memory card may contain a configuration file containing firmware settings required for cellular connection parameters, video server address and port number, operator information, etc. The firmware should save the last configuration data for use, if no configuration file is present.

[**0086**] Preferably, there should not be a gap in video and audio recording while the camera is switching between the replaceable memory modules, or files. Preferably, video history equal to or greater than half of the recording time available to a replaceable memory module capacity is main-

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tained. A memory/data storage change button directs the camera to change recording to the "other" replaceable memory module. This allows the user to eject, replace and save the SD memory card containing video and audio history.

[0087] In one embodiment, a power connector provides DC auxiliary power source for camera operation. When the camera is plugged in to an auxiliary power source the camera operates as normal and recharge the Li-ion battery. The LCD should indicate that the battery is currently being charged.

[0088] A memory/data storage eject sliding latches allow the SD memory cards to be ejected. A battery case open latch keeps the battery cover closed and locked. To remove the battery case, the battery case open latch is pressed and the top of the battery case is rotated away from the camera body.

[0089] A wireless data connection button manually establishes a data connection to transmit video and audio to pre-programmed service (for example Verizon™ 1×RTT Express Network). The MDRS sends a secondary MPEG data stream to designated server. An end wireless data connection button ends the wireless transmission. In one embodiment, an embedded non-telescoping antenna is used for wireless transmission/reception of data.

[0090] In one embodiment, finger print sensor technology is overlaid on top of the display screen to provide a mechanism for fingerprints to be captured and transmitted in real-time to a remote facility for evaluation. In one embodiment, the MDRS includes facial scanning/identity software to provide real-time crowd scanning and facial profile transmission back to a remote facility for identity processing.

[0091] In one embodiment, in addition to one or more USB interface, the MDRS includes PCcard interface to use existing wireless PCcard technologies in the USA and internationally. These cards currently support Cellular data, IEEE 802.11 Communication Standards, Bluetooth, etc. An Internet interface for connecting to, browsing, and downloading data from the Internet may also be provided with the MDRS.

[0092] **FIG. 4A** illustrates an exemplary wireless adaptor for a mobile digital recording system, according to one embodiment of the present invention. The adaptor fits onto the main MDRS like a sleeve, by sliding the main MDRS unit into the adaptor from the top down. This wireless adaptor contains a battery **41**, and a slot **42**, into which a wireless card is fitted. The wireless adaptor provides the MDRS unit with an integrated solution for broadcasting live audio and video from a remote location. The wireless card slot utilizes existing wireless technologies, like PCcard cellular modems and 802.11 cards, to transmit video and audio as a data stream to a remote monitoring facility.

[0093] **FIG. 4B** shows a mobile digital recording system next to a wireless adaptor and the general alignment of the two units, according to one embodiment of the present invention. In this embodiment, the MDRS includes a flexible support **43** for the camera head (not shown), an LCD screen **44**, a memory/data storage change button **45**, an LCD On/Off button **46**, a memory/data storage eject **47**, a MDRS unit body **48**, removable memory card slots **49**, and a wireless adaptor body **50**.

[0094] **FIG. 4C** is an exemplary charging base for a mobile digital recording system, according to one embodiment of the present invention. This Charging base supplies continuous power to an MDRS unit for operations and recharging. This Charging base is designed for easy mounting. Power is provided through a power cable **51**.

[0095] It will be recognized by those skilled in the art that various modifications may be made to the illustrated and other embodiments of the invention described above, without departing from the broad inventive scope thereof. It will be understood therefore that the invention is not limited to the particular embodiments or arrangements disclosed, but is rather intended to cover any changes, adaptations or modifications which are within the scope of the invention as defined by the appended claims.

What is claimed is:

1. A mobile recording device comprising:

a flexible camera head for capturing video stream data in real time;

a microphone for capturing audio data in real time;

a position determining module for capturing position data for the mobile recording device; and

a first and a second replaceable memory modules for storing the video stream data and the audio data, wherein the first replaceable memory module can be replaced when the second replaceable memory module is being used to store the video and audio data and the second replaceable memory module can be replaced when the first replaceable memory module is being used to store the video and audio data.

2. The mobile recording device of claim 1 further comprising a wireless transceiver for wirelessly transmitting the video, the audio, and the position data to a remote location and receiving data from the remote location.

3. The mobile recording device of claim 2 wherein the wireless transceiver receives a command from the remote location to start transmitting data.

4. The mobile recording device of claim 1 further comprising a compass for indicating a direction the camera head is pointing to.

5. The mobile recording device of claim 1 wherein the flexible camera head is configured to swivel.

6. The mobile recording device of claim 1 wherein the flexible camera head is configured to include user replaceable lenses.

7. The mobile recording device of claim 1 further comprising a LCD for displaying data.

8. The mobile recording device of claim 1 further comprising input keys for entering text data to be overlayed on the video stream data.

9. The mobile recording device of claim 1 further comprising a button for establishing wireless connection with a pre-programmed remote location for transmitting the video, audio and location data.

10. The mobile recording device of claim 1 further comprising a finger print sensor for capturing and transmitting finger print data in real time.

11. The mobile recording device of claim 1 further comprising a facial scanning module for capturing and transmitting facial profiles in real time.

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12. A mobile recording device comprising:

a flexible camera head for capturing video stream data in real time;

a microphone for capturing audio data in real time;

a circular buffer for continuously storing the video stream data and the audio data; and

a wireless transceiver for transmitting the video and audio data in real time to a remote location.

13. The mobile recording device of claim 12 wherein the wireless transceiver receives a command from the remote location to start transmitting data.

14. The mobile recording device of claim 12 further comprising a compass for indicating a direction the camera head is pointing to.

15. The mobile recording device of claim 12 wherein the wireless transceiver receives a command from the remote location to start recording data.

16. The mobile recording device of claim 12 further comprising a position determining module for capturing position data for the mobile recording device

17. The mobile recording device of claim 12 further comprising a finger print sensor for capturing and transmitting finger print data in real time.

18. The mobile recording device of claim 12 further comprising a facial scanning module for capturing and transmitting facial profiles in real time.

19. A mobile recording device comprising:

a flexible camera head for capturing video stream data in real time;

a microphone for capturing audio data in real time;

a finger print sensor for capturing finger print data in real time; and

a wireless transceiver for transmitting the video, audio, and finger print data in real time to a remote location and for receiving commands from the remote location.

20. The mobile recording device of claim 19 further comprising a circular buffer for continuously storing the video stream data and the audio data.

* * * * *

Appendix V

US006995668B2

(12) **United States Patent**
Junqua

(10) **Patent No.: US 6,995,668 B2**
(45) **Date of Patent: Feb. 7, 2006**

(54) **DISTRIBUTED APPARATUS TO IMPROVE SAFETY AND COMMUNICATION FOR SECURITY APPLICATIONS**

(75) Inventor: **Jean-Claude Junqua**, Santa Barbara, CA (US)

(73) Assignee: **Matsushita Electric Industrial Co.,Ltd.**, Osaka (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/886,498**

(22) Filed: **Jul. 7, 2004**

(65) **Prior Publication Data**

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Related U.S. Application Data

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(51) **Int. Cl.**
G08B 1/08 (2006.01)

(52) **U.S. Cl.** **340/539.13**; 340/539.12; 340/5.82; 340/5.83; 340/573.1; 380/23; 380/25; 348/142; 348/143; 235/380; 235/382

(58) **Field of Classification Search** 340/539.13, 340/539.12, 5.82, 5.83, 573.1; 380/23, 25; 235/380, 382; 348/142, 143

See application file for complete search history.

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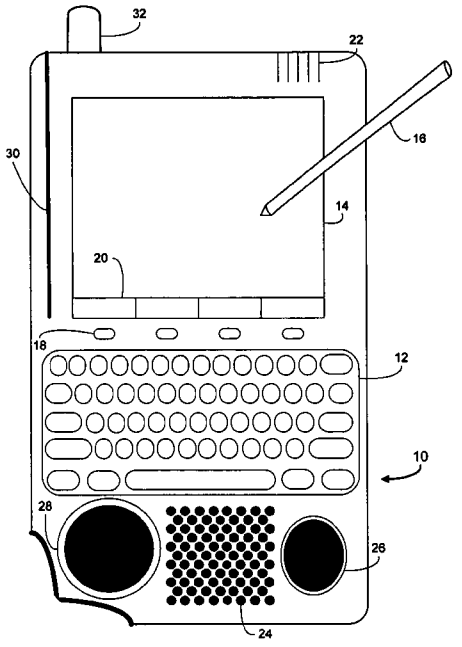
* cited by examiner

Primary Examiner—Daniel Wu
Assistant Examiner—Tai T. Nguyen
(74) *Attorney, Agent, or Firm*—Harness, Dickey & Pierce, PLC

(57) **ABSTRACT**

A wearable, computerized apparatus for use with law enforcement has an evidence collector adapted to collect evidentiary information of a type collected according to law enforcement procedures and useful for identification of a suspect. It further has a safety monitor adapted to collect safety information relating to well-being of an officer. A wireless communications link communicates the evidentiary information and the safety information to a centralized component of a distributed communications system to assist in identifying suspects and dispatching assistance.

21 Claims, 5 Drawing Sheets



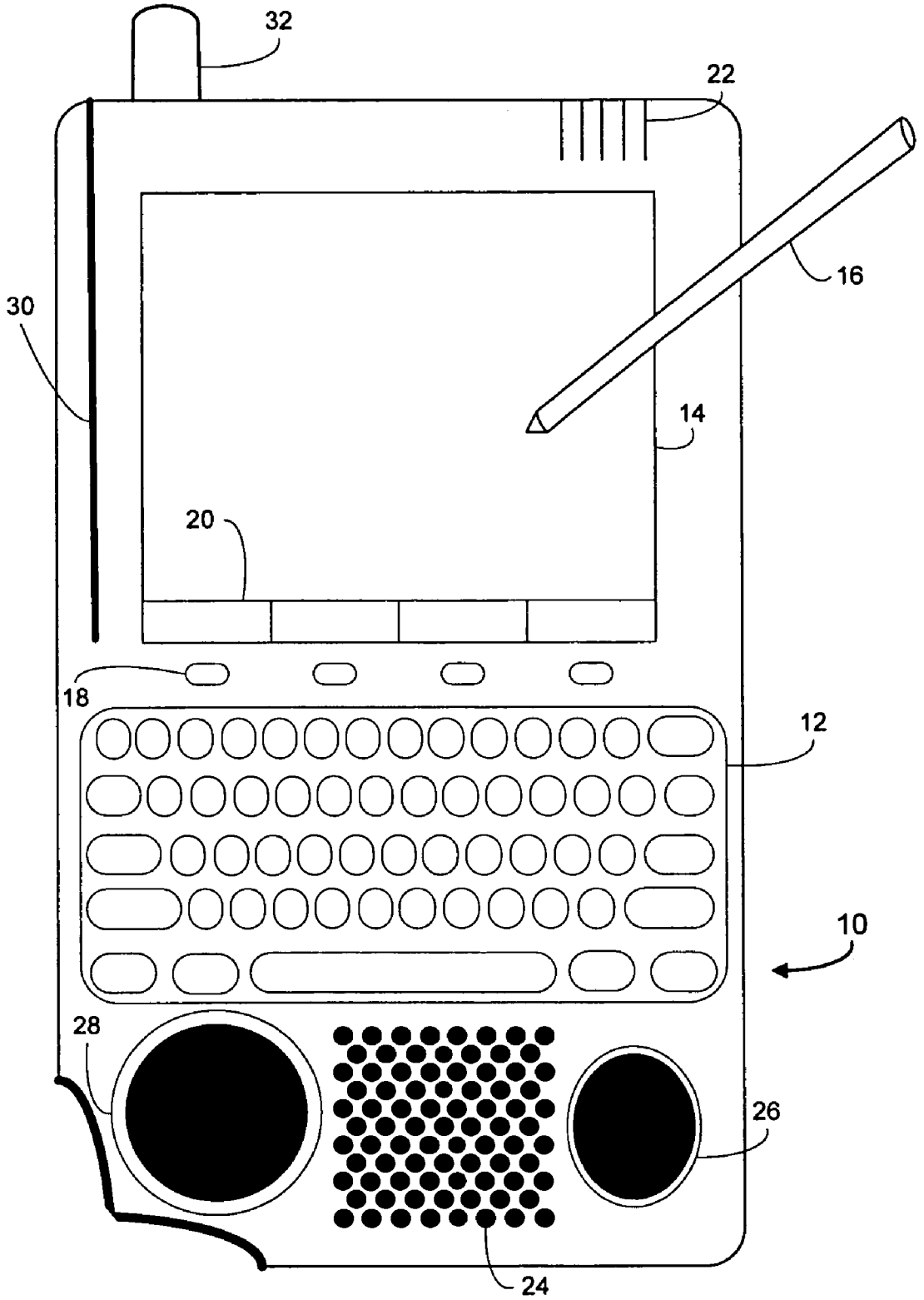


FIG. 1

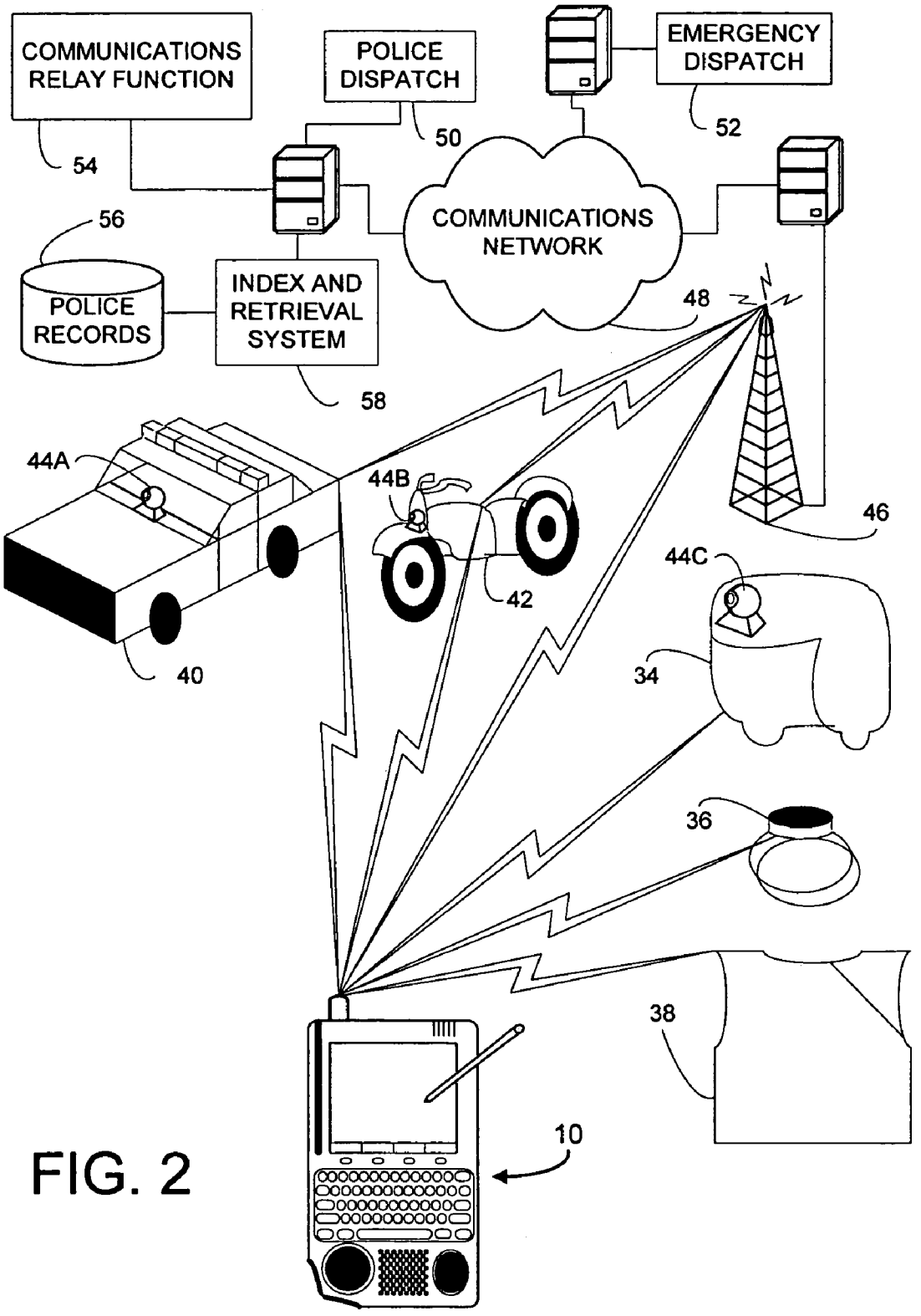

COMMUNICATIONS RELAY FUNCTION
54
POLICE DISPATCH
50
EMERGENCY DISPATCH
52
COMMUNICATIONS NETWORK
48
56
POLICE RECORDS
INDEX AND RETRIEVAL SYSTEM
58
44A
44B
42
40
46
44C
34
36
38
10

FIG. 2

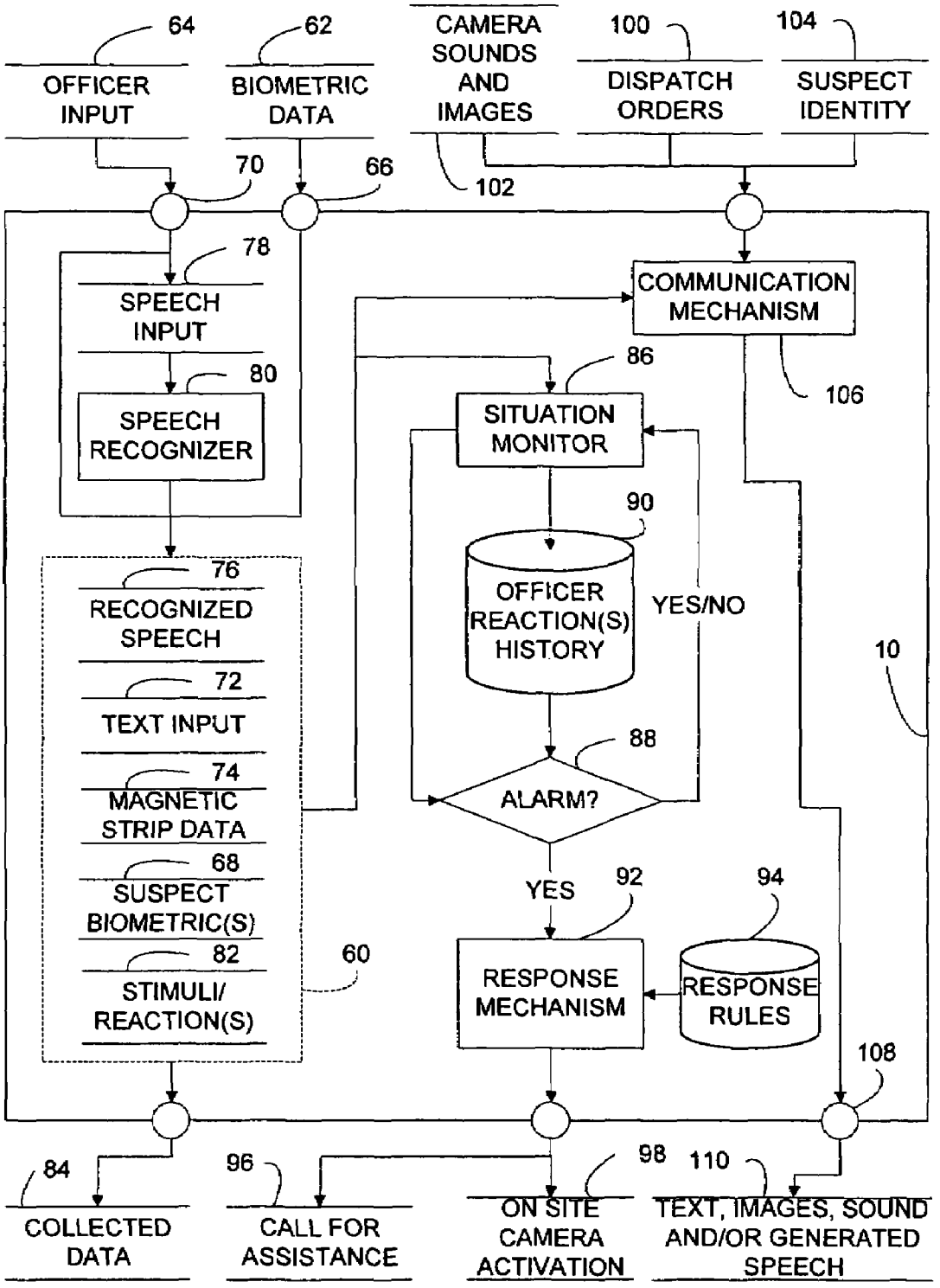

64
OFFICER INPUT
62
BIOMETRIC DATA
CAMERA SOUNDS AND IMAGES
100
DISPATCH ORDERS
104
SUSPECT IDENTITY
70
66
102
78
SPEECH INPUT
80
SPEECH RECOGNIZER
COMMUNICATION MECHANISM
86
106
SITUATION MONITOR
90
OFFICER REACTION(S) HISTORY
YES/NO
10
76
RECOGNIZED SPEECH
72
TEXT INPUT
74
MAGNETIC STRIP DATA
68
SUSPECT BIOMETRIC(S)
82
STIMULI/ REACTION(S)
60
88
ALARM?
YES
92
94
RESPONSE MECHANISM
RESPONSE RULES
108
84
96
98
110
COLLECTED DATA
CALL FOR ASSISTANCE
ON SITE CAMERA ACTIVATION
TEXT, IMAGES, SOUND AND/OR GENERATED SPEECH

FIG. 3

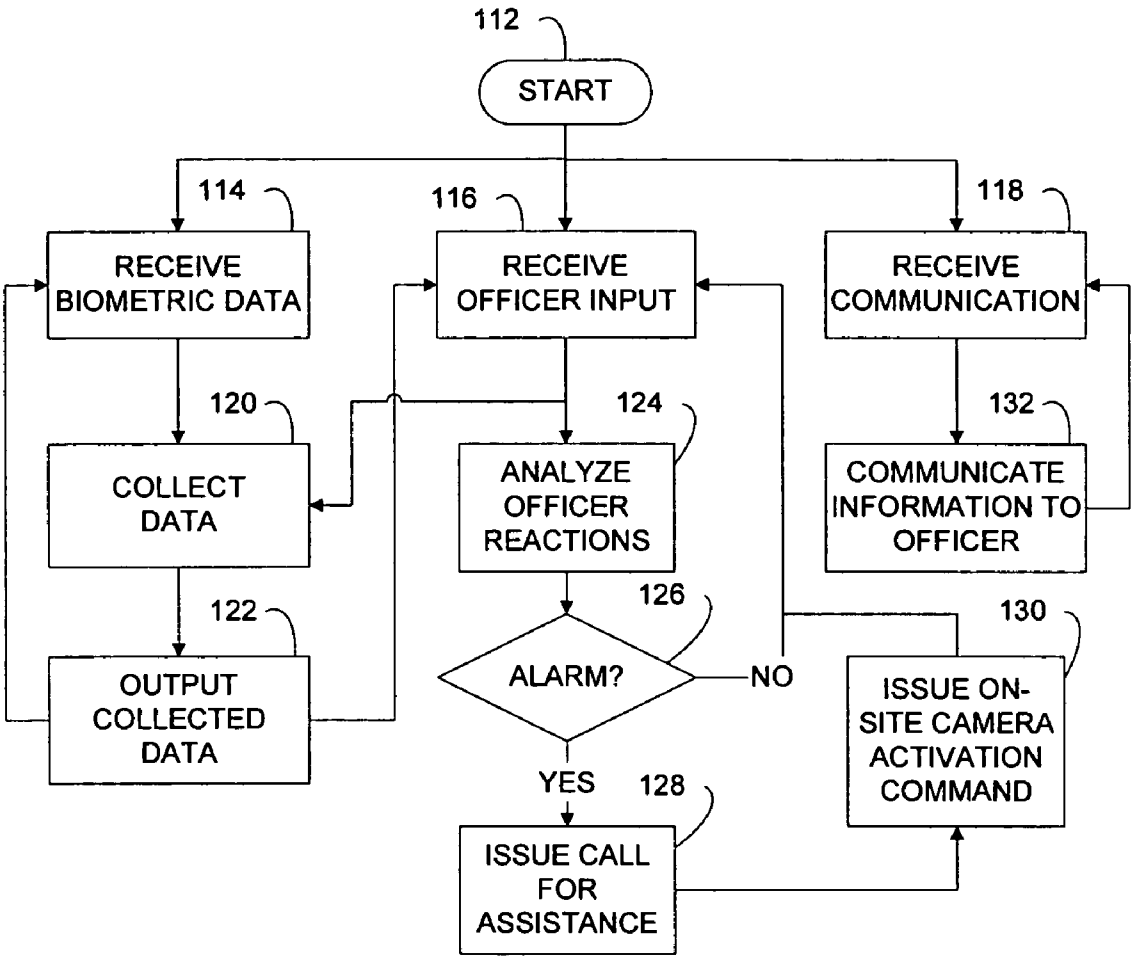

112
START
114
RECEIVE BIOMETRIC DATA
116
RECEIVE OFFICER INPUT
118
RECEIVE COMMUNICATION
120
COLLECT DATA
124
ANALYZE OFFICER REACTIONS
132
COMMUNICATE INFORMATION TO OFFICER
122
OUTPUT COLLECTED DATA
126
ALARM?
NO
130
ISSUE ON-SITE CAMERA ACTIVATION COMMAND
YES
128
ISSUE CALL FOR ASSISTANCE

FIG. 4

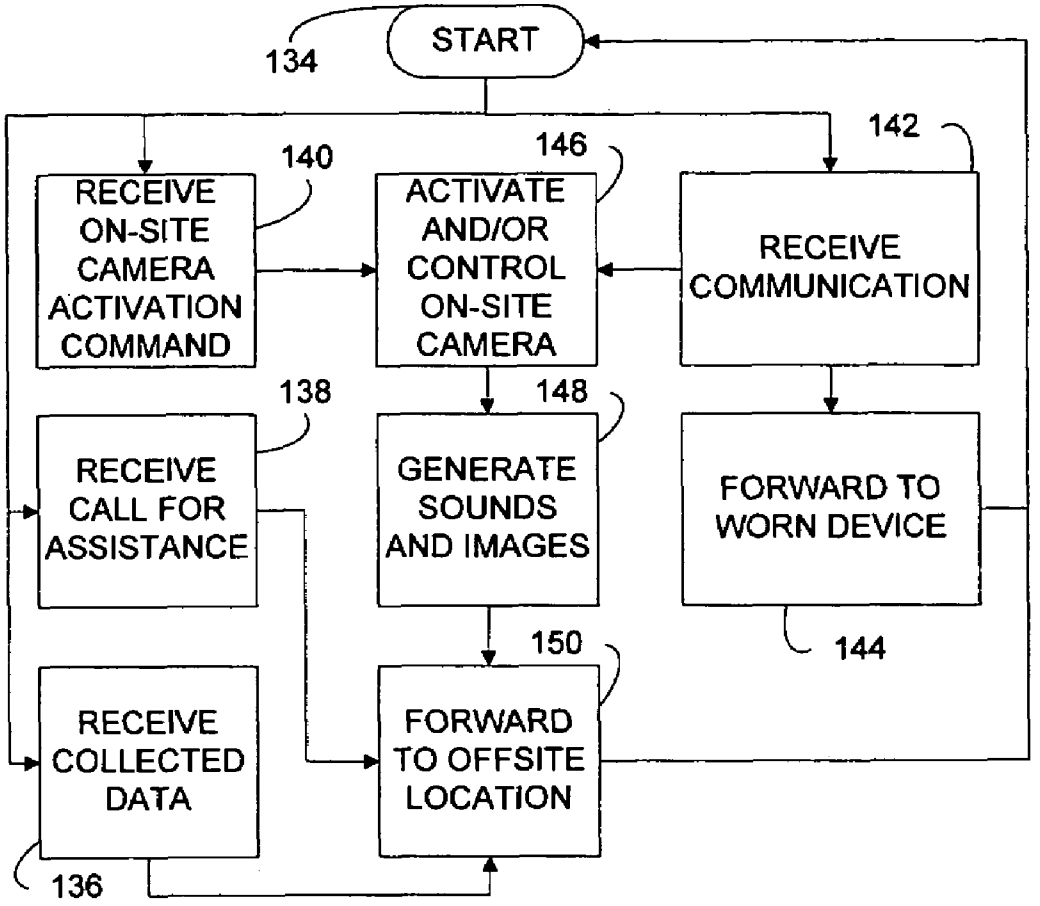

START
134
142
140
146
RECEIVE ON-SITE CAMERA ACTIVATION COMMAND
ACTIVATE AND/OR CONTROL ON-SITE CAMERA
RECEIVE COMMUNICATION
138
148
RECEIVE CALL FOR ASSISTANCE
GENERATE SOUNDS AND IMAGES
FORWARD TO WORN DEVICE
144
150
RECEIVE COLLECTED DATA
FORWARD TO OFFSITE LOCATION
136

FIG. 5

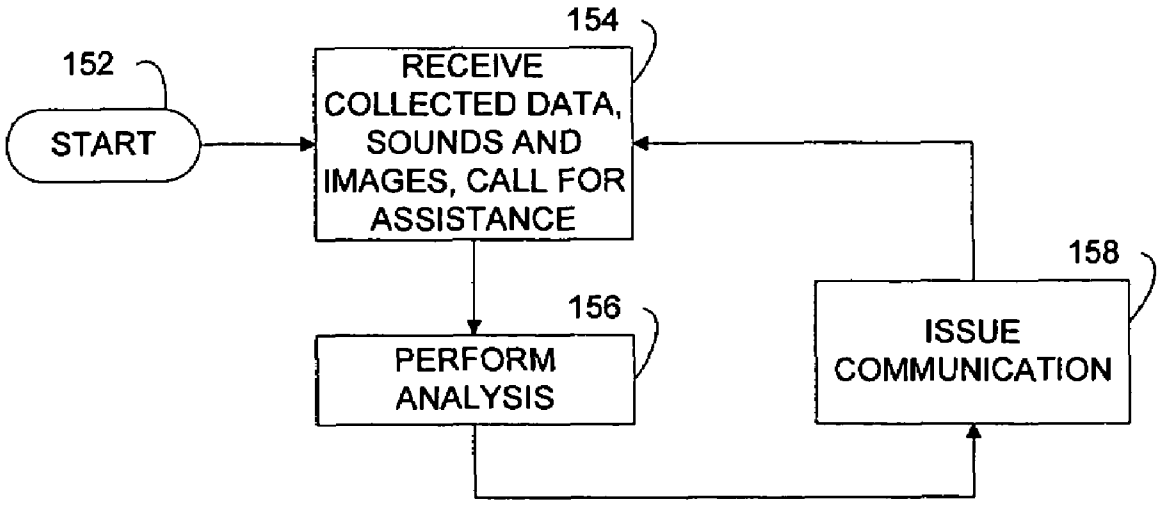

152
START
154
RECEIVE COLLECTED DATA, SOUNDS AND IMAGES, CALL FOR ASSISTANCE
156
PERFORM ANALYSIS
158
ISSUE COMMUNICATION

FIG. 6

DISTRIBUTED APPARATUS TO IMPROVE SAFETY AND COMMUNICATION FOR SECURITY APPLICATIONS

FIELD OF THE INVENTION

The present invention generally relates to distributed computer systems for law enforcement applications, and particularly relates to distributed communications systems for law enforcement implementing a wearable, computerized component.

BACKGROUND OF THE INVENTION

Today, laptops are becoming very common in police cars. There exist, however, many safety issues related to operation of these laptops because police officers have to take their eyes off the road or away from an arrested suspect to operate the laptop computer. Furthermore, the computer still has limited communication capabilities, with a central server that is generally only able to respond to requests typed by an officer using a keyboard. Thus, officers are generally limited to typing in driver's license and license plate numbers in the field. These limitations make it difficult for an officer to attempt to identify a suspect or provide information to a centralized, dispatch facility at times when it is most needed.

What is needed is a device that an officer can take into the field and use to safely collect information on-site, communicate the information off-site to a centralized, dispatch facility, and communicate information from the off-site facility to the officer. The present invention provides such a device in concert with a distributed communications system.

SUMMARY OF THE INVENTION

According to the present invention, a wearable, computerized apparatus for use with law enforcement has an evidence collector adapted to collect evidentiary information of a type collected according to law enforcement procedures and useful for identification of a suspect. It further has a safety monitor adapted to collect safety information relating to well-being of an officer. A wireless communications link communicates the evidentiary information and the safety information to a centralized component of a distributed communications system to assist in identifying suspects and dispatching assistance.

The distributed communication system according to the present invention is advantageous over previous distributed computer systems for law enforcement applications in that the wearable, computerized component assists an officer in collecting and communicating important information quickly and conveniently, and with increased safety. A vehicular component having an on-site camera can receive data from the wearable, computerized component via a wireless connection, automatically activate the camera at times of stress and/or distress, and forward collected information off-site to a centralized, dispatch facility via a wireless connection. The centralized, dispatch facility can, in turn, dispatch any needed assistance based on the type of situation and the camera images. It can further process biometric data of suspects to assist in identifying suspects, and determine if any warrants are issued with respect to an identified suspect. The camera images, suspect identification, and information relating to the suspect can be forwarded to vehicles of other officers and to the vehicle of the officer in question. Received communications may be wirelessly communicated to the wearable, computerized component and, thus, to the officer. The wearable computerized component preferably makes use of speech recognition and speech generation technologies to allow hands-free operation of the device wherever possible. Further areas of applicability of the present invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating the preferred embodiment of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

FIG. **1** is a block diagram providing a perspective view of a wearable, computerized component of a distributed computer system for law enforcement applications according to the present invention;

FIG. **2** is a partial perspective view and block diagram depicting various components of the distributed computer system according to the present invention;

FIG. **3** is a schematic block diagram of a wearable, computerized component of a distributed communication system according to the present invention;

FIG. **4** is a flow chart depicting a method of operation for a wearable, computerized component of a distributed communication system according to the present invention;

FIG. **5** is a flow chart depicting a method of operation for an on-site, vehicular component of a distributed communication system according to the present invention; and

FIG. **6** is a flow chart depicting a method of operation for an off-site, centralized component of a distributed communication system according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention is described below with reference to a distributed architecture employing a wearable, computerized component, an on-site, vehicular component, and an off-site, centralized component. The following description of the preferred embodiment, however, is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses.

The wearable, computerized apparatus **10** according to the present invention is illustrated in FIG. **1**. It is generally modeled on a personal digital assistant (PDA) having a small keyboard **12**, touch screen **14**, and stylus **16**. A plurality of hot keys **18** provide easy access to pre-programmed functions **20**, such as license plate number voice input, driver's license number scanning, retinal scanning, fingerprint sensing, on-site camera activation, and/or calling for assistance. These functions **20** are also preferably selectable by voice using speech recognition technology. Thus, apparatus **10** has a microphone input **22**, and also a speaker output **24** to permit communication of sound, including generated speech. Additionally, a fingerprint sensor **26** and retinal scanner **28** are provided for collecting biometric data from a suspect, as well as a smart card reader **30** for reading a magnetic strip on a driver's license. Also, a two-way, wireless link **32** is capable of transmitting and receiving data in at least one of many possible ways. The distributed communications system of FIG. **2** demonstrates many of the ways apparatus **10** can communicate with other components of the system. For example, apparatus **10** can use a short

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range wireless link, such as Bluetooth, to communicate with sensors disposed in various accoutrements of the officer, such as a helmet **34**, wristwatch **36**, and bullet-proof vest **38**. These sensors, in turn, can sense and communicate data relating to stimuli affecting the officer and officer reactions to stimuli. Thus, a sensed impact to the bullet proof vest and/or external temperature, can be communicated as stimuli to the apparatus. Similarly, sensed heart rate, respiratory rate, body temperature, blood pressure, perspiration, and/or blood loss can be communicated as officer reactions to apparatus **10**.

Another way that apparatus **10** can communicate with other components of the system is by using a mid-range wireless link, such as radio wave. This mid-range wireless link can be used to communicate with a vehicular component of the system, such as a police car **40** or motorcycle **42**. Thus, suspect biometric data, sensed officer reactions, stimuli, scanned input, text input, voice input and/or sounds and images from various on-site cameras **44**A–C can be communicated to and from various on-site components of the distributed communications system.

Still another way that apparatus **10** can communicate with other components of the system is by using a long-range communication link, such as shortwave radio and/or cell phone technology, to communicate off-site via a communications tower **46** and adjacent network **48**. Additionally, a vehicular component of the system can use a long range wireless link to forward any communications between an off-site, centralized component of the system and apparatus **10**. It should be readily apparent that several combinatorial options are available according to this same communications architecture, including long-range communication capability being provided by various officer accoutrements.

Off-site centralized components of the system can use these same available communications mechanisms to communicate with apparatus **10**. for example, a dispatch order from a police dispatch function **50** and/or an emergency dispatch function **52** can be communicated to apparatus **10**. Also, suspect biometric data, sensed officer reactions, stimuli, scanned input, text input, voice input and/or sounds and images from various on-site cameras **44**A–C can be communicated from one on-site location to another on-site location via communications relay function **54**. Further, an identification of a suspect and/or information relating to an identified suspect, such as issued warrants, resulting from use of police record database **56** and index and retrieval system **58** can be communicated to apparatus **10**. This distributed communications architecture is important to functionality of apparatus **10** as further explored in FIG. **3**, and to other components of the system.

In operation, apparatus **10** is able to collect information **60** based on biometric data **62** and officer input **64**. The biometric data **62** is input using one or more biometric sensors **66**, such as a retinal scanner and/or fingerprint sensor, and includes suspect biometrics **68**. The officer input **64** is received by one or more interface devices **70**, such as a keyboard, touch screen with stylus, microphone, smart card reader, and short-range data link with associated sensors. Thus, the officer input **64** may include text input **72**, data embodied in a magnetic strip **74**, recognized speech **76** from a speech input **78** processed via a speech recognizer **80**, and/or sensed stimuli and/or reactions **82**. Suspect biometrics **68**, text input **72**, data embodied in a magnetic strip **74**, recognized speech **76**, and sensed stimuli and/or reactions **82**, thus, are exemplary types of collected information **60** that can be output as collected data **84** for delivery off-site.

Various components of collected information **60** are further useful in connection with operation of apparatus **10**. For example, recognized speech **76**, text input **72**, and sensed stimuli and/or reactions **82** may be communicated to situation monitor **86**. In turn, situation monitor **86** may determine cause for alarm as at **88** based on recognized speech **76**, a hot key activation component of text input **72**, and/or sensed stimuli of sensed stimuli and/or reactions **82**. Further, situation monitor **86** may determine cause for alarm as at **88** based on sensed stimuli and/or reactions **82** based on an adaptive threshold mechanism using an officer reactions history **90**. Thus, a sudden increase in heart rate, respiration, and/or perspiration may be interpreted as cause for alarm at **88**. Similarly, detection of blood, a drop in blood pressure and/or absence of heart rate and/or respiration may be interpreted as cause for alarm at **88**. Accordingly, response mechanism **92** issues an alarm based on predetermined response rules **94**, thus resulting in output of call for assistance **96** and/or a command for on-site camera activation **98**.

Yet further to the operation of apparatus **10**, received communications from off-site, such as dispatch orders **100**, camera sounds and images **102** from another on-site location, and/or suspect identity **104** with relevant information, are processed by a communication mechanism **106**. Communication mechanism **106** displays camera images and suspect identity **104** and relevant information via a touch screen of interface **108**, while generating speech to communicate important portions of relevant information. Camera sounds, dispatch orders, and generated speech are communicated to the officer via a speaker output of interface **108**. Recognized speech **76** and/or text input **72** are also communicated to communication mechanism **106** as needed to permit the officer to carry on a dialogue with apparatus **10**. Thus, the officer can prompt the device for specific types of information, and/or express preferences relating to how the communications are presented. As a result, text, images sound, and/or generated speech **110** are communicated to the officer in a facilitated fashion.

A method of operation for a wearable, computerized component of a distributed communications system according to the present invention is illustrated in FIG. **4**. Beginning at **112**, biometric data, officer input, and communications from off-site are received respectively at steps **114**, **116**, and **118**. Received suspect biometrics and officer input are collected as data at step **120**, and the collected data is output at step **122** in accordance with transmission and routing protocols selected by voice input and/or hot key activation, and in accordance with selectable pre-programmed functions. Officer reactions, such as sensed vital signs, are analyzed at step **124**, and if the reactions warrant an alarm or if officer input indicates an alarm state as at **126**, then a call for assistance is issued at step **128** concurrent with an on-site camera activation command at step **130**. Received communications are communicated to the officer at step **132**.

The method of operation for the wearable, computerized component of the present invention is designed to operate in concert with methods of operation for an on-site, vehicular component and an off-site centralized component. These methods are illustrated respectively in FIGS. **5** and **6**. Beginning at **134**, the method of operation for an on-site, vehicular component according to the present invention accommodates reception of collected data, a call for assistance, and/or an on-site camera activation command from the wearable, computerized component at steps **136**, **138**, and **140**, respectively. The method further accommodates

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reception of communications from an off-site, centralized component at step **142**. The communications received at step **142** are typically forwarded to the worn device at step **144**. One example exception involves camera control signals affecting control of an on-site camera, which are communicated to the on-site camera. Concurrently, the on-site camera activation and/or control command received at step **140** prompts activation and/or control of an on-site camera at step **146**, such that sounds and images generated at step **148** are forwarded to the off-site, centralized component at step **150**. In one embodiment, the camera may sense a position of the signal source from the device, and automatically track the position in absence of specific control-signals from the centralized component of the system and/or the wearable, computerized component of the system. Further, the collected data and/or call for assistance respectively received in steps **136** and **138** are concurrently forwarded to the off-site, centralized component at step **150**.

The method of operation for an off-site, centralized component according to the present invention begins at **152**, and accommodates reception of collected data, sounds and images, and/or a call for assistance at step **154**. An analysis of the information received in step **154** takes place in step **156**, and any appropriate action may concurrently be taken based on the analysis. For example, a human dispatcher may receive the call for assistance, collected data corresponding to officer vital signs, and on-site camera sounds and images. The human dispatcher may issue camera control signals in step **158** to gain better images and/or sounds, and select to dispatch appropriate assistance and forward on-site camera sounds and images to assisting officers and/or medical personnel in step **158**. Alternatively or in addition, a suspect name, received biometric data, license plate information, and/or a driver's license number can be automatically processed to identify a suspect and obtain relevant information, such as issued warrants, vehicle ownership, insurance information, and/or arrest records. This automatically retrieved information can be forwarded to the on-site officer and/or to assisting personnel at step **158**.

It should be readily understood that the communications architecture can be modified from the form presented herein without departing from the spirit and scope of the present invention. For example, a wearable device according to the present invention may be able to communicate directly with a-police station, without requiring a vehicle component or a communications network. Also, wearable computerized components at different on-site locations may be able to communicate directly with one another. It should also be readily understood that functions performed by a particular component of the present invention can be shifted from one component to another without departing from the spirit and scope of the present invention. For example, the situation monitor function may be allocated to the on-site vehicle component or the off-site, centralized component. Further, a backup safety monitoring mechanism may be employed that expects to continuously or periodically receive a signal from the wearable, computerized device, and issues an alarm if the signal is not received as expected. Still further, the microphone and speakers for the wearable device do not have to be on the wearable device, but can be placed on the police officer (headset microphone and headphones) and connected to the wearable device. Thus, the systems and methods of the present invention may take various forms other than those of the preferred embodiment without departing from the spirit and scope of the present invention. Moreover, the description of the invention is merely exemplary in nature and, thus, variations that do not depart from the gist of the invention are intended to be within the scope of the invention.

What is claimed is:

1. A distributed communications system for use with security applications, comprising:

a plurality of wearable, computerized components adapted to collect evidentiary information according to security procedures and useful for identification of suspects, and adapted to wirelessly send the evidentiary information;

a centralized component wirelessly receiving the evidentiary information, wherein said centralized component is adapted to process the evidentiary information to identify suspects; and

a plurality of imaging devices positioned to capture visual information in regions proximate to security personnel possessing said wearable, computerized components, said plurality of imaging devices operable to wirelessly send captured visual information to said centralized component, said centralized component being operable to dispatch assistance to an endangered officer and communicate visual information captured in proximity to the endangered officer to assisting personnel dispatched as part of the assistance, wherein said centralized component communicates the captured visual information to the assisting personnel via one or more of said wearable, computerized components possessed by the assisting personnel.

2. The system of claim **1**, comprising a plurality of vehicular components wirelessly receiving the evidentiary information from the wearable, computerized components and wirelessly relaying the evidentiary information to the centralized component.

3. The system of claim **1**, wherein said centralized component is adapted to wirelessly communicate suspect identifications and information relevant to the suspect identifications to the officers via the wearable computerized components.

4. The system of claim **1**, wherein said evidentiary information corresponds to biometric data relating to a suspect, including at least one of:

(a) a fingerprint;

(b) a retinal pattern;

(c) an iris image;

(d) facial characteristics;

(e) DNA; or

(f) a voice pattern.

5. The system of claim **1**, wherein said plurality of wearable, computerized components is further adapted to collect safety information relating to well-being of officers, and further adapted to wirelessly send the safety information, wherein said centralized component further wirelessly receives the safety information, wherein said centralized component is further adapted to dispatch assistance based on the safety information.

6. The system of claim **5**, said plurality of imaging devices adapted to receive the safety information from the wearable, computerized components, and adapted to automatically commence operation when the safety information indicates a state of emergency, thereby wirelessly communicating visual information to said centralized component.

7. The system of claim **5**, comprising a plurality of sensors attached to the officers and sending safety information to the

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wearable, computerized devices, wherein said sensors are adapted to sense officer reactions to stimuli, including at least one of:

(a) heart rate;

(b) respiratory rate;

(c) body temperature;

(d) blood pressure; or

(e) perspiration.

8. The system of claim **5**, comprising a plurality of sensors attached to the officers and sending safety information to the wearable, computerized devices, wherein said sensors are adapted to sense stimuli affecting the officers, including at least one of:

(a) a force impacting the officers; or

(b) environmental conditions.

9. A distributed communications system for use with security applications, comprising:

a plurality of wearable, computerized components adapted to collect safety information relating to well-being of officers, and adapted to wirelessly send the safety information;

a centralized component wirelessly receiving the safety information, wherein said centralized component is further adapted to dispatch assistance based on the safety information;

a plurality of imaging devices positioned to capture visual information in regions proximate to the officers, said plurality of imaging devices operable to wirelessly send captured visual information to said centralized component, said centralized component being operable to communicate visual information captured in proximity to an endangered officer to assisting personnel dispatched as part of the assistance, wherein said centralized component communicates the captured visual information to the assisting personnel via one or more of said wearable, computerized components possessed by the assisting personnel.

10. The system of claim **9**, further comprising a plurality of vehicular components wirelessly receiving the safety information from the wearable, computerized components and wirelessly relaying the safety information to the centralized component.

11. The system of claim **9**, said plurality of imaging devices adapted to receive the safety information from the wearable, computerized components, and adapted to automatically commence operation when the safety information indicates a state of emergency, thereby wirelessly communicating visual information to said centralized component.

12. The system claim **11**, wherein said centralized component is adapted to receive the captured visual information, and to dispatch assistance based on the captured visual information.

13. The system of claim **12**, wherein said centralized component is operable to communicate the captured visual information to assisting personnel dispatched as part of the assistance, wherein said centralized component communicates the captured visual information to the assisting personnel via one or more of said wearable, computerized components possessed by the assisting personnel.

14. The system of claim **9**, comprising a plurality of sensors attached to the officers and sending safety information to the wearable, computerized devices, wherein said sensors are adapted to sense officer reactions to stimuli, including at least one of:

(a) heart rate;

(b) respiratory rate;

(c) body temperature;

(d) blood pressure; or

(e) perspiration.

15. The system of claim **9**, comprising a plurality of sensors attached to the officers and sending safety information to the wearable, computerized devices, wherein said sensors are adapted to sense stimuli affecting the officers, including at least one of:

(a) a force impacting the officers; or

(b) environmental conditions.

16. The system of claim **9**, wherein said plurality of wearable, computerized components is further adapted to collect evidentiary information of a type collected according to security procedures and useful for identification of suspects, and further adapted to wirelessly send the evidentiary information, wherein said centralized component is further adapted to process the evidentiary information to identify suspects.

17. The system of claim **16**, wherein said centralized component is adapted to wirelessly communicate suspect identifications and information relevant to the suspect identifications to the officers via the wearable computerized components.

18. The system of claim **16**, wherein said evidentiary information corresponds to biometric data relating to a suspect, including at least one of:

(a) a fingerprint;

(b) a retinal pattern;

(c) an iris image;

(d) facial characteristics;

(e) DNA; or

(f) a voice pattern.

19. The system of claim **9**, comprising a plurality of imaging devices positioned to capture visual information in regions proximate to the officers, said imaging devices responsive to wireless manipulation via at least one of said plurality of wearable, computerized components, and said centralized component, said plurality of imaging devices operable to wirelessly send captured visual information.

20. The system of claim **1**, further comprising a safety monitor adapted to collect safety information relating to well-being of an officer, wherein said safety monitor has an officer reaction monitor module receptive of sensed officer reactions to situational stimuli, wherein said officer reaction monitor module is adapted to generate an alarm when the officer reactions deviate from a safe zone that is adaptively computed based on a continuously maintained officer reactions history.

21. The system of claim **9**, further comprising a safety monitor adapted to collect safety information relating to well-being of an officer, wherein said safety monitor has an officer reaction monitor module receptive of sensed officer reactions to situational stimuli, wherein said officer reaction monitor module is adapted to generate an alarm when the officer reactions deviate from a safe zone that is adaptively computed based on a continuously maintained officer reactions history.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

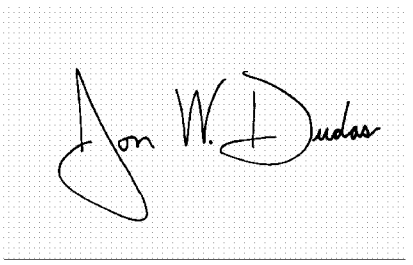
PATENT NO. : 6,995,668 B2
APPLICATION NO. : 10/886498
DATED : February 7, 2006
INVENTOR(S) : Jean-Claude Junqua

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 7,
Line 25, after "information" insert -- and --.
Line 49, after "system" insert -- of --.

Signed and Sealed this

Twenty-seventh Day of June, 2006



JON W. DUDAS
Director of the United States Patent and Trademark Office

Appendix W

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(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2001/0005217 A1

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(54) INCIDENT RECORDING INFORMATION TRANSFER DEVICE

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(21) Appl. No.: **09/758,645**

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Related U.S. Application Data

(63) Continuation-in-part of application No. 09/088,267, filed on Jun. 1, 1998. Continuation-in-part of application No. 09/327,828, filed on Jun. 8, 1999, now Pat. No. 6,211,907.

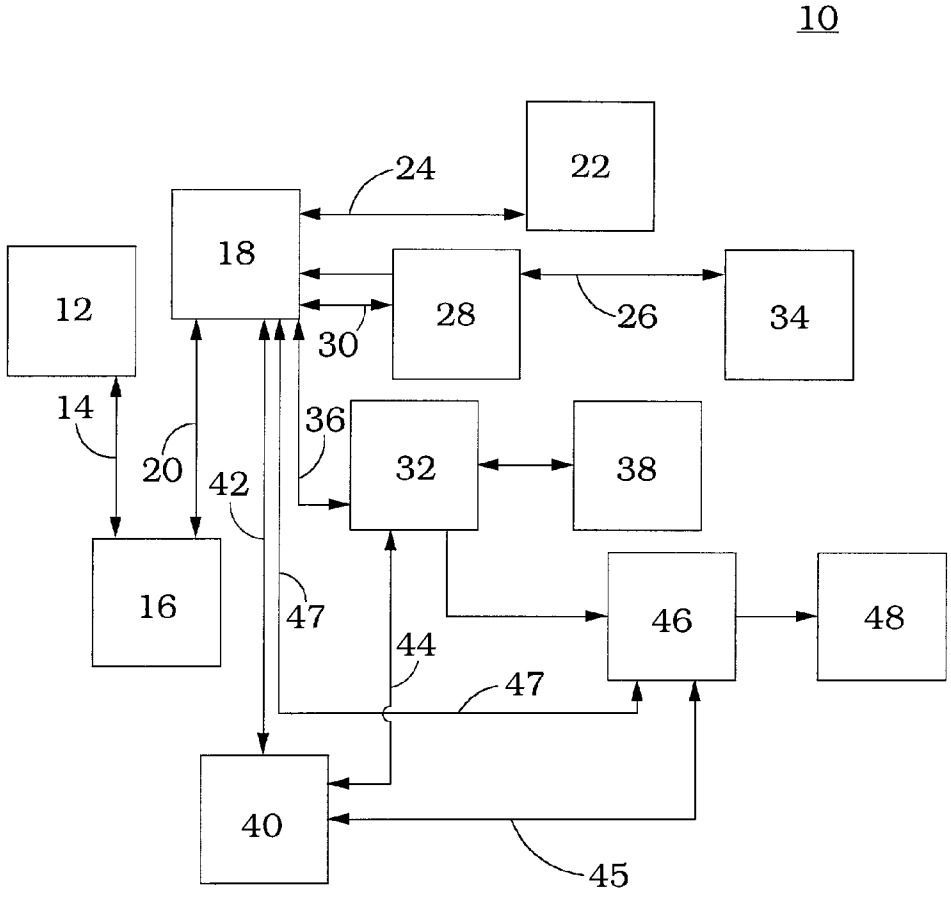
Publication Classification

(51) **Int. Cl.**[7] **H04N 7/18**

(52) **U.S. Cl.** **348/148**

(57) **ABSTRACT**

A novel device for remote information download and transfer for downloading a secure, permanent record of criminal activity and/or accident evidence relating to a vehicle for evidentiary purposes which may be directly transferred to an information center and/or the authorities through a transmission link which is preferably a satellite up/link-down/link or saved directly onto the downloading device. The remote downloading device may be activated automatically or upon a trigger signal and comprises an interface, an information capturing storage device, a video monitor display and preferably a transceiver. The interface communicates with an information storage device, downloads the information saved therein and transmits it to the capture storage device, transceiver or both. The information may be displayed on the visual display monitor or transmitted via the transceiver to an off site location.



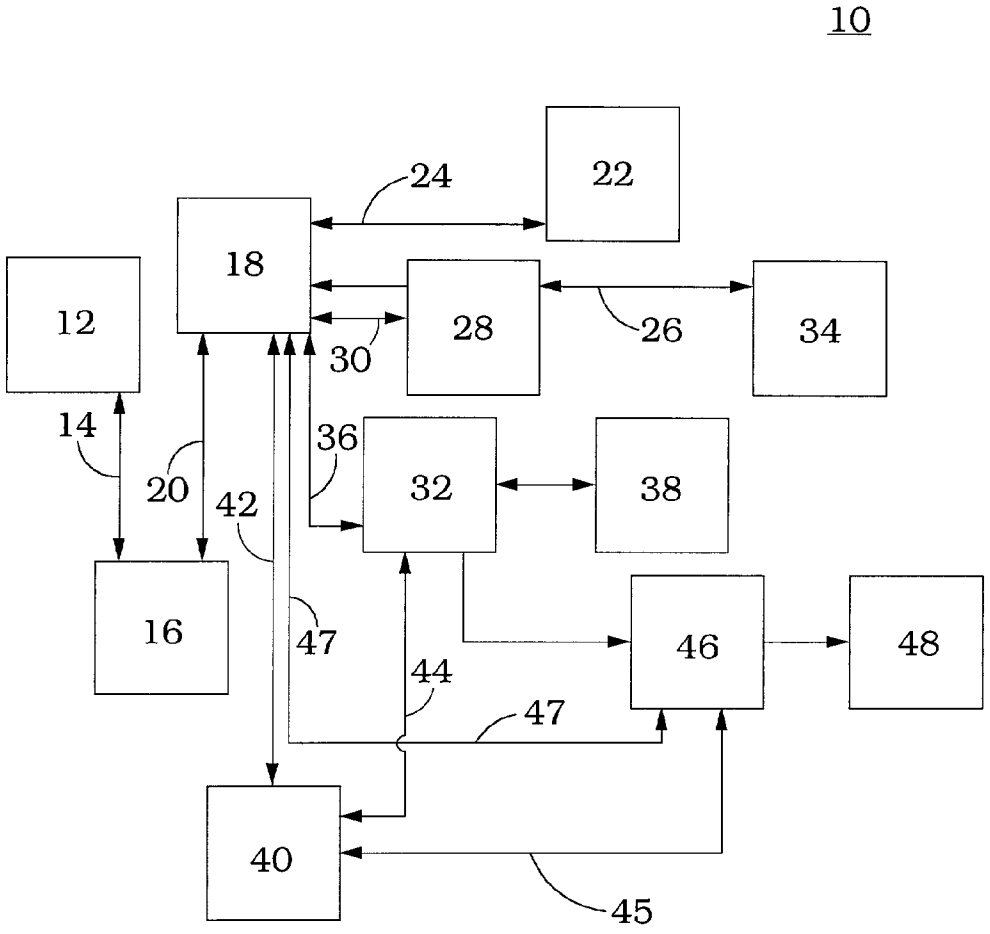


FIG. 1

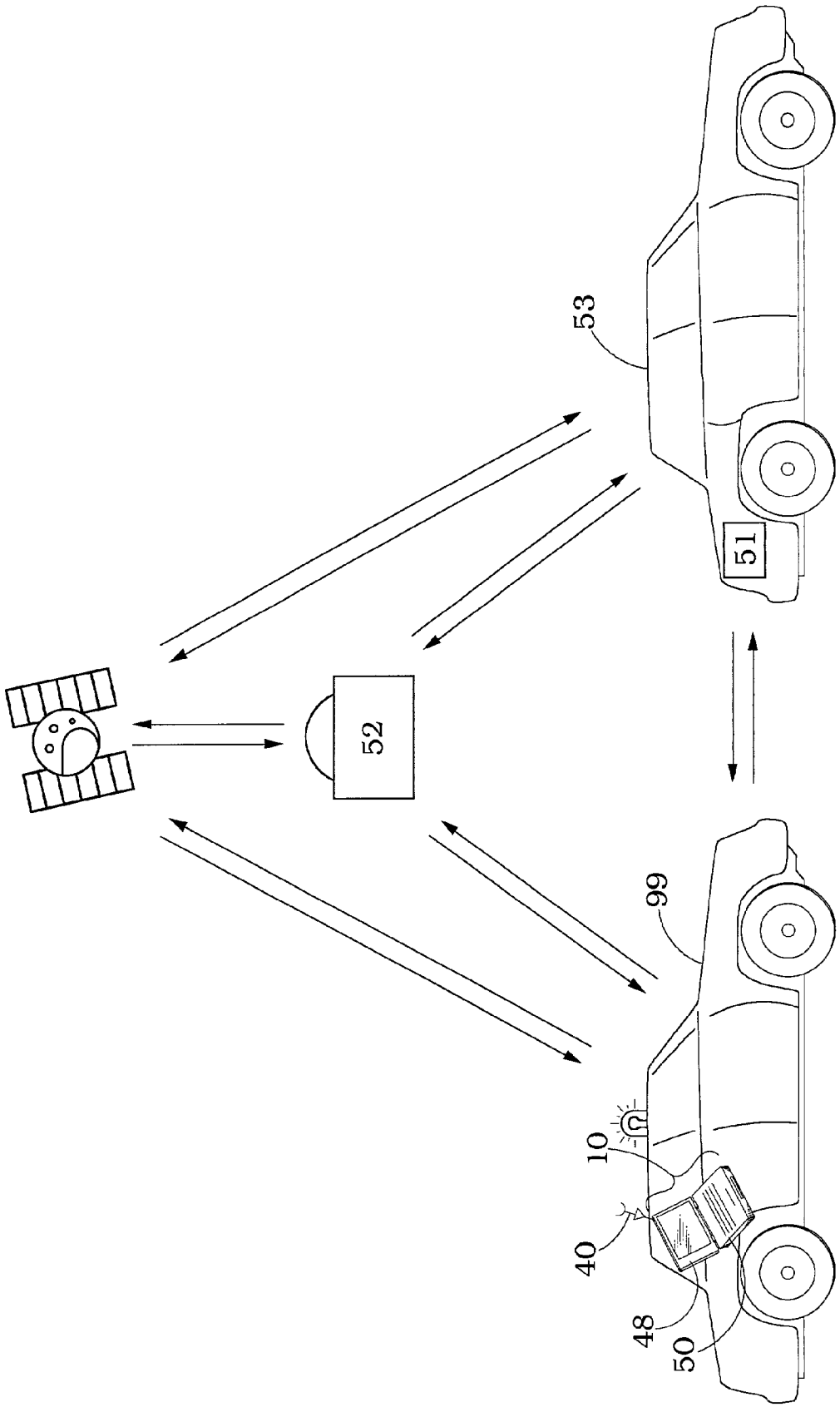


FIG. 2

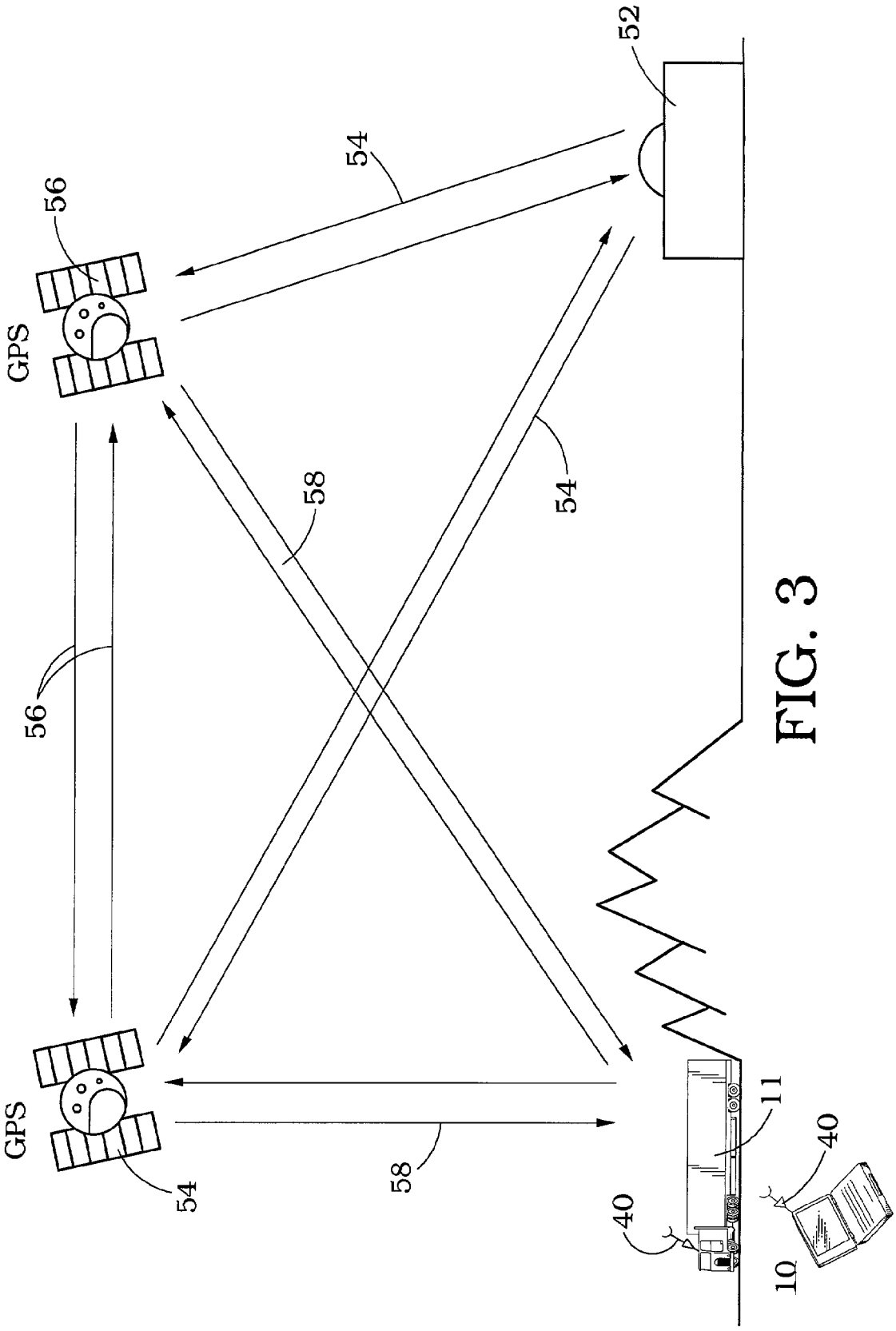


FIG. 3

INCIDENT RECORDING INFORMATION TRANSFER DEVICE

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present application is a Continuation-in-Part of parent application Ser. No. 9/088,267 filed Jun. 1, 1998, for a "Secure, Vehicle Mounted, Incident Recording System" and a Continuation-in-Part of application Ser. No. 09/327,828 filed Jun. 8, 1999 for a "Secure, Vehicle Mounted, Surveillance System". The parent application, which is incorporated by reference in its entirety, discloses an on-board, vehicle incident recording system for producing a secure, permanent record of vehicular accidents for evidentiary purposes and downloading the permanent record through on site or remote means such as through a wireless transmission.

[0003] The continuation-in-part application, which is incorporated by reference in its entirety, discloses an on-board, vehicle surveillance system for producing a secure, permanent record of criminal activity relating to the vehicle for evidentiary purposes which may be transferred directly to an information center and/or the authorities via a transmission link which is preferably a satellite up/link-down/link.

[0004] The instant invention is broadly directed to an on-board, vehicle surveillance system; and, more particularly, to a remote information download and transfer device for downloading a secure, permanent record of criminal activity and/or accident evidence for evidentiary purposes.

[0005] 2. Related Art

[0006] Vehicle insurance carriers are continually looking for ways to reduce losses as well as the cost associated with handling claims. In our prior applications, we addressed the losses associated with vehicular mishaps and vehicular vandalism and/or theft. Each year there are over 35 million on-the-road accidents in the United States alone. There are many other vehicles, including water craft, and off-road vehicles, which also are involved in mishaps. These can vary from one vehicle to multi-vehicle incidents. These mishaps or accidents cause billions of dollars of property and personal injury damage every year. In most cases, one or more of the parties is at fault, and law enforcement officers, insurance adjusters, and the like are required to find credible witnesses to re-account the factual evidence so that culpability and liability may be accurately determined.

[0007] Likewise, each year, theft and vandalism of vehicles account for losses that approach the magnitude of those resulting from accidents. These also are insured losses that must be handled by insurance carriers. In many cases, however, the loss either is caused by carelessness or is in fact an "inside job." The insurance industry, which is responsible for investigation and replacement or coverage of the losses, spends millions of dollars investigating such activity, as well as billions of dollars in replacing or compensating policy holders for avoidable losses.

[0008] In both of the above scenarios, the recording, storage, and remote access of information relating to the events of an accident or theft which later can be used as reliable evidence would be very beneficial in both streamlining accident and vehicle claims and ensuring that only valid claims are compensated. Further, having remote access to this information and the ability to download it off site would be useful in, for example, expediting the investigation of an accident or theft, providing accurate medical attention in the event of an accident, assisting in the apprehension of perpetrators, and locating and retrieving stolen vehicles.

[0009] With respect to the Secure, Vehicle Mounted, Incident Recording System, the ability to download the secure information to a permanent off site location is particularly helpful in expediting insurance claims because the adjuster's presence at the scene of the accident is not required, nor would the adjuster be required to analyze the damaged vehicle in order to ascertain fault. Instead, the information downloaded from the Secure, Vehicle Mounted, Incident Recording System could be reviewed easily and quickly and a determination of fault could be made. Further, it would be helpful if the authorities, rescue workers, hospitals, and the like could download the information en route to an accident scene, or at the scene itself, in order to ascertain the extent of the damage, fault, the equipment required (i.e., tow truck, jaws of life, etc), and the extent and cause of any injuries.

[0010] It therefore would be advantageous to have a remote device that could access, remotely or on site, the information being generated and/or securely stored on the Secure, Vehicle Mounted Incident Recording System (hereinafter, the "Recording System"), download that information, and instantaneously transmit the information via a transceiver to authorities, rescue vehicles, hospitals, and/or to an off site storage location. Thus, the transmission could be real time or delayed. Further, it would be advantageous to have a device that incorporated a video output interface to a display screen monitor such that a police officer, rescue unit, hospital, or the like actually could view the incident in order to provide better assistance. It would also be advantageous to have a device that, in addition to video output display, could download, transmit, and display information regarding certain physical phenomenon associated with a vehicular accident or theft, such as vehicle dynamic information including position, speed, and acceleration, and also audio, and the like, that had been monitored and recorded by the Recording System and could be utilized by police, hospitals, rescue workers, and the like in ascertaining certain information, such as the extent of any injuries, determination of fault in an accident, whether a crime is ongoing, and the proper equipment needed for a particular incident.

SUMMARY OF THE INVENTION

[0011] A remote information access and transfer device for accessing, receiving and/or downloading information from a Recording System, and transmitting the information to a remote station or storage facility has now been discovered. The invention broadly contemplates an off-board downloading device for accessing information on a Recording System and for viewing and/or transferring that information to an off site location. The remote information access and transfer device of the present invention is capable of accessing a remotely located Recording System and downloading information to the remote information access and transfer device from the Recording System either instantaneously or upon up-link command. The information can be downloaded from the Recording System in a variety of ways, including instantaneously, at various set intervals, in response to

certain events, and/or in response to remote commands. The information on the Recording System can be accessed by the device either in real time, as the incident is being recorded, or after the incident has been recorded and stored on the Recording System.

[0012] For the purpose of clarity, this description is directed to use of the remote information access and transfer device with a single Recording System. The remote information access and transfer device of the instant invention, however, can function equally well with either a single Recording System or with a multiplicity of Recording Systems, as one possessing ordinary skill in the art appreciates.

[0013] In the broad aspect, the remote information access and transfer device of the instant invention comprises a portable computer system having information input means for entering commands and information used in accessing and communicating with a remote Recording System; and a transceiver for receiving, downloading, and transmitting information from a Recording System. In one embodiment, the device further comprises a visual display for viewing information downloaded from a Recording System. In another embodiment, the device further comprises information storage means for storing information downloaded from a Recording System. The device can be free-standing or mounted in a vehicle, such as a police car or other rescue vehicle for example, or can be utilized from a stationary facility, such as a hospital, a police station, or an insurance company office for example, for downloading, viewing, and instantly transmitting the downloaded information to a secure, off-site location.

[0014] In a preferred embodiment, the device is capable of downloading both secure, encrypted information and non-encrypted information for real time viewing and/or transmitting and storing the downloaded information at an off site location. To enable real time viewing of the downloaded information, the device has an off board video output interface to display the incident that is downloaded on a display screen or monitor, thereby providing certain physical and/or dynamic information, such as the orientation, position, speed, and acceleration of a vehicle, the location of vehicles and/or people, impact parameters, information regarding the positions of the vehicle controls such as brakes, gears, steering wheels, lights, windshield wipers, and the like, that may facilitate investigation of the incident. The device further is capable of downloading and playing back audio information associated with incidents recorded and stored by a Recording System.

[0015] In a preferred aspect, the remote downloading device has at least one transceiver for accessing, downloading, and remotely transmitting information to an off site location, such as a base station, a hospital, an insurance company, law enforcement, a rescue vehicle, or the like. The transceiver receives signals from a remote unit, such as a Recording System, which allows the device to transmit recorded and/or stored information directly from the safe box or hard drive located on the Recording System to an off site location and/or instantaneously as it is generated. The transmitter may transmit the information via tower, radio wave, satellite band width, or the like. In an effort to protect the integrity of the transmitted information, the transceiver is located upstream of the Recording System safe box or hard drive, and the downloaded information is transmitted simultaneously to an off site location. Thus, the transceiver on the device communicates directly with the Recording System to transmit the information to an off site location as the information is being downloaded to the device and prior to the user being able to view the information via the display screen. This also allows for the information to be transmitted to the remote location and viewed in real time. The device is triggered to download and transmit information or information from a Recording System in a variety of ways, such as, for example, on a real time basis, based on preset commands, based upon the occurrence of a predetermined event, and/or in accordance with transmitted instructions or commands. The downloaded information is transmitted or broadcast to the remote location through a transmission link. The transmission link is preferably a direct satellite up/link-down/link, but the link also can be accomplished through a modem, a cell phone, radio frequency (RF), infrared, or any other means for transmitting information, as made available through advances in the relevant technology and as practiced in the art.

[0016] In another aspect of the invention, electronic access codes and encryption keys are utilized to provide authorized access, and to prevent unauthorized access, to the information stored in the safe box of the Recording System. The downloading device has a limited access interface, such as a direct plug-in LED for example, for entering access codes or encryption keys to communicate with the Recording System. Once the access codes or encryption keys are received and accepted by the Recording System, the device downloads the information and transfers the information onto a carrier wave for storage at a secure, remote facility. In a preferred embodiment, the device reencrypts the downloaded, de-encrypted information so that the information remains encrypted once it is downloaded, transmitted, and stored so that the integrity of the information is maintained and tampering is prevented.

[0017] In a preferred embodiment, the device has a direct transfer, solid state repository, such as a flash memory, a hard disc drive, or the like, for allowing the downloaded information to be stored directly in the downloading device as well as, or instead of, being stored at the remote storage facility.

[0018] In another aspect, the device has a video output interface to a display screen or monitor, such as an LCD display screen for example, so that a user can transport the remote information access and transfer device to the scene of an accident or crime, for example, to establish a remote, wireless communications link with the Recording System at the scene and to view the scene in real time and/or as it was recorded and stored by the Recording System. In this way, law enforcement, medical personnel, or other emergency and rescue personnel can view an incident occurring at a remote location, such as at the scene of an accident or a crime for example, while en route to the scene, while assistance is being rendered to a victim, or while a perpetrator is being pursued. Additional information pertaining to certain physical phenomena, such as vehicle speed, braking distance, time of the incident, audio recordings, and the like, can accompany the video output to permit rescue workers, medical personnel, and police officers, for example, to

ascertain such things as the extent of any injuries, fault, the types of rescue devices required, and/or whether a suspected perpetrator is armed.

[0019] Other objects, features, and advantages of the present invention will become apparent to those skilled in the art from the following detailed description. It should be understood, however, that the detailed description and specific examples, while indicating preferred embodiments of the present invention, are given for purposes of illustration and not of limitation. Many changes and modifications within the scope of the present invention may be made without departing from the spirit thereof, and the invention includes all such modifications.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] The above and further objects of the invention will become more readily apparent as the invention is more fully understood from the detailed description to follow, with reference being made to the accompanying drawings in which like reference numerals represent like parts throughout and in which:

[0021] **FIG. 1** is a schematic illustration of the instant invention.

[0022] **FIG. 2** is a component location in accordance with an exemplary embodiment of the instant invention.

[0023] **FIG. 3** is a conceptual diagram of an exemplary embodiment of the system of the instant invention using a GPS up/link down/link system.

DESCRIPTION OF EXEMPLARY EMBODIMENT

[0024] The downloading device of the instant invention **10** is shown in **FIG. 1**, which is a schematic only. The downloading device **10** is remotely located from the Recording System. The downloading device is preferably mounted in a police cruiser, rescue vehicle and the like. In a preferred embodiment, upon activation, a receiver **12** communicates with the system controller **16** via link **14** to request access codes and/or encryption keys. The system controller **16** communicates with interface **18** via link **20** to activate the transmission of the access codes or encryption keys to the Recording System controller **22** located on the Recording System via code access link **24** for verification. Upon receipt of the verification of access codes or encryption keys from the Recording System controller **22** via code access link **24** to the interface **18** and via link **20** to the system controller **16**, the system controller **16** triggers the interface **18** to begin downloading the information from hard drive **34** located on the Recording System through information stream link **26**. The interface **18** is directly connected to an decryption buffer **28** via information junction link **30** which can encrypt or decrypt the information stored on the hard drive **34**.

[0025] As the interface **18** accesses the information stored on the hard drive **34** located on the Recording System, the information is encrypted or decrypted by the buffer **28**, and then downloaded via information stream link **26**. The interface **18** stores the information on the download device **10** by directly communicating with the download device's information storage means **32** via link **36**. The information storage means **32**, which has the capacity to store the information for 48 hours or more, records the encrypted or unencrypted information accessed by the interface **18**. Hard disk storage is preferred for large capacity. Any configured hard disk device can be used for example, a Seagate UDMA 8.6 GB hard drive. Additionally tape drive storage can be used either as primary or backup. The information storage means **32** is controlled by the system controller **16** to activate the information storage means **32**, play back recorded information, find referenced events, decode the stored information and the like. This permits authorities at the scene of an accident or crime to be in full control of the information storage means **32** located in the downloading device so that they may reconstruct and view information on sight or en route, and monitor any previous incident recorded by the Recording System. Preferably, the system controller **16** prohibits recording over a previously downloaded portion of the information, prior to the drive space being released to the device **10**. In this manner a permanent, non-corrupted record is retained on the downloading device **10**. The system controller **16** remembers the point on the disk where the prior recording was terminated and will index to that point on the disk, prior to the resumption of recording, in response to the activating of the downloading device **10**. The information storage means **32** also communicates with a backup disc or tape drive **38** which provides for the information to be removed from or copied from the information storage means **32** either in encrypted or non-encrypted form onto a transferable tape or disk. The tape or disk can then be transported to another location, such as, for example, a hospital for viewing by medical personnel treating an accident victim.

[0026] The interface **18** also directly communicates with transceiver **40** via first transmission link **42**. This interface allows real time transmission of data, simultaneously with storage. The transceiver **40** can comprise a direct satellite uplink, RF radio, modem, cell phone, or the like. In accordance with this embodiment, the transceiver **40** can receive remote signals which allows the interface **18** of the download device **10** to directly transmit the information simultaneously as it is being downloaded from the hard drive **34** located on the Recording System. The download device's information storage means **32** can also communicate with the transceiver **40** via transmitting link **44** so the information can be transmitted, via the transceiver **40**, to a remote location after it is stored on the download device's information storage means **32**. Additionally, the transceiver **40** can communicate with the Recording System directly in order to transmit the information in real time to an offsite location or directly to the video output buffer **46** via second transmission link **45** for viewing in real time, on the visual display monitor **48**.

[0027] In operation, the system of the instant invention can operate in many modes from real time transmission to a remote location to transmission of stored information upon command. For example, a police officer, who is en route or arrives at the scene of an accident or vehicle theft can access the information pertaining to the incident stored in the safe box of the Recording System and watch a video replay at the scene by inputting access codes or encryption keys into the keyboard of the information transfer device. The codes will be transmitted to the Recording System by the interface. Upon their authentication, the downloading device will communicate with the Recording System in order to download the information onto the download device. The downloading device also communicates with a transceiver unit in

order to transmit the information to an offsite location. The information can then be displayed via the video output interface onto a visual display screen. Attendant with recorded information displayed on the visual display screen may be information on such physical phenomena as the speed of the vehicle, brake distance, time of the accident, video information, etc. The information may thereafter be saved into the downloading device's information storage means.

[0028] In another aspect, the download device **10** will contain a unique encryption key that may be accessible by a remote station so that the transceiver **40** of the downloading device **10** can be activated remotely to start transmission download at any time from either the interface **18**, the information storage means **32** or the hard drive **34**.

[0029] The interface **18** also communicates directly via third transmission link **47** or via the information storage means **32** with a video output buffer **46**. The video output buffer **46** is connected to a visual display monitor **48**. The visual display monitor **48** is preferably a color LCD display but can be a CRT or other screen-type monitor. The visual display monitor **48** provides for the information downloaded from the information storage means **34** located on the Recording System to be viewed on the scene or en route by for example, authorities trying to apprehend a perpetrator or medical personnel trying to provide medical attention to an accident victim.

[0030] In another embodiment the information recorded from certain monitors and transducers located on the Recording System can be downloaded by the interface **18** from hard drive **34** located on the Recording System and superimposed on recorded video information also downloaded from hard drive **34** located on the Recording System. This additional information can be stored on the downloading device's **10** information storage means **32**, on transferable disk or tape, transmitted to an off site location via transceiver **40** or can be transmitted along with the video signals via the video output buffer **46** and displayed on the visual display monitor **48**.

[0031] Turning to **FIG. 2**, there is shown a component location diagram in accordance with an exemplary embodiment of the instant invention. In this exemplary embodiment, the download device **10** is implemented in a form that is similar to that of a laptop computer with a visual display monitor **48** and keyboard **50**. The download device **10** may be self-contained with, for example, a phone jack and/or a modem hooked to a mobile phone or SET for direct satellite transmission via transceiver **40**. In the depicted embodiment, the Recording System **51** is located in a vehicle **53**, and the download device **10** is located remotely from the Recording Systems **51** such as, for example, in a police cruiser **99**. One with ordinary skill in the art appreciates that the download device **10** could also be located in a wide variety of other mobile locations, including an emergency vehicle such as a fire truck, ambulance or the like, or in a military vehicle such as a tank or helicopter, or in the vehicle of an insurance adjuster, or a fleet manager, or a site manager. Alternatively, the download device **10** could be implemented in a variety of packaging configurations to enhance its mobility, for example to be carried by hand or in a carrying case or even a napsack or a backpack. Of course, the download device **10** could also be implemented as a stationary fixture as well.

[0032] In the exemplary embodiment of **FIG. 2** the download device **10** is activated to retrieve the vehicle information by a command entered via the keyboard **50** or alternatively, as a result of a transmission trigger from a Recording System **51**. In an exemplary embodiment, the downloading transmission may be triggered by the occurrence of a predetermined event or series of events or even the failure of the occurrence of an event or series of events. Additionally, as one with ordinary skill in the art appreciates, a download may be triggered by satisfaction of, or the failure to satisfy, a variety of logical criteria relating to the vehicle or its surrounding environment and/or its contents including, for example, position, velocity, acceleration, direction, time, temperature, pressure, mechanical deformation, chemical presence or exposure, sound, proximity, conductivity or other electrical properties, magnetic or electromagnetic field strength or orientation or other magnetic or electromagnetic properties, or radioactivity, or any combination thereof.

[0033] Upon activation, the information, which can be recorded information and/or live information, can be transmitted from the Recording System **51** to a secure location **52** or, upon request, directly to the download device **10**, which, in this case, is located in the police cruiser **99**. Utilizing access codes, the download device **10** may alternatively retrieve the information from the Recording System **51** or the secure location **52**. Further, one with ordinary skill in the art appreciates that the transmissions of information in each case, whether from the Recording System **51** to the download device **10** or to the secure location **52**, or from the secure location **52** to the download device **10**, or from the download device **10** to the secure location **52**, may be via tower, radio wave, satellite band width, or the like. As the information is downloaded, the monitor **48** can display the video information, and the download device **10** can play audio or other information as desired, either on the scene or en route to the scene or from any other desired vantage point chosen, for example, for safety or convenience or comfort. The transceiver **40** can also communicate directly with a Recording System **51** in order to transmit the information instantaneously, or in real time, to an off site location **52** through a transmitter or transceiver and/or via satellite **56** or other means which are readily understood by one skilled in the art.

[0034] Referring to **FIG. 3**, there is shown the relationship between the GPS satellite system, and the transceiver **40** located on the downloading device **10** and transceiver **52** located at an off-site location. To inject information into the system, transceiver **52** up/links by mimicking the L3 link by transmitting a signal **54** in the VHF/UHF band to the nearest satellite **56** in view. The signal **54** is an anti-jam, frequency-hopped transmission. Upon reception, the satellite **56** dehops and demodulates the signal **52**, reformats and remodulates signal **54** and then transmits the signal **58** on the L3 link at 1381.05 MHZ. The satellite also re-transmits the signal **58** on a cross-link to other GPS satellites in order to effect global coverage. Crosslinked transmission signals **58** are downlinked on L3 as well. Although the L3 link on the GPS navigation satellite system is contemplated as the best mode for communication between the transceiver **40** and the off site location or authorities, hospitals and the like, other satellite systems are also anticipated as functioning in place of the GPS satellites **56**, with the transceiver **52** suitably modified.

[0035] The system and method of downloading the secure information of the present invention becomes indispensable with respect to the Secure, Vehicle Mounted, Surveillance System. Specifically, thieves gaining access to a vehicle may ferret out the on board safe box containing the stored information and remove it. Additionally, in cases of car jacking, the thieves have control of the vehicle as well as the Secure, Vehicle Mounted, Surveillance System, making the probability of recovery of the information stored on the vehicle slight. Additionally, the ability of the instant invention to receive in real time the circumstances surrounding a vehicle after the theft is invaluable to the safety of law enforcement personnel. For example, officers will be able to ascertain whether a perpetrator is still lurking around the vehicle and if any one is armed.

[0036] Another advantageous aspect of the instant invention is the ability to immediately download information, either from a Recording System or directly from an information source such as a sensor or video sensing element such as a CCD element or an audio sensor on the monitored vehicle or site, and to transmit a secure copy of the downloaded information, via a transceiver communicating with a satellite or the like, to an off site location for analysis by insurance adjusters and/or for use as evidence in court proceedings and/or for storage. In this manner, a repository of all information from various devices in various vehicles, including ones involved a simultaneous event, such as a multi-car accident, can be securely stored in a single repository accessible by authorities and insurance adjusters so that a particular incident can be "reconstructed" in a side-by-side or frame-by-frame manner. The information can also be stored onto the downloading device's information storage means and a copy made in the devices back up information storage means, such that a tape or disk can be made of the incident for transport to, for example, a hospital.

[0037] It will be realized that other information may be gathered, encoded and stored in the synchronized information system. For example, GPS tracking information or the like. In this manner hijacked vehicles can be tracked, recovered or the site of an accident located.

[0038] Although the present invention has been described with reference to preferred or exemplary embodiments, including particular materials and size parameters, those skilled in the art will recognize that various modifications and variations to the same can be accomplished without departing from the spirit and scope of the present invention and that such modifications are clearly contemplated herein. No limitation with respect to the specific embodiments disclosed herein and set forth in the appended claims is intended nor should any be inferred.

What is claimed is:

1. A remote information downloading device for wireless access to and downloading of vehicle information from a remote, on-board, vehicle incident recording system, the downloading device comprising:

a) at least one interface communicating with and accessing and receiving incident data from the vehicle incident recording system;

b) an information datalink coupled to said interface for transferring said received incident data from said interface; and

c) a transceiver coupled to said information datalink for accessing, receiving, downloading, and transmitting said vehicle information from the vehicle incident recording system.

2. The device of claim 1 further including an information storage device coupled to said vehicle incident recording system for capturing and storing said vehicle information.

3. The device of claim 2 wherein said information storage device is selected from the group consisting of a video tape drive, a hard disk drive, a CD ROM drive, and a solid state repository.

4. The device of claim 3 wherein said information storage device is adapted to prevent said vehicle information from being overwritten for extended periods of time.

5. The device of claim 1 wherein said vehicle information comprises identification information.

6. The device of claim 1 wherein said vehicle information comprises video information.

7. The device of claim 1 further comprising playing means for displaying said vehicle information.

8. The device of claim 7 wherein said playing means comprises a visual display.

9. The device of claim 8 wherein said visual display is adapted for viewing video information.

10. The device of claim 8 wherein said visual display comprises a visual output interface to a display screen.

11. The device of claim 8 wherein said visual display comprises an off-board visual output interface.

12. The device of claim 1 wherein said vehicle information comprises audio information.

13. The device of claim 7 wherein said playing means is adapted for playing audio information.

14. The device of claim 1 wherein said vehicle information comprises time information.

15. The device of claim 1 wherein said vehicle information comprises vehicle dynamic information.

16. The device of claim 1 wherein said vehicle information comprises vehicle control information.

17. The device of claim 1 wherein said interface is a second transceiver.

18. The device of claim 17 wherein said transceiver includes a download trigger for initiating downloading of information from said recording system.

19. The device of claim 18 wherein said download trigger is adapted to respond to the occurrence of a predetermined event.

20. The device of claim 18 wherein said download trigger is adapted to respond to transmitted instructions.

21. The device of claim 18 wherein said download trigger is adapted to require input of an electronic access code.

22. The device of claim 17 wherein said transceiver is adapted to download encrypted information from said recording system.

23. The device of claim 22 wherein said device is further adapted to decrypt said information.

24. The device of claim 3 wherein said information storage device is remotely located from said vehicle.

25. The device of claim 17 wherein said transceiver is adapted to transmit information to an off-site location.

26. The device of claim 25 wherein said transceiver provides a transmission link.

27. The device of claim 26 wherein said transmission link is a direct satellite up-link/down-link.

28. The device of claim 25 wherein said transceiver provides a transmission trigger for initiating transmission of information to an information storage device.

29. The device of claim 28 wherein said transmission trigger is adapted to respond to the occurrence of a predetermined event.

30. The device of claim 28 wherein said transmission trigger is adapted to respond to transmitted instructions.

31. The device of claim 1 wherein said device is adapted for use in a vehicle.

32. The device of claim 31 wherein said vehicle is selected from the group consisting of a police cruiser, an ambulance, a fire truck, and a rescue vehicle.

33. The device of claim 1 wherein said device is adapted for use in a stationary facility.

34. The device of claim 33 wherein said facility is selected from the group consisting of a hospital, a police station, and a fire station.

35. The device of claim 1 wherein said interface is a limited access interface.

36. A method for remotely accessing and downloading stored information from a recording system located on a vehicle, comprising the steps of:

a) activating a downloading device having an interface for accessing and downloading said stored information from said recording system,

b) receiving and playing said downloaded information; and

c) displaying said played information.

37. The method of claim 36, said information comprising vehicle identification information.

38. The method of claim 36, said information comprising video information.

39. The method of claim 36, said information comprising audio information.

40. The method of claim 36, said information comprising time information.

41. The method of claim 36, said information comprising vehicle dynamic information.

42. The method of claim 36, said information comprising vehicle control information.

43. The method of claim 36, including the steps of transmitting said information to an off-site location.

44. The method of claim 43, said transmitting performed via a transmission link.

45. The method of claim 44 wherein said transmission link is a satellite up-link/down-link.

46. The method of claim 36, including capturing and storing said information.

47. The method of claim 46, including storing said information remotely.

48. The method of claim 46, including capturing and storing said information to a device selected from the group consisting of video tape, a hard disk, a CD ROM, and a solid state repository.

49. The method of claim 46, including temporarily preventing said information from being overwritten.

50. The method of claim 36, including inputting an electronic access code.

51. The method of claim 36, including encrypting said information.

52. The method of claim 51, including decrypting said information.

* * * * *

Appendix X

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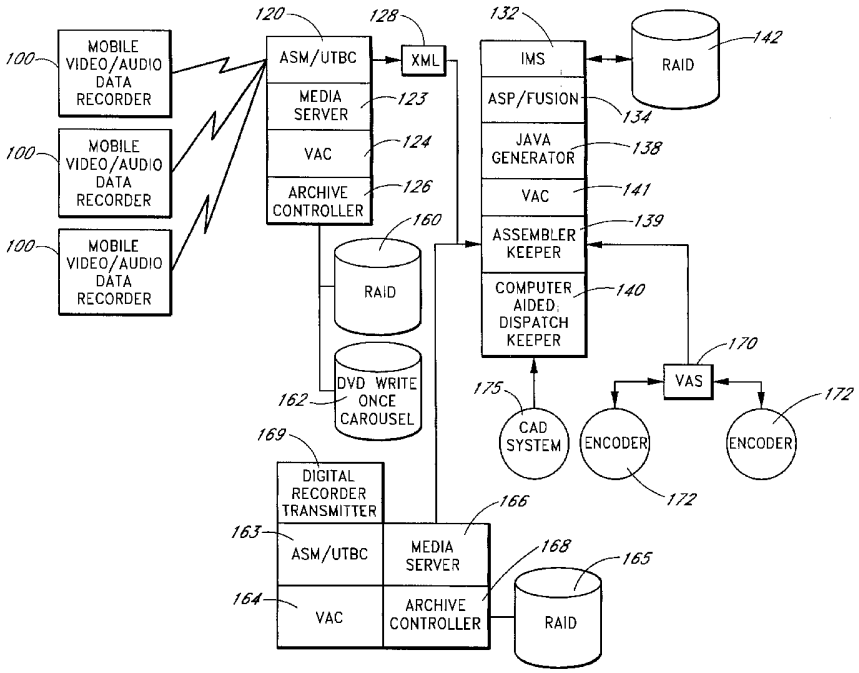
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(54) Title: VIDEO AND TELEMETRY APPARATUS AND METHODS



(57) Abstract: The present invention is related to methods and systems for acquiring, storing, and distributing video and telemetry. Methods and systems are provided for the comprehensive management of audio, video and data recorded by one or more sensors, such as surveillance sensors. Users can select and play back video records based on meta-data embedded within the video record. The frame rate and resolution of the video can be customized to be appropriate for the user terminal.

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VIDEO AND TELEMETRY APPARATUS AND METHODS

Background of the Invention

Field of the Invention

The present invention is related to video and telemetry, and in particular to methods and systems for acquiring, storing, and distributing video and telemetry information.

Description of the Related Art

Conventional video surveillance systems often suffer from many deficiencies. For example, many conventional video surveillance systems fail to deliver television-quality streaming video with synchronized audio. Instead, many systems use a technique called motion JPEG or Wavelet "push" technology. Disadvantageously, motion JPEG and Wavelet systems are primarily designed to provide a series of individual "photographs" from a video camera source. This process of transporting individual pictures is sometimes called "Serial Still Frame" transport, or "SSF." SSF does not adequately synchronize audio and other data. Further, the bandwidth needed for SSF transmission can be relatively high, as with conventional systems each individual picture is separately encoded, recorded and transmitted.

Further, once the image data is captured, it can be very difficult to find a particular frame or sequence of frames without having to manually search by viewing large number of the frames to locate the desired frame or sequence of frames.

In addition, many conventional systems do not provide tamper-proof archiving technologies to ensure that archived data is not later improperly modified or edited. For example, some conventional video archiving systems rely on watermarks embedded within the video frames during the recording process to detect tampering. This method however, can often be circumvented, and so these systems often do not have adequate evidentiary credibility.

Summary of the Invention

The present invention is related to methods and systems for acquiring, storing, and distributing video and telemetry. Example embodiments further provide methods and systems for the comprehensive management of audio, video and data recorded by one or more sensors. Thus, embodiments of the present invention enables users to select and play back video records based on meta-data embedded within the video record.

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One embodiment is a recording and transmission system comprising: a recorder mountable in a police vehicle configured to record video and meta-data synchronized with the video, wherein the recorded video includes a plurality of segments having fixed lengths, the recorder including a wireless transmitter configured to wirelessly transmit the recorded video segments and meta-data, wherein the meta-data includes: data related to vehicle status; subjective time information; objective time information; serial data. An assembler is configured to wirelessly receive the transmitted video segments and assemble the video segments into a file including the meta-data, the assembler further including a mass storage device used to store the assembled video and transmit the assembled video. An information management system is coupled to the assembler to receive the assembled video and to store the meta-data in a relational database, wherein the information management system is configured to receive a user search query from a first terminal having a first resolution, conduct a search of the meta-data based at least in part on the search query, transmit the results of the search to the first terminal, receive a user selection of at least a first of the results, configure the video corresponding to the selected result for the first terminal based at least in part on the first resolution, and transmit the configured video to the first terminal.

Another embodiment is a method of storing and providing video data, the method comprising: receiving a first video file including video and embedded meta-data, the meta-data including at least timing information and status information; storing copies of at least a portion of the first video file in a second video file on a first data storage system and in a third file on a second storage system; generating at least a first string searchable file based at least in part on the meta-data; receiving a user search query; conducting a search of information in the first string searchable file based at least in part on the user search query; presenting results of the search to the user via a user terminal; receiving a user search results selection corresponding to the second video file; retrieving the second video file and the third video file based at least in part on the user selection; comparing at least a first portion of the meta-data in the second video file with a corresponding portion in the third video file in order to determine if file tampering has occurred; and transmitting at least a portion of the second video file to the user terminal.

One embodiment is a method of storing and providing video data, the method comprising: receiving and storing data including a video sequence and synchronized meta-data; generating at least a first string searchable data structure based at least in part on the

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meta-data; receiving a user search query; and conducting a search of information in the first string searchable data structure based at least in part on the user search query.

One embodiment is an apparatus for storing and providing video data, the apparatus comprising: a storage device configured to store data including a video sequence and synchronized meta-data; a first instruction configured to generate at least a first string searchable data structure based at least in part on the meta-data; a second instruction receive a user search query; and a third instruction configured to conduct a search of information in the first string searchable data structure based at least in part on the user search query.

Brief Description of the Drawings

Figure 1 illustrates an example video acquisition, storage and distribution system.

Figure 2 illustrates an example authentication process and system.

Figure 3 illustrates an example Web page used to display a retrieved video.

Figures 4A, 4B and 4C illustrate example video files with embedded timing information.

Figure 5 illustrates example video segments.

Figure 6 illustrates an example assembler file conversion process.

Figure 7 illustrates an example of merging data from multiple sources for rendering on a user terminal.

Figure 8 illustrates an example search page.

Figure 9 illustrates an example file access, download and rendering process.

Figure 10 illustrates an example encoding process.

Detailed Description of the Preferred Embodiment

The present invention is related to methods and systems for acquiring, storing, and distributing video and telemetry. Example embodiments further provide video archive management that enables users to select and play back video records based on meta-data embedded within the video record.

For example, when used in a law enforcement patrol vehicle scenario, the meta-data may include, by way of example, date, time, vehicle identification, personnel names, global positioning coordinates, and a comprehensive variety of additional data, including mobile data terminal traffic, event logs or intrusion alarms. As discussed in greater detail below,

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automated upload of video files onto archive storage media and automatic entry into a corresponding database is also provided, optionally with little to no user intervention.

For example, in the law enforcement patrol vehicle scenario, in one embodiment, files, including video, audio, and meta-data, are temporarily stored onboard vehicle-based recording units which are transmitted to an archive database when the vehicle returns to its home station. The meta-data is optionally stored both in the home station archive database, as well as on a remote centralized database that stores meta-data from a plurality of station archive databases.

A variety of electronic sensors and associated electronics and software, that encode, transmit, and record video, audio, and many channels of streaming real-time meta-data, such as telemetry and event information, can be included in an embodiment of a surveillance system to detect a variety of events or occurrences. The meta-data is embedded and synchronized with the recorded video. The sensors may be positioned on mobile platforms, such as cars, trains, or planes, or on stationary platforms, such as buildings, posts, fences, and the like. The sensors can include, by way of example, one or more of pan/tilt/zoom, passive and active infrared and visible light cameras, covert wireless cameras and microphones, glass breakage detectors, door open/close detectors, gun discharge detectors, crash detectors, light bar on/off inputs, siren on/off inputs, gun rack detectors that sense when a gun is removed from and/or placed in the rack, vehicle speed sensors, tachometer, radar gun, fuel level, heartbeat monitors, pulse monitors, chemical weapons detectors, GPS systems, radio receive and transmit switches, public address ports, and the like.

Advantageously, the sensors and supporting circuitry are optionally capable of simultaneously transmitting live (low latency) video, audio, and data telemetry wirelessly over wireless networks while recording, and further provide data terminal functionality. In one embodiment, a variety of server components are used to cost effectively and securely deliver video, audio, and data telemetry, such as that recorded via the sensors and supporting circuitry, to long-term storage archives, optionally in accordance with Federal Evidentiary Rules.

Upon receiving the recorded files that include video, audio, and data telemetry, an example apparatus automatically extracts and parses pre-determined data-points from the recorded telemetry to construct a scalable video meta-data "comparator" file that is used by

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a central database to enter the data to fields for sorting; seek extract, and include selected data and information from other databases related to the recording for central access; and provide for string-searches of meta-data embedded in videos. For example, in response to user string searches and using the meta-data entered into the meta-data database, specific videos and even specific segments or frames within a video sequence are located and retrieved from the video archives. The located videos can be substantially instantly delivered to the requesting user starting from the moment of a selected meta-data "incident" or data-points, or beginning at a selected time period relative to the incident or data point. Thus, use of an embodiment of the present invention can result in the reduction or elimination in the need to spend time manually locating and retrieving video records, or manually viewing such records in order to locate specific events.

Further, the system advantageously optionally provides secure user access locally and/or remotely, optionally without needing customized client display software on the user computer or terminal. For example, access to and display of videos and meta-data can be provided using a standard browser, such as Microsoft Internet Explorer or the like, and a standard media player, such as Windows Media Player or Apple QuickTime, executing on a personal or server computer, personal digital assistant, cell phone, and the like, thereby lowering the client cost and easing maintenance. However, custom media players and browsers can be used as well.

In addition, video teleconferencing interfaces, such as the standard H.323 teleconferencing, is provided for remote observers. By optionally using an existing teleconferencing standard the system is compatible with legacy video teleconferencing systems. Optionally, the system and applicable sensors can utilize one or more of ISO MPEG-4, MPEG-1, MPEG-2, and H.323 encoding/decoding. Optionally, for certain application, the system employs extremely compressed video to reduce bandwidth and storage requirements. For example, in one embodiment, an I (intracoded) frame is only transmitted when at least a certain number or percentage, such as 25% of pixels change luminance and/or chrominance relative to the previous intracoded frame, otherwise P (predicted) frames or B (bi-directionally interpolated) frames are used. As is well known in the field, I frames generally utilize many more bits than P or B frames. Optionally, this process allows six frames/second to be transmitted using as little as about 5.9 kbs, and at a

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nominal transmission rate of 7.2kbps, which is well within the capacity of existing cellular data transmission services.

One embodiment advantageously utilizes asymmetrical encoding which provides a multi-session digital video compression process that enables multiple simultaneous transmissions of various video resolutions and frames rates while a high quality recording is created or played. This process permits various users utilizing dissimilar devices to view live and/or prerecorded video transmissions appropriate for the type of viewing device in use.

The foregoing methods and systems will be described in greater detail below with reference to the figures. Throughout the following description, the term "Web site" is used to refer to a user-accessible server site that implements the basic World Wide Web standards for the coding and transmission of hypertextual documents. These standards currently include HTML (the Hypertext Markup Language) and HTTP (the Hypertext Transfer Protocol). In addition, reference is made to Java script (also referred to as JavaScript), though other types of script, programming languages, and code can be used as well. For example, VBScript or Active X objects can be used with appropriate platforms. It should be understood that the term "site" is not intended to imply a single geographic location, as a Web or other network site can, for example, include multiple geographically distributed computer systems that are appropriately linked together. Furthermore, while the following description relates to an embodiment utilizing the Internet and related protocols, other networks, such as networked interactive televisions, and other protocols may be used as well.

In addition, unless otherwise indicated, the functions described herein are preferably performed by executable code and instructions running on one or more general-purpose computers, terminals, personal digital assistants, cellular phones, or the like. However, the present invention can also be implemented using special purpose computers, state machines, and/or hardwired electronic circuits. The example processes described herein do not necessarily have to be performed in the described sequence, and not all states have to be reached or performed.

Further, while the following description may refer to "clicking on" a link or button, or pressing a key in order to provide a command or make a selection, the commands or

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selections can also be made using other input techniques, such as using voice input, pen input, mousing or hovering over an input area, and/or the like.

The overall system is shown in Figure 1 to which reference is hereby made. The system includes a mobile video/audio data recorder 100 which records high quality video/audio and serial data telemetry while simultaneously transmitting specially formatted live video/audio and information to personnel using a variety of reception devices or terminals. For example, the mobile video/audio data recorder 100 optionally records at 30 frames per second, though other frame rates can be used as well. Optionally, the mobile video/audio data recorder 100 utilizes RTSP (real time streaming protocol), a client-server multimedia presentation control protocol, which provides efficient delivery of streamed multimedia over IP networks. The RTSP may utilize RTP (Realtime Transport Protocol), which is a packet format for multimedia data streams.

The mobile video/audio data recorder 100 optionally saves video files in multiple file segments, the length and/or duration of which is selectable by a user or system administrator. For example, if segment sizes of 300 seconds are selected with a recording bit-rate of 800kbits per second, mobile video/audio data recorder 100 will break long duration recordings into files of approximately 30Mbytes each. The foregoing process advantageously provides enhanced file resiliency, thereby reducing the incidence of file corruption, and facilitating the recovery of damaged or corrupted files by limiting the size of each binary recording. The recorder 100 can transmit files, including video records, audio records, and/or meta-data, using one or more of CDPD, GPRS, GSM, satellite, dial-up, or broadband Internet networks.

Optionally the frame rate, bit rate and resolution for transmission can be selected based on the wired or wireless network and the receiving terminal. For example, some devices, such as palm-held personal digital assistants (PDAs) and hybrid cell phones may have limited display resolution and processor power. In applications where such devices are used to view the video, such as by remote field personnel performing surveillance, the recorder 100 maintains compatibility with the target device by optionally formatting video specifically for the target device. By way of example, personnel equipped with a PDA that may only be capable of displaying 15 video frames (pictures) per second at a resolution of 320x240 pixels connect to a special URL (Universal Resource Location) associated with a Web site, and are provided video specifically formatted for the receiving device. At the

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same time, when video and data streams to devices that can display full resolution and frame rates, such as notebooks and PCs, the devices receive full resolution frames at the recorded frame rate.

Thus, for example, live video can selectively be transmitted at one or more of the following video frame/bit rates, while at the same time optionally recording at a minimum frame rate and resolution, such as 30 FPS at a minimum resolution of 352 x 240 with 48KHz audio:

6 FPS (frames per second) with a resolution of 160 x 120 utilizing less than 8 kilobits per second via CDPD, GSM, GPRS, 802.11g, 802.11b, 802.11a, or Ethernet 10/100.

15 FPS with a resolution of 320 x 240 at 47 kilobits per second via GPRS, GSM, 802.11g, 802.11b, 802.11a, or Ethernet 10/100.

30 FPS with a resolution of 352 x 240 at 192 to 600 kilobits per second via 802.11g, 802.11b, 802.11a, or Ethernet 10/100.

The mobile video/audio data recorder 100 can be located in and transmit from a variety of stationary and mobile locations, such as aircraft, ships, patrol vehicles, buildings, lots, fields and the like.

In one example embodiment, a ring buffer in a recorder, such as recorder 100, captures video, audio and data until an instruction or trigger to start the recording process occurs. When the instruction or trigger is received, the content of the ring buffer is assigned a new serial record number. A file is created in the system's local temporary archive with a file name including the serial record number, system identifier, and the user assigned file naming convention is appended. The start instruction can be the result of any particular event, such as a patrol vehicle light bar being turned on, or as a result of a user providing a manual signal start instruction. Files, including video, audio, and meta-data, are then recorded and closed in optionally fixed duration intervals. The file intervals can be specified by the user or administrator during system set-up. As discussed above, the files can include embedded video, audio, and meta-data. Meta-data is recorded as virtual channels utilizing a packet-based addressing scheme, enabling a large number of virtual channels, such as up to 256 or more virtual channels. The meta-data can optionally correspond to inputs from one or more of the sensors and detectors discussed above. As each file is closed, a buffer, such as the ring buffer, captures the data for the next file

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segment so that data is not lost. Advantageously, the data, video, and audio sources and encoders can remain active during file close intervals.

The files are stored in an archive clearing directory, and are serialized and identified by a record event string in preparation for automated file upload to an assembler server system 120.

The video/audio data signals recorded by the mobile video/audio data recorder 100 are uploaded either wirelessly or via a wired connection to the assembler server system 120. By way of further example, if the mobile video/audio data recorder 100 is located in a police or other vehicle, the recorder 100 can automatically upload the recorded video/audio and data using 802.11(b, g, or a) protocol upon reaching the police station at which the vehicle is based. The data transmitted with the video/audio can, for example, include the date and time of recorded segments, together with organization and sequencing information, as well as digital serial data and event data. This data may also include police vehicle number, shift, time, personnel designations, and other fields, as desired.

The date and time information can be embedded in the video file with high accuracy, such as, in one embodiment, to within 1/30 of a second accuracy. Advantageously, because the date and time are recorded as meta-data, the date and time information does not have to be recorded in the actual visible video frame. Thus, upon viewing or playback, the date and time do not obstruct information in the video frame, and instead are optionally displayed in a separate window.

The serial data, for example, can include records of data communications of an external remote data terminal, alarm data from an external security sensor system, or other data from other serial interfaces, such as an RS-232 or IP interface. The serial data can be embedded in the video stream and recorded in the video file to within 1/30 of a second accuracy, though greater or less accuracy can be used in other embodiments. In one embodiment, up to 256 external data sources can be simultaneously supported, though in other embodiments more than 256 data sources can be recorded. In addition to serial data, parallel data can be recorded as well. In one embodiment, parallel data is first serialized and then recorded as serial data. Advantageously, because the data from any virtual channel are recorded as meta-data, the data and/or information derived therefrom does not have to be recorded in the actual visible video frame. Thus, upon viewing or playback, the

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data and/or information do not obstruct information in the video frame, and instead are optionally displayed in a separate window.

One embodiment of the recorder 100 provides event-based recording that enables users to activate a recording session by either pressing a button or activating another device used as an event trigger such as a vehicle light bar, or an alarm contact or other sensor. In cases where a recording is already in progress, a digital "flag" is created and embedded that enables a viewer to find the event during playback. Recording may optionally be started remotely by network connection, either manually, or automatically using a plurality of pre-determined external events, parameters, or triggers.

Optionally, a record of the location of a vehicle, such as a patrol vehicle or aircraft, can be embedded in the video file. For example, the GPS data can be provided by a GPS system within the vehicle and embedded in the same fashion as serial data.

In particular, when a recorder 100 comes into proximity with its designated home network, using, by way of example, an 802.11 wireless network, the assembler 120 recognizes each recorder 100, and interrogates the recorder 100 for new records or files. If the recorder 100 contains new recordings, the assembler 120 automatically commences the file upload process. Once the files have been transferred and verified, the assembler 120 notifies the recorder 100 that the file upload is complete, and instructs the recorder 100 to clear its record volume for new recordings. The assembler 120 optionally returns the recorder 100 to normal operations mode, or shuts the recorder 100 down.

The assembler 120 can, for example, be located in a facility with which the recorder 100 is likely to come within close proximity with on a regular basis, such as a station house. This allows a relatively short-range wireless network, such as 802.11g, to be used to communicate information and video between the recorder and the assembler 120.

The assembler 120 is coupled to a media server 123, such as Microsoft Media Server, which is coupled to a video access controller (VAC) 124, which is coupled to an archive controller 126. The archive controller 126 is coupled to mass storage units 160, 162.

The assembler server 120 optionally "assembles" associated files into a one cohesive and user-playable video recording. The assembler extracts and parses meta-data from the meta-data channels of the newly archived video file. A string searchable format file, such as an XML document, is then created by an XML generator 128 and associated

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with the video recording, parsed by information type, to enable "string" searches of the data embedded with the video and audio. The searchable document is stored in an information management system (IMS) 132. In one example embodiment, the assembler 120 combines related files into a single Internet streamable file containing the original data while preserving encoded RTP/RTSP streaming protocols embedded in the files by the recorder 100.

The video/audio stream is then transmitted, either immediately, or by predetermined schedule, by the assembler 120 to an appropriate video-on-demand database or storage media, such as the storage units 160 and 162 controlled by the archive controller 126. The storage unit 160 can be implemented as a RAID (redundant array of inexpensive disks) system providing high speed storage and retrieval, while the storage unit 162 can be implemented as a plurality of high capacity optical digital data storage disks providing relatively more capacity at lower overall long-term storage cost than the storage unit 160. The storage unit 162 provides a more permanent record of video stored in the RAID system 160, however, the write/read time may be slower than that provided by RAID system 160. Optionally, the storage unit 162 may be in the form of an optical WORM (write once, read many) drive or carrousel, including DVD disk or disks, the use of which prevents the editing of recorded files.

The system may include one or more digital recorder transmitter units 169, which can include or be connected to a plurality of mobile video/audio data recorders. For example, the digital recorder transmitter unit 169 can optionally record on internal magnetic or optical media 165 large amounts of video, such as one year or more of CIF video from, each of several cameras at relatively high frame rates. For example, one embodiment records at 30 frames per second (fps) for 160 video cameras at CIF simultaneously, with multiple audio channels, though other frame rates, resolutions, and quantity of video cameras can be used as well. The digital recorder transmitter unit 169 can further record one or more audio sources and multiple streaming data sources, such as data from alarm panels and machine controls. The system can also include one or more encoder systems 172, which is an MPEG multichannel encoder coupled to a plurality cameras transmitting live video, coupled to assembler keeper 139 via (Video Access System) VAS 170.

The digital recorder transmitter unit 169 also includes an omniport which includes or acts as a television tuner card. The omniport acts as a capture device so that the digital

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recorder transmitter unit 169 can be tuned to receive CCTV cable channels. This provides the capability for frequency division multiplexing to view desired images. This capability enables the user of the digital recorder transmitter unit 169 to capture the video/audio images that may be generated in such a closed circuit television system of the type often utilized for security purposes in various facilities.

The omniport interfaces into existing frequency modulation CCTV signals. This may include a number of different cameras, for example 160 or more cameras, the images of which are substantially simultaneously transmitted within a particular facility. The user of the digital recorder transmitter unit 169 may then select the desired channel in addition to being able to record images from other cameras. One such specific application where security is involved is on trains.

Trains or other vehicles traveling through various geographic regions will encounter communication and other device frequencies that could interfere with the wireless transmission of video/audio data signals. Under such circumstances, the video/audio data signals in analog format are frequency modulated and then are applied to the AC or DC electrical network utilized within the trains or other like vehicles. This frequency modulated signal may then be acquired through the omniport resident on the digital recorder transmitter unit structure in much the same manner as acquisition of a frequency modulated CCTV signal as described above.

The digital recorder transmitter unit 169 also includes an assembler server system 163, a VAC 164, a media server 166, and an archive controller 168, which functions in the same manner as described above with respect to the assembler server system 120. The output from the digital recorder transmitter units 169 may then be transmitted to the assembler keeper 139 as was the XML signal from the assembler 120. The video/audio signal is then transmitted directly to a storage medium, such as the RAID system 165. As previously discussed with regard to the mobile video/audio data recorder 100, the meta-data and other identifying information regarding the video/audio is transmitted to the IMS 132.

With regard to both the mobile video/audio data recorder 100 and the digital recorder transmitter units 169, the archive controllers 126 and 168 respectively control the recording of the video in the RAID systems 160 and 165. Optionally, the storage unit 162 stores an exact copy of at least a portion of the meta-data and/or video on more permanent storage, such as on a optical media, of selected files recorded in the RAID system 160 for

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authentication purposes, as discussed below, and for backup purposes. Further, having the recorded copy can be kept at a site geographically remote, such as more than 150 meters distant, from the RAID system 160 provides for increased security.

The IMS 132 will now be discussed. The IMS 132 includes one or more relational databases, such as Oracle 9i or 10g, an ASP (Active Server Page)/Fusion module 134, a Java generator 138, an assembler keeper 139, and a computer aided dispatch (CAD) keeper 140. The CAD keeper 140 is further coupled to a CAD system 175.

The ASP/Fusion module 134 is used to generate pages, such as HTML pages, that include one or more scripts, such as JavaScript or VBScript. The module 134 processes the scripts on a Web server associated with the module 134 to customize the pages for the user and to provide transaction security. The customization can be based on information received from the user or the user terminal. By way of example, the information can be provided by way of a URL or address for an appropriate Web site page. The URL can be provided by the user browser when requesting a page to access data from one or more of the system databases. The ASP/Fusion module 134 can then build the requested page in substantially real time and send it, via a Web server, to the requesting user terminal for display in a browser or other application. By way of example, the ASP/Fusion module 134 can be implemented using Macromedia's ColdFusion product, including the ColdFusion Studio and the ColdFusion Server, though other applications and Web servers can be used as well.

The CAD system 175 can, for example, be used to process emergency or help calls from the public and handle police dispatches to police officers or police vehicles. Of course the CAD system 175 can also be used to handle dispatches from other entitites, such as fire department dispatches, hospital dispatches, and dispatches of other governmental or non-governmental entities. By way of further example, a CAD system 175 can be used to guide a call-taker or dispatcher into collecting relevant information, such as the address or location, related to an incident or compliant being reported, which the call-taker then enters into a form presented by the CAD system 175 on the call-taker's computer terminal. The information is optionally then stored in a CAD database. The CAD system 175 may check to make sure certain information, such as the address, is valid. The CAD system 175 or other entity may assign an incident or case number or code to the incident.

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Appropriate resources, such as one or more police cars, foot patrols, motorcycle officers, and/or ambulance units are then selected and dispatched to handle the incident. The CAD database also stores information on which resources were selected and dispatched to handle the incident. One or more status events for each resource may also be recorded in the database. For example, the status can include an acknowledgement from the resource that the dispatch was received. Another status can include a report from the resource that the resource has arrived at the scene of the incident. Still another status might relate to the resource leaving the scene.

In particular, the IMS 132 provides users with the ability to view a particular video record which has been made of a particular event in the past. The IMS 132 further enables the user to search for meta-data associated with archived videos, permits users to play back recordings at subjective times based on the meta-data and data field searches, and enables playback of specific records when selected by a user. Authorized users also have the ability to navigate and play back requested files on the storage system, provided that they have clearance to do so. There can be multiple levels of clearance, such as up to 30 or more levels of authorization that are used to determine user access to file types and specific data. The authorization can be centrally specified by the system administrator. The IMS 132 tracks user access to files and user activity on the IMS 132. Thus, for example, if a user chooses a file by going directly to the storage system to commence playback directly from archive, the user's activities are automatically logged. User's are optionally prevented from erasing archived files. Access to "housekeeping" functions are optionally reserved to the system administrator.

The IMS 132 extracts files created by the assembler 120 and automatically enters files to its database that are initially designated by the system administrator or other user during system set-up. Video files are stored in a separated storage volume, such as storage unit 160, accessible to users provided that they receive access authorization from the IMS 132.

For example, upon occasion an individual may desire to view a particular video record which has been made of a particular event in the past. With reference to Figure 2, when such is desirable, a user may access the IMS 132 over a network 204 through the utilization of a terminal 212, which can be a personal computer, personal digital assistant, cell phone, interactive television, or the like. The network 204 can be a local or wide area

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network, the Internet, or an intranet. When contact has been made between the user's terminal 212 and the IMS 132, the user logs on by providing a user identifier and pass code. After the log in has been completed and appropriately acknowledged by the IMS 132, the active server page/fusion module 134 generates a web page which will appear in a browser on the user terminal's screen 302, as illustrated in Figure 3.

Optionally, the web page is configured specifically for this particular user and will identify for the user, depending upon his position, the various files to which the user is entitled to have access. This web page is built in conjunction with the JAVA.generator 138 which generates appropriate JavaScript. A web page, an example of which is illustrated in Figure 8, provides the ability for the user to enter a specific string of information into a database search field or value field for the purpose of generating a search for a specific event or for a specific period of time. The user can initiate a search by clicking on the "find" button, cancel a search in progress by clicking on the "cancel" button, initiate a new search by clicking on the "new search" button, add criteria by clicking on the "add criteria" button. The user can also specify as to whether subfolders are to be searched by clicking on the "recurse" field.

The query can include a Boolean combination of one or more of an incident or case identification code, the identity (for example, name or employee identification code) of a person or officer responding to a dispatch, the name of a person reporting an incident, the name of a person arrested, cited, or questioned during an incident, the police vehicle number, the video camera identification number, the date and/or time of an incident, the date and/or time of a video recording, an event, such as a weapon removal from a rack, a light bar turning on/off, a siren turning on/off, a vehicle speed, a vehicle door opening/closing, a gun discharge, an alarm signal, a crash signal, geographical location, GPS geographical position coordinates, and the like.

For example, the user can request or search for files associated with a particular vehicle that were recorded in response to the vehicle light bar being turned on in order to locate the beginning of all situations in which the officer issued a traffic ticket. In another example, in order to determine if an office was driving unnecessarily fast, the user can request files wherein a police vehicle driven by a named officer exceeded 65 miles/hour when the vehicle light bar was not turned on. Similarly, the user can request files associated with a specific incident number to locate videos and meta-data associated with

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the incident, even when the video and meta-data was recorded by different recorders, such as recorders in all police vehicles assigned to respond to the incident. By way of further example, the user can request files associated a specific incident number that were originally recorded within 1 hour after an officer responded to a dispatch. By way of yet another example, the user can request files associated with the swiping or entering a driver's license number taken during a traffic stop in order to locate video for a particular citation incident.

In response to the query, the user will be provided a list of files which matches the search string and which the user is authorized to access. The list can be sorted by time of date, time, size, name, incident code, officer name, name of person reporting an incident, event, and/or on other fields, including customizable fields. Optionally, the user can specify one or more search properties, one or more operators, including Boolean and other operators (such as AND, OR, XOR, NOT, exact match, NEAR), values, and the like.

As similarly discussed above, in one optional embodiment, the particular file of interest may not be stored in the IMS 132, and is accessed from the storage device 160 coupled to the assembler 120 or alternatively the RAID storage system 165 associated with a corresponding digital recorder transmitter unit 169.

Access to video files and data can be restricted and controlled. For example, when the user clicks on a link corresponding to a particular video file of interest, the video access controller (VAC) 124 generates a certificate in the form of an ultra long alphanumeric string, such as a 64, 128, or 256 bit string, which can be arbitrary in nature. That certificate is transmitted as shown at 208 to the user terminal 212 along with a command to redirect the user's browser to the particular file which resides on the storage system 160, for example, as is shown at 210. Substantially simultaneously, the video access controller (VAC) 124 will transmit the identical certificate directly to the archive manager or RAID system 160 as shown at 206. The certificates, transmitted by the video access controller 124 as shown at 206 and redirected by the computer 212 as shown at 210, are then matched to ascertain identical confirmation thereof. In the event that a match is obtained within a predetermined of time such as a very short period of time (seconds), access to the selected file is then granted and the file is forwarded to the computer 212 and appears on the screen 302 as illustrated graphically at 304. Thus, the video associated with the selected file is

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displayed, as well as the synchronized meta-data that was recorded and embedded in the video file.

For example, if a recorded event occurs, such as the light bar being turned on, the user will see that discrete recorded event happening at a certain time during the video. If the user desires to search for the light bar "on" event, the video will begin playing at the moment when the light bar is activated. Similarly, the user can search on other data or events, such as a drivers license number, which was either embedded in the video file at the time of the recording, or associated with the file during the data mining procedure after the comparator file was delivered to the IMS. Likewise, a user can search for the removal of a weapon from a weapon rack, activation of a siren, the vehicle reaching a specified speed, specified data communication transmitted to police car terminal, that were either recorded at the time of the creation of the record, or associated with the video during the data mining procedure.

As the video plays, the user may control what appears on the screen. For example, the user may play the whole video in full screen. Alternatively, as illustrated by display 718 in Figure 7, multiple frames or windows can be provided. For example, a GPS map may be generated and displayed, as well as terminal traffic (including data entered by the officer or other user), speedometer readings, date and time, and like in corresponding windows or frames. Other displayed information can show the status of various other events, such as the status of firearms, seat belts, and the like. The foregoing information optionally will appear scrolling up synchronized to the video/audio, map location, speedometer reading, etc. If the recorded video did not have a data terminal, then that information would not be displayed. Under those circumstances, the page gets reconfigured automatically and so what is displayed is something that is size appropriate reconstructed in substantially real time because it is generated for the specific user. So now the video is larger and the telemetry data is repositioned to whatever is most convenient. The ASP/fusion generator module 134 automatically determines the best or preferred way to display the desired file.

If there is a failure to obtain the desired match up between the certificate directed by the VAC to the storage device 160 with the redirect from the computer 32 to the storage device 160, then the following process is optionally performed. The connection is immediately terminated. The period of time within which this match of the ultra long alphanumeric string needs to occur can be any time desired for the particular application,

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such as for example, a few seconds or a few minutes. If the match does not occur within the specific period of time, then the user is optionally required to again log on to the IMS 132, establish the secure connection, enter the pass code and again request the file as described above.

If the system fails to obtain a match up of the alphanumeric string for a predetermined number of times, for example, three, then the user attempting to obtain access is optionally locked out of the system and will not be able to obtain access to the files desired without obtaining clearance through the system administrator. This process for video access control is referred to as a temporally extinguished certificate. It will be recognized by those skilled in the art that what has occurred is that when the user has established initial user authentication and when the temporally extinguished certificate matches within the specified period of time, then the particular file which the user has selected and particularly for the specific moment from which playback is to start appears on the screen as shown in 304 in Figure 3. Once access has been granted, then the user may control viewing of the selected video by going forward, backward, stop framing or the like as long as the socket remains open. Optionally, unless appropriately authorized by the appropriate supervisor or administrator, the user will have no overwrite capabilities of any type and may only view the video.

Because the user is requesting a specific video file identified on the web page which has been generated specifically for that user by the ASP/fusion module 134 and-JAVA generator 138, the URL for the media server for that particular storage media is provided by the video access control (VAC) and is contained in the redirect 210 generated by the video access controller 124 and transmitted to the user's computer 212. The video is streamed to the user's terminal or computer 212, and so television-quality video playback can start very quickly, such as within seconds or faster, without having to wait for files to transfer to the local user's machine. Optionally, however, the entire file can be transferred to the local user terminal 212 before playback begins, though this may be a more time consuming process.

The media storage may also include information which is obtained from alien databases obtained and associated with the specific file during a data mining procedure as described below. Alien databases are databases controlled or existing outside of the information management system 132. In one embodiment, through the utilization of the

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CAD keeper 140 a search is made of the alien or external databases to obtain information which is relevant to the information being generated from the video stored in the overall system. That information is automatically entered into the IMS relational database stored on the RAID 142 that is connected to the IMS 132, and optionally associated with corresponding video files. This information is then also available and will appear for utilization by the user on the web page generated and displayed on the terminal 212 when log in occurs and is authenticated.

The database searches can be performed in substantially real time by generating quires, or in batch mode. By way of example, the alien databases can include one or more of a DMV (department of motor vehicle records) database, a CAD database included in the CAD system 175, a database of police reports filed by police officers, a database of 911 emergency phone calls, a database of incident reports, and so on. By way of further example, as similarly discussed above with respect to CAD system 175, the CAD database can include information related to an incident or compliant being reported, such as the incident or case number, the date and time the incident was reported, the date, time and location of the incident, the type of incident, which resources were assigned to handle the incident, the status of those resources before during and after handling the incident, and related incident reports.

In some applications, such as for evidentiary purposes law enforcement, it can be important to ensure that archived video and meta-data has not been tampered with. Therefore, in one embodiment when a record is being uploaded for storage in a database, the IMS 132 creates a second duplicate meta-data record and stores it in a file, and optionally on a different storage device at a removed location, separate from the original uploaded record. When a user requests a record the IMS 132 automatically compares the two stored meta-data records, including for example the objective time ticks, subjective time ticks, event data, serial data, and so on, to authenticate the record. If the original digital record has been modified, such as by deleting or replacing one or more video frames, the duplicate meta-data record will not match, and the IMS will alert the user and/or system administrator of the match failure. Further, because most of the encoded, stored video frames are predicted or interpolated from other frames, the deletion of one or more frames can cause the other frames to visibly render properly, further indicating tampering.

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An XML compare file is provided below. The file is generated by the assembler 120 and is used to transmit extracted data embedded by a recorder 100 into a video data channel of an archive file for automated data entry by the assembler keeper to the IMS relational database. In addition, the file is used to authenticate an archived record by comparing subjective time tick proximity to data for file validation. The file is further used to format the ASP user interface for concurrent data display of video and meta-data from multiple sources.

1. <?xml version="1.0" encoding="UTF-8"?>
2. <xs:schema xmlns:xs= (ASM Comparator File)
3. <xs:element name="Mobile video/audio data recorder File ID" type=" xs:string "/>
4. <xs:element name="Mobile video/audio data recorder ID" type=" xs:string "/>
5. <xs:element name="Event Date Objective Value" type=" xs:string "/>
6. <xs:element name="Event Start Objective Time" type="xs:string"/>
7. <xs:element name="Event Start Objective TimeZone" type="xs:string"/>
8. <xs:element name="User Label" type=" xs:string"/>
9. <xs:element name="Subjective Duration" type="xs:duration"/>
10. <xs:element name="EndingValue" type="xs:float"/>
11. <xs:element name="Increment" type="xs:int"/>
12. <xs:element name="System Label" type="xs:string"/>
13. <xs:element name="Element List" type=" xs:string .
14. <xs:element name="Video Format" type=" xs:string "/>
15. </xs:sequence>
16. <xs:element ref="subjective time tick"/>
17. <xs:element name="State Change Name" type="xs:float"/>
18. <xs:element name="Serial Data Channel Name" type="String"/>
19. <xs:element name="Objective DateTime" type="String"/>
20. <xs:element ref="subjective time tick"/>
21. <xs:element name="State Change Name" type="xs:float"/> (state change labels assigned to Mobile video/audio data recorder digital IO ports corresponding to application – any number of different elements to maximum available IOs)
22. <xs:element name="Serial Data Channel Name" type="String"/> (serial data labels assigned to Mobile video/audio data recorder serial data or network IO ports corresponding to application – any number of different elements to maximum available IOs)
23. <xs:element name="Objective DateTime" type="String"/>
24. <xs:element ref="subjective time tick"/>
25. <xs:element name="State Change Name" type="xs:float"/> (state change labels assigned to Mobile video/audio data recorder digital IO ports corresponding to application – any number of different elements to maximum available IOs)
26. <xs:element name="Serial Data Channel Name" type="String"/> (serial data labels assigned to Mobile video/audio data recorder serial data or network IO ports corresponding to application – any number of different elements to maximum available IOs)
27. <xs:element name="Objective DateTime" type="String"/>
28. <xs:element ref="subjective time tick"/>

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29. <xs:element name="State Change Name" type="xs:float"/> (state change labels assigned to Mobile video/audio data recorder digital IO ports corresponding to application – any number of different elements to maximum available IOs)
30. <xs:element name="Serial Data Channel Name" type="String"/> (serial data labels assigned to Mobile video/audio data recorder serial data or network IO ports corresponding to application – any number of different elements to maximum available IOs)
31. <xs:element name="Objective DateTime" type="String"/>

Lines 1-14 comprise the header information used to define constants, such as recorder identifier, date, time increments, and the like. The other lines are used to specify information specific to a segment, such as the value or change in status of events, time tick values, and the like.

Line 1 of the example file format provides the version number and the encoding type. In this example, UTF-8 is used, though other encoding types can be used as well. UCS characters U+0000 to U+007F (ASCII) are encoded as bytes 0x00 to 0x7F (ASCII compatibility). Advantageously, files and strings which contain 7-bit ASCII characters have the same encoding under both ASCII and UTF-8.

Line 2 is used to declare the namespace.

Line 3 is used to define the mobile video/audio data recorder file identifier.

Line 4 is used to define the mobile video/audio data recorder identifier.

Line 5 is used to specify the event date using an objective date, such as the Greenwich Mean Time (GMT) date.

Line 6 is used to specify an event start time using an objective time, such as GMT.

Line 7 is used to specify the time zone being used in lines 5 and 6. For example, the objective time zone can be GMT or Pacific standard time (PST).

Line 8 is used to specify the user label, which can be a easily remembered label, such a "Bank" recorder if the recorder is located in a bank, or "Intersection of Westwood and Wilshire" if the recorder is located on a post located at the intersection of Westwood and Wilshire.

Line 9 is used to specify the subjective duration

Line 10 is used to specify the file size.

Line 11 is used to specify the time increment used for the subjective time ticks.

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Line 12 is used to specify the system label, such as the System ID which can indicate that the system is associated with a certain entity, such as the Los Angeles Police Department, California Highway Patrol, FBI, and so on.

Line 13 is used to specify the element list that assigns channels to data sources. For example, GPS coordinates can be assigned to channel 1, and terminal traffic can be assigned to terminal 2. This information can also be stored in a unit configuration file in the IMS database.

Line 14 is used to specify the video format, such as MPEG 1, MPEG 2, MPEG 4, H.323 encoding.

Line 15 is used to as compositor to define the virtual data channel sequence. Because, in one embodiment, channels that contain no data are not transmitted, the sequence provides an efficient way of delineating what the ASM keeper is about to parse.

Line 16 is used to specify the current subjective time tick for the corresponding segment.

Line 17 is used to specify state change values for labels assigned to the mobile video/audio data recorder digital IO ports corresponding to a given application.

Line 18 is used to specify the serial data values for labels assigned to the mobile video/audio data recorder serial data or network IO ports corresponding to a given application.

Line 19 is used to specify the objective data and time for the corresponding segment.

Lines 20-31 are used to specify the subjective time ticks, state change values, serial data values and objective dates and times for additional segments.

As will be clearly understood from the foregoing description, the user may wish to simultaneously access different video files from the storage media. For example, as illustrated in Figure 4, three different video files labeled A, B, and C may be retrieved for simultaneous display on the user's screen. It will often be desired to synchronize the video streams A, B and C in order to assure that the events being viewed arc being viewed with relation to the exact time which they occurred even though the video streams A, B and C may have been generated by totally different cameras and, even in some instances, totally different parts of the world.

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To facilitate such synchronization, each of the video streams A, B and C have an objective time recorded thereon as shown at 404, 412 and 416. The time indicators 404, 412 and 416 are each objective time. The objective time can be Greenwich Mean Time (GMT), sometimes referred to as ZULU time, though other time zones can be used as well. As a result, the video stream A and the video stream B may be synchronized so that the objective times 404 and 412 are identical or substantially identical, as well as having the video stream C also synchronized so that the events occurring on each of the video streams A, B and C are all occurring based upon commencement at the objective times 404, 412 and 416.

In addition, each of the video streams will have a subjective time marking as shown at 406, 410 and 414, respectively, on the video streams A, B and C. Each of these subjective time markings are relative to the duration of the specified video file. As an example, the ticks of the clock are recorded for each video frame or picture within the file. Once the video streams A, B and C are properly synchronized according to the objective time designations times 404, 412 and 416, the user may then be able to correspond the events being depicted on each of the video steams A, B and C with the local time at the particular venue for purposes of analysis, comparison to other events, or the like. This ability to synchronize is provided using a UTBC (Universal Time Base Controller) included in the assembler 120.

Figure 5 illustrates an example video sequence 500 which includes video 502, a first audio channel 504, a second audio channel 506, and meta-data 508. The variable vA is the bit rate variable, which is related to the number of frames/second and the image quality. The variable vB is the audio bit rate, which can relate to bit depth, how many audio channels are being recorded, the dynamic range. The variable vC is the meta-data bandwidth which is related to maximum bit-per second of aggregate channels. A recorder, such as recorder 100, can be constantly capturing data 510 in a buffer, such as a ring buffer or FIFO, until an instruction or start event starts the recording. The duration of the buffer is v1. The recorder then records multiple segments, such as multiple segments 512, 514, 516, 518, 520 of duration v2. The time v2 can be specified by the user and/or the system administrator. Figure 6 illustrates the conversion of the segments 512-520 illustrated in Figure 5 into an assembled file 602 as assembled or merged by the assembler.

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Figure 7 illustrates the process of converting assembled video/audio and meta-data files into a Web page for display on a user terminal. The meta-data in file 602 is packetized for transmission over the meta-channel 710 using an address header 704 and a barer channel variable length packet 706, wherein the meta-data can include channels corresponding to multiple datasources.

Figure 9 illustrates an example process of accessing and rendering video streams. At state 902 a user accesses the IMS. As similarly described above, the user may need to log on and provide a user identifier and password. At state 904 a determination is made as to what files the user is authorized to view, and the list of authorized files are sorted and transmitted to the user terminal. The list can be sorted by time of day, date, size, event, or on other fields, including customizable fields. In response to the user selecting one or more of the files, at state 906 the ASP downloads the selected file or files. The frame rate, bit rate and resolution for transmission can be selected based on the wired or wireless network being used and/or on the receiving terminal resolution and frame rate rending capability. At state 908 data, including video, audio, and meta-data may be transmitted from more than one source, such as the IMS and/or ASM. For example, the IMS may transit a GPS map and the ASM can transmit GPS coordinates that was recorded by a vehicle in synchronization with video taken by a video camera mounted in the vehicle. At state 910 the data in rendered on the user terminal screen, such as in the user's browser.

Figure 10 illustrates an example encoding process for live source transmission and recording from up to four different simultaneous streams generated from a single camera source, though fewer or more cameras can be used and fewer or more streams can be transmitted and recorded. The example encoding process optionally uses a dedicated processor for MPEG 1, MPEG 2, MPEG 4, CIF, D-1, and High Definition, as well as using real-time software-based encoders that substantially simultaneously encode at various bitrates/frame rates/frame sizes for playback or viewing on a plurality of different user devices such as PDAs, notebooks, and desktop computers. In this example, the "Stream controller" is a infinite pin tee that replicates video/audio data from a single sample source device to enable multiple encoders to simultaneously access different memory addresses for the same data stream. Those familiar with the art will recognize that this is also a software driver "wrapper" used to "spoof" the functionality of a device driver for each of the

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replicated signal sources. Each of the encoded video streams may be recorded, formatted for RTP/RTSP, while any or all of them are simultaneously available for live transmission .

It should be understood that certain variations and modifications of this invention would suggest themselves to one of ordinary skill in the art. The scope of the present invention is not to be limited by the illustrations or the foregoing descriptions thereof.

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WHAT IS CLAIMED IS:

1. A recording and transmission system comprising:

a recorder mountable in a police vehicle configured to record video and meta-data synchronized with the video, wherein the recorded video includes a plurality of segments having fixed lengths, the recorder including a wireless transmitter configured to wirelessly transmit the recorded video segments and meta-data, wherein the meta-data includes:

data related to vehicle status;

subjective time information;

objective time information;

serial data;

an assembler configured to wirelessly receive the transmitted video segments and assemble the video segments into a file including the meta-data, the assembler further including a mass storage device used to store the assembled video and transmit the assembled video; and

an information management system coupled to the assembler to receive the assembled video and to store the meta-data in a relational database, wherein the information management system is configured to receive a user search query from a first terminal having a first resolution, conduct a search of the meta-data based at least in part on the search query, transmit the results of the search to the first terminal, receive a user selection of at least a first of the results, configure the video corresponding to the selected result for the first terminal based at least in part on the first resolution, and transmit the configured video to the first terminal.

2. The system as defined in Claim 1, wherein the assembler is configured to provide the information management system with the meta-data as a string searchable file.

3. The system as defined in Claim 1, wherein the assembler is configured to provide the information management system with the meta-data as an XML file parsed by information type to enable string searches of the meta-data.

4. The system as defined in Claim 1, further comprising a certificate configured to be passed to the user and at least one other destination.

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5. The system as defined in Claim 1, wherein the mass storage device includes both a magnetic and optical memory, and the assembled video is stored on both the magnetic and optical memory.

6. The system as defined in Claim 1, wherein the recorder records in an MPEG compatible format.

7. The system as defined in Claim 1, wherein the wireless transmitter is compatible with at least one of CDPD, GSM, GPRS, and 802.11.

8. The system as defined in Claim 1, wherein the video is configured using an Active Server Page generator.

9. The system as defined in Claim 1, wherein the vehicle status is related to the status of a light bar.

10. The system as defined in Claim 1, wherein the vehicle status is related to the status of vehicle speed.

11. The system as defined in Claim 1, wherein the vehicle status is related to the status of a weapon rack.

12. A method of storing and providing video data, the method comprising:

receiving a first video file including video and embedded meta-data, the meta-data including at least:

timing information;

status information;

storing copies of at least a portion of the first video file in a second video file on a first data storage system and in a third file on a second storage system;

generating at least a first string searchable file based at least in part on the meta-data;

receiving a user search query;

conducting a search of information in the first string searchable file based at least in part on the user search query;

presenting results of the search to the user via a user terminal;

receiving a user search results selection corresponding to the second video file;

retrieving the second video file and the third video file based at least in part on the user selection;

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comparing at least a first portion of the meta-data in the second video file with a corresponding portion in the third video file in order to determine if file tampering has occurred; and

transmitting at least a portion of the second video file to the user terminal.

13. The method as defined in Claim 12, further comprising:

determining the display capabilities of the user terminal based at least in part on a URL received from the user terminal; and

tailoring the portion of the second video file based at least in part on the user terminal display capabilities.

14. The method as defined in Claim 12, wherein the timing information includes subjective timing information, and comparing at least a first portion of the meta-data in the second video file with a corresponding portion in the third video file further comprises comparing subjective timing information.

15. The method as defined in Claim 12, wherein the meta-data includes serial digital data, and comparing at least a first portion of the meta-data in the second video file with a corresponding portion in the third video file further comprises comparing at least a portion of digital serial data.

16. The method as defined in Claim 12, wherein the first video file is received from a storage device located in a vehicle.

17. The method as defined in Claim 12, wherein tailoring the portion of the second video file is performed in substantially real time.

18. The method as defined in Claim 12, wherein tailoring the portion of the second video file is based at least in part of a URL provided by the user terminal.

19. The method as defined in Claim 12, wherein the status includes at least a vehicle status.

20. The method as defined in Claim 12, wherein the status includes at least a weapon status.

21. The method as defined in Claim 12, wherein the status includes at least an alarm status.

22. The method as defined in Claim 12, further comprising:

generating a certificate;

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transmitting a first instance of the certificate to the user terminal and a second instance of the certificate to the first data storage system; and

comparing the first instance of the certificate with the second instance of the certificate to determine whether to transmit the portion of the second video file to the user terminal.

23. The method as defined in Claim 12, further comprising:

transmitting GPS coordinate information from a first data storage device to the user terminal; and

transmitting from a second data storage device a map corresponding to the GPS coordinate information to the user terminal.

24. A method of storing and providing video data, the method comprising:

receiving and storing data including a video sequence and synchronized meta-data;

generating at least a first string searchable data structure based at least in part on the meta-data;

receiving a user search query; and

conducting a search of information in the first string searchable data structure based at least in part on the user search query.

25. The method as defined in Claim 24, wherein the search query includes an incident code.

26. The method as defined in Claim 24, wherein the search query includes a police officer identifier.

27. The method as defined in Claim 24, wherein the search query relates to a vehicle light bar status.

28. The method as defined in Claim 24, wherein the search query relates to a vehicle speed.

29. The method as defined in Claim 24, wherein the search query relates to a vehicle identifier.

30. The method as defined in Claim 24, wherein the search query relates to a driver license identifier.

31. The method as defined in Claim 24, wherein the search query relates to a time.

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32. The method as defined in Claim 24, wherein the search query relates to a weapon status.

33. The method as defined in Claim 24, wherein the search query relates to a sensor status.

34. The method as defined in Claim 24, wherein the search query relates to a geographic location.

35. The method as defined in Claim 24, further comprising:

transmitting at least a portion of the results of the search to the user via a user terminal;

receiving a user search results selection corresponding to the video sequence;

retrieving the video sequence based at least in part on the user selection; and

transmitting at least a portion of the video sequence to the user terminal.

36. The method as defined in Claim 24, further comprising:

transmitting at least a portion of the results of the search to the user via a user terminal.

receiving a user search results selection corresponding to the video sequence;

retrieving at least a first copy and a second copy of the video sequence based at least in part on the user selection;

comparing at least a first portion of the meta-data in the first copy with a corresponding portion in the second copy in order to determine if file tampering has occurred; and

transmitting at least a portion of the first copy to the user terminal.

37. The method as defined in Claim 24, further comprising displaying at least a portion of the video sequence on a first area of a user terminal display at the same as displaying meta-data in a second area of the user terminal display, wherein the first area and the second area do not overlap.

38. The method as defined in Claim 24, further comprising associating data from a plurality of databases with the video sequence.

39. The method as defined in Claim 24, further comprising:

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transmitting at least a portion of the results of the search to the user via a user terminal;

receiving a user search results selection corresponding to the video sequence;

retrieving the video sequence based at least in part on the user selection;

retrieving related data from a plurality of alien databases; and

transmitting at least a portion of the second video file and related data to the user terminal.

40. The method as defined in Claim 24, further comprising:

transmitting at least a portion of the results of the search to the user via a user terminal;

receiving a user search results selection corresponding to the video sequence;

retrieving the video sequence based at least in part on the user selection;

retrieving related data from a computer aided dispatch system database; and

transmitting at least a portion of the second video file and related data to the user terminal.

41. The method as defined in Claim 24, further comprising:

transmitting at least a portion of the results of the search to the user via a user terminal;

receiving a user search results selection corresponding to the video sequence;

retrieving the video sequence based at least in part on the user selection, wherein the video sequence is related to an incident reported to a government entity;

retrieving data related to a resource dispatched to respond to the incident, the data including one or more of an acknowledgement from the resource that the dispatch was received, and data indicating that the resource has arrived at the scene of the incident; and

transmitting at least a portion of the second video file and related data to the user terminal.

42. The method as defined in Claim 24, wherein the video is recorded using intracoded frames, predicted frames, and bi-directional frames, wherein at least a first

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quantity of intracoded frames are generated when at least 25%, of pixels change in at least one of luminance and chrominance relative to a previous intracoded frames.

43. The method as defined in Claim 24, wherein the video sequence is received at 6 FPS (frames per second) with a resolution of 160 x 120 pixels.

44. The method as defined in Claim 24, wherein the video sequence is received 15 FPS with a resolution of 320 x 240 pixels.

45. The method as defined in Claim 24, wherein the video sequence is received at 30 FPS with a resolution of 352 x 240 pixels.

46. The method as defined in Claim 24, wherein the video sequence is received as streaming video.

47. An apparatus for storing and providing video data, the apparatus comprising:

a storage device configured to store data including a video sequence and synchronized meta-data;

a first instruction configured to generate at least a first string searchable data structure based at least in part on the meta-data;

a second instruction receive a user search query; and

a third instruction configured to conduct a search of information in the first string searchable data structure based at least in part on the user search query.

48. The apparatus as defined in Claim 47, further comprising a recorder system configured to be mounted in a vehicle, wherein the recorder is configured to wirelessly transmit the video sequence for storage on the storage device.

49. The apparatus as defined in Claim 47, further comprising a recorder system configured to record data in non-volatile memory in response to an event trigger.

50. The apparatus as defined in Claim 47, further comprising a recorder system, wherein when the recorder system comes into proximity with a designated network, the recorder system is interrogated for new records, and if the recorder contains new records, uploads the new records to a recipient.

51. The apparatus as defined in Claim 47, further comprising a recorder system configured to receive and record a plurality of closed circuit television channels.

52. The apparatus as defined in Claim 47, further comprising a video camera.

53. The apparatus as defined in Claim 47, further comprising a light bar on/off detector input.

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54. The apparatus as defined in Claim 47, further comprising a weapon rack sensor input.

55. The apparatus as defined in Claim 47, further comprising a weapon discharge sensor input.

56. The apparatus as defined in Claim 47, further comprising a vehicle speed sensor input.

57. The apparatus as defined in Claim 47, further comprising a tachometer sensor input.

58. The apparatus as defined in Claim 47, further comprising a radar sensor input.

59. The apparatus as defined in Claim 47, further comprising a vehicle door status input.

60. The apparatus as defined in Claim 47, further comprising a fuel level detector input.

61. The apparatus as defined in Claim 47, further comprising at least one of a heartbeat sensor input and a pulse rate sensor input.

62. The apparatus as defined in Claim 47, further comprising a chemical weapons sensor input.

63. The apparatus as defined in Claim 47, further comprising a GPS signal input.

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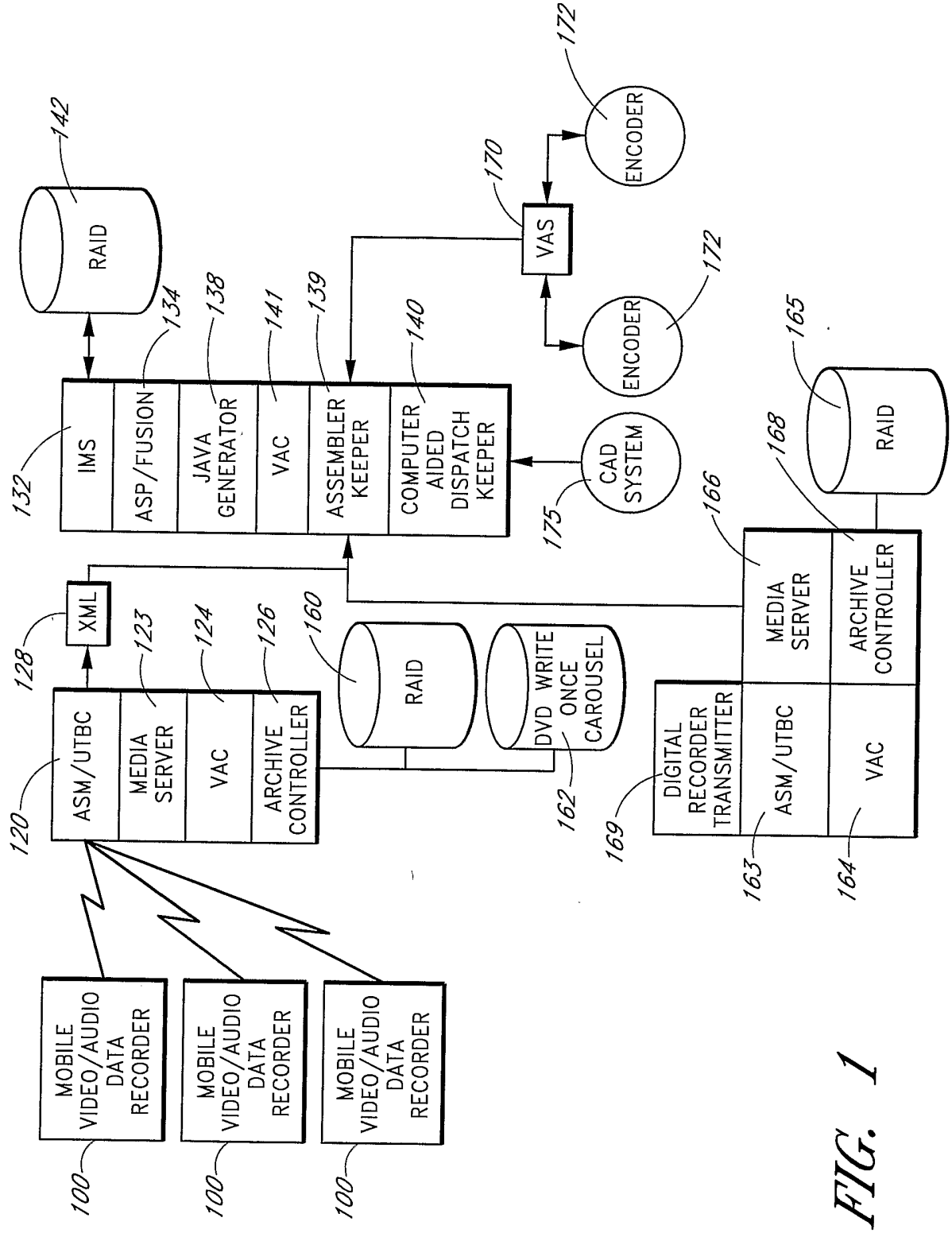

MOBILE VIDEO/AUDIO DATA RECORDER
100
MOBILE VIDEO/AUDIO DATA RECORDER
100
MOBILE VIDEO/AUDIO DATA RECORDER
100
ASM/UTBC
MEDIA SERVER
VAC
ARCHIVE CONTROLLER
120
123
124
126
XML
128
RAID
160
DVD WRITE ONCE CAROUSEL
162
IMS
ASP/FUSION
JAVA GENERATOR
VAC
ASSEMBLER KEEPER
COMPUTER AIDED DISPATCH KEEPER
132
134
138
141
139
140
RAID
142
CAD SYSTEM
175
VAS
170
ENCODER
172
ENCODER
172
DIGITAL RECORDER TRANSMITTER
169
ASM/UTBC
163
VAC
164
MEDIA SERVER
166
ARCHIVE CONTROLLER
168
RAID
165

FIG. 1

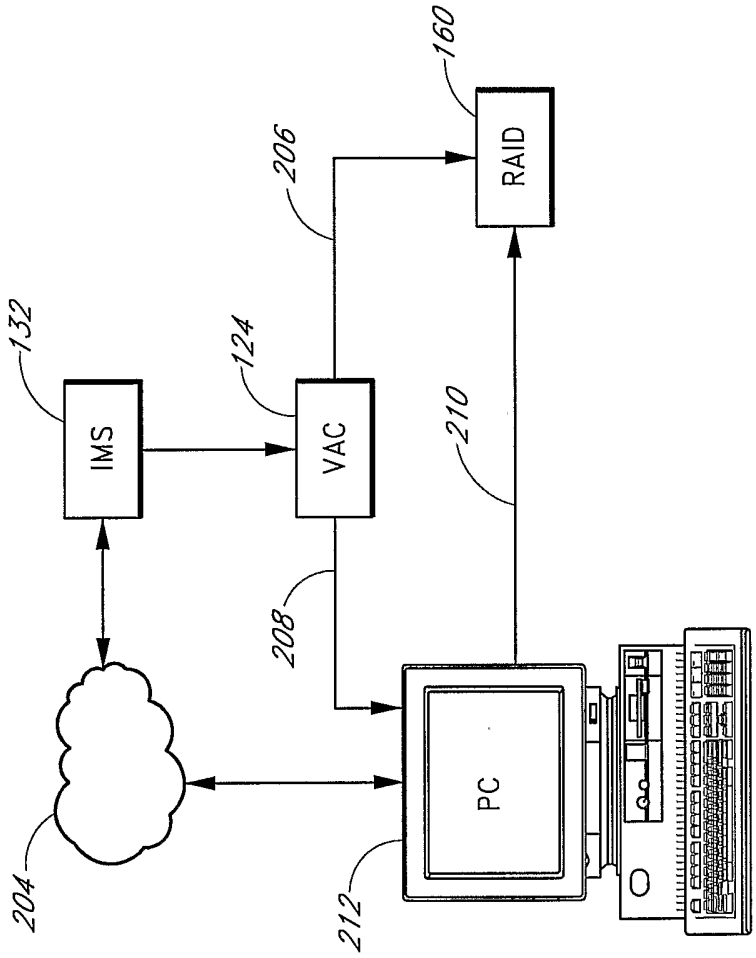


FIG. 2

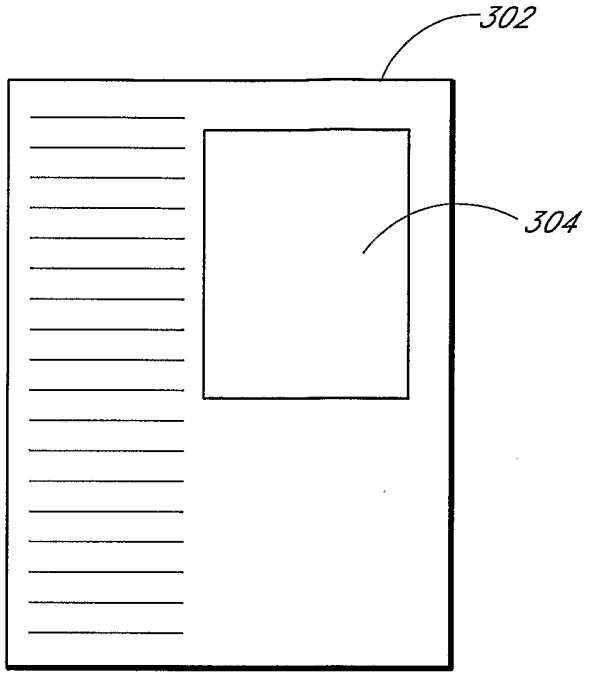


FIG. 3

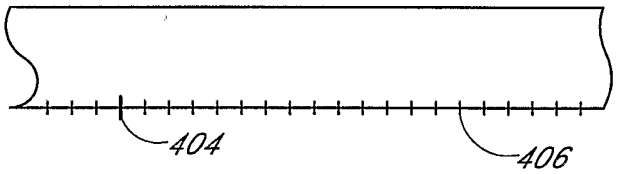


FIG. 4A

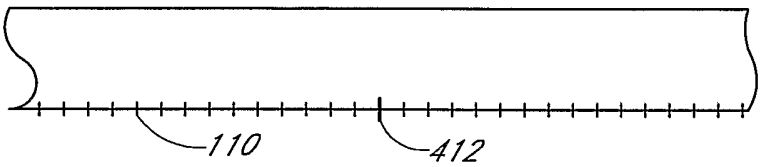


FIG. 4B

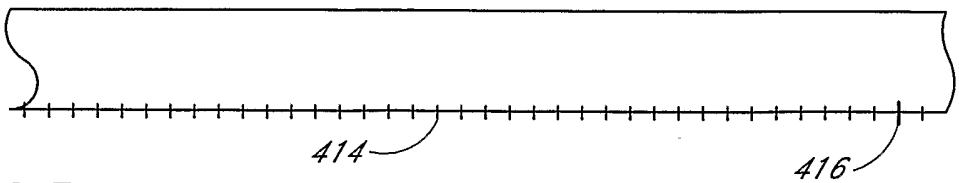
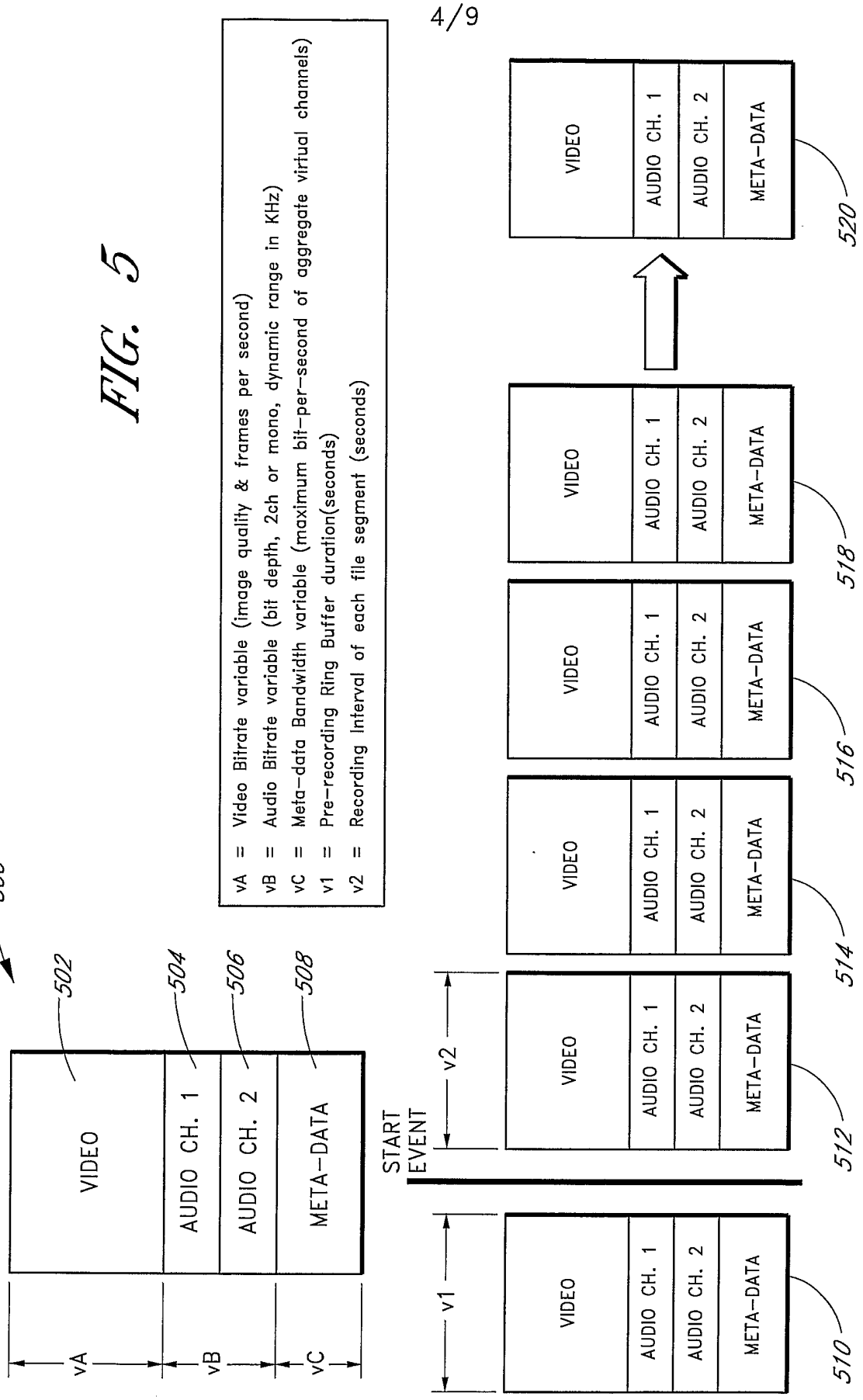


FIG. 4C

FIG. 5


vA = Video Bitrate variable (image quality & frames per second)
vB = Audio Bitrate variable (bit depth, 2ch or mono, dynamic range in KHz)
vC = Meta-data Bandwidth variable (maximum bit-per-second of aggregate virtual channels)
v1 = Pre-recording Ring Buffer duration(seconds)
v2 = Recording Interval of each file segment (seconds)
500
502
504
506
508
VIDEO
AUDIO CH. 1
AUDIO CH. 2
META-DATA
vA
vB
vC
START EVENT
v1
v2
510
512
514
516
518
520

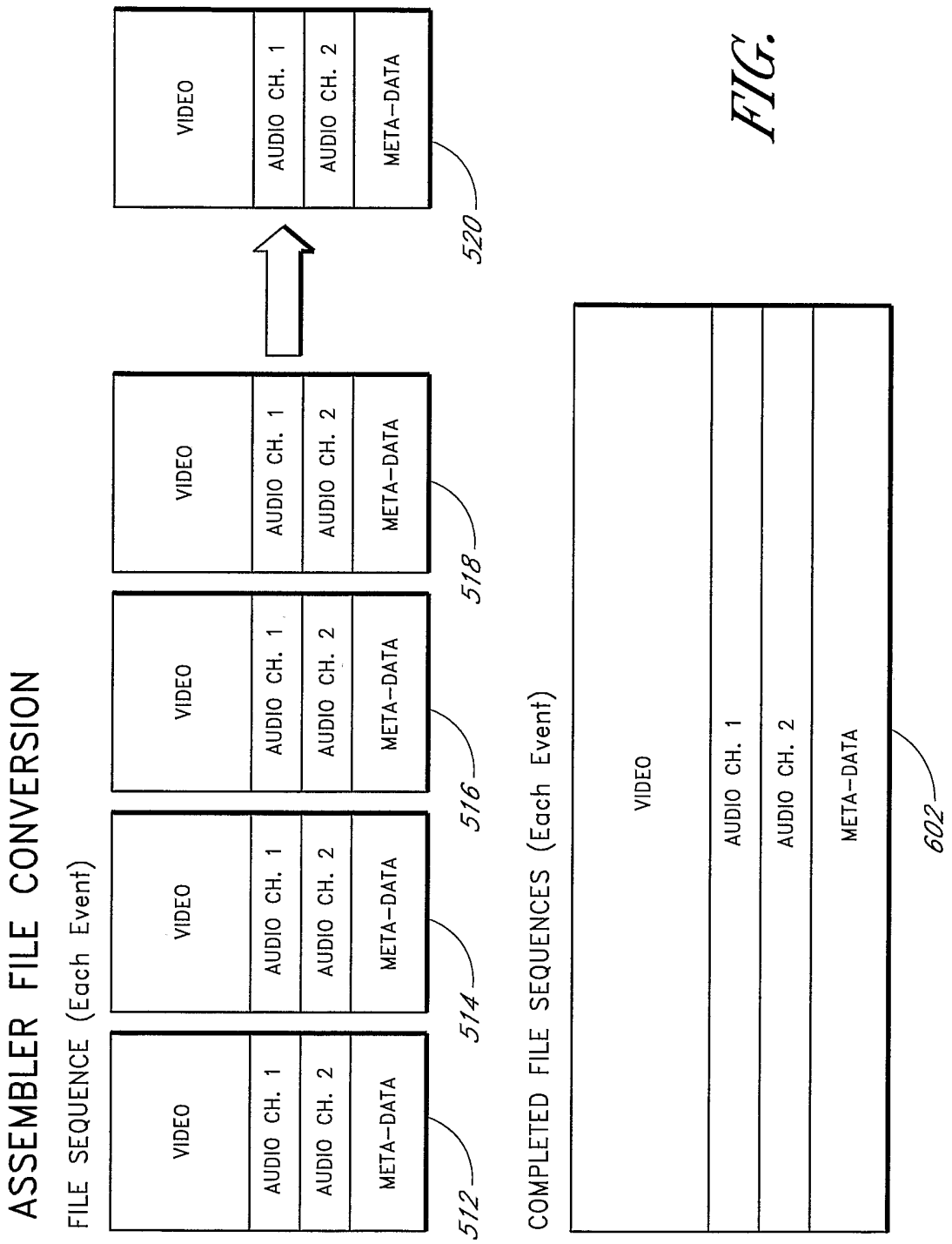
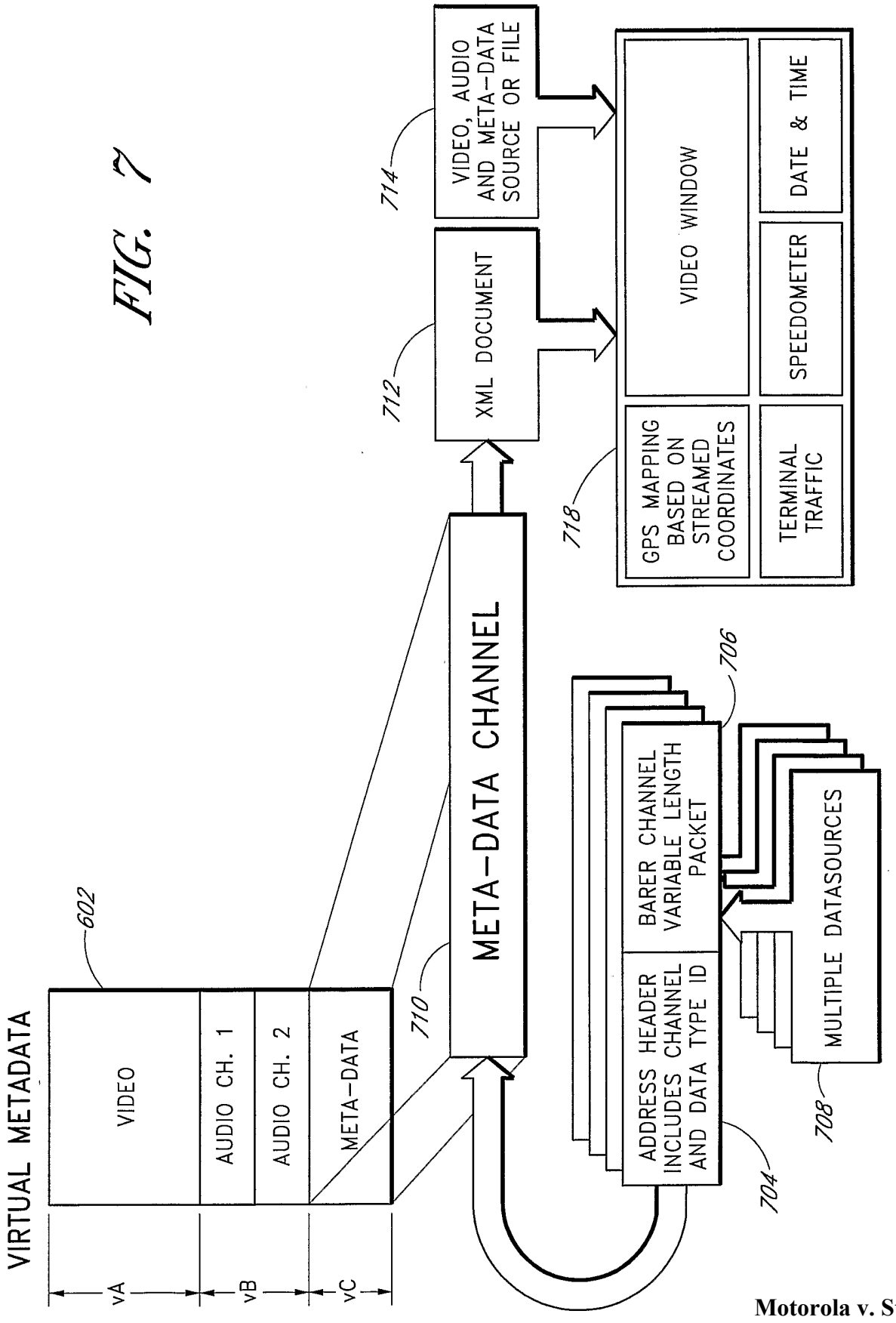

ASSEMBLER FILE CONVERSION
FILE SEQUENCE (Each Event)
VIDEO
AUDIO CH. 1
AUDIO CH. 2
META-DATA
512
514
516
518
520
COMPLETED FILE SEQUENCES (Each Event)
602

FIG. 6

FIG. 7



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Find/Locate Document

Use the input fields to enter your search criteria. To enter additional criteria, click the "Add" button. Select an "AND" or an "OR" operator to combine the criteria. Once all the criteria have been entered, click the Find button to submit the search. The search results are confined to the current folder. To expand the search to the current folder's subfolders, click the "Recurse into subfolders" check box. Click the New Search button to clear the current entries and create a new query string. Click Cancel to return to the System Documents page. Note: use the % character to do wildcard searches when using the "like" operator. Enter dates in the form dd-mmm-yyyy. For example 03-FEB-1989

NOTE: The active folder is the **Root** folder. If the **"Recurse into subfolders"** checkbox is checked, **ALL** folders in the system will be searched.

QUERY STRING:

hidden Find

Property Operator Value Recurse into subfolders

(none) = New Search Cancel

NEW CRITERIA: 1 Add

FIG. 8

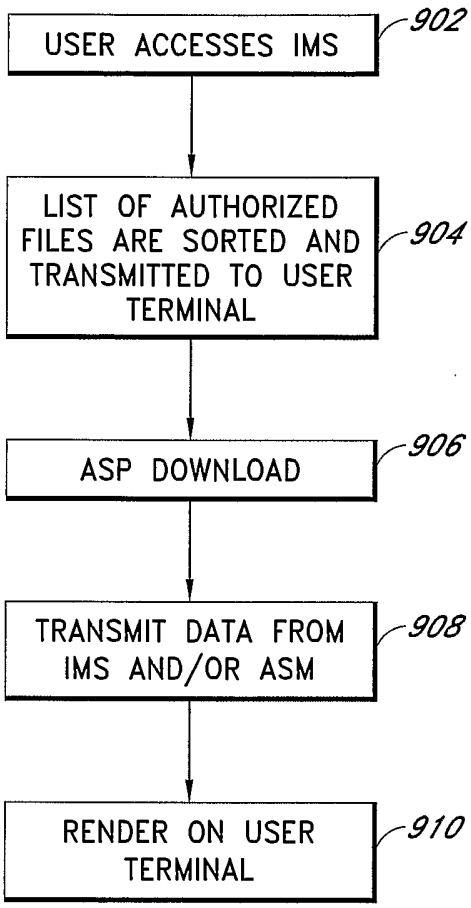

USER ACCESSES IMS
902
LIST OF AUTHORIZED FILES ARE SORTED AND TRANSMITTED TO USER TERMINAL
904
ASP DOWNLOAD
906
TRANSMIT DATA FROM IMS AND/OR ASM
908
RENDER ON USER TERMINAL
910

FIG. 9

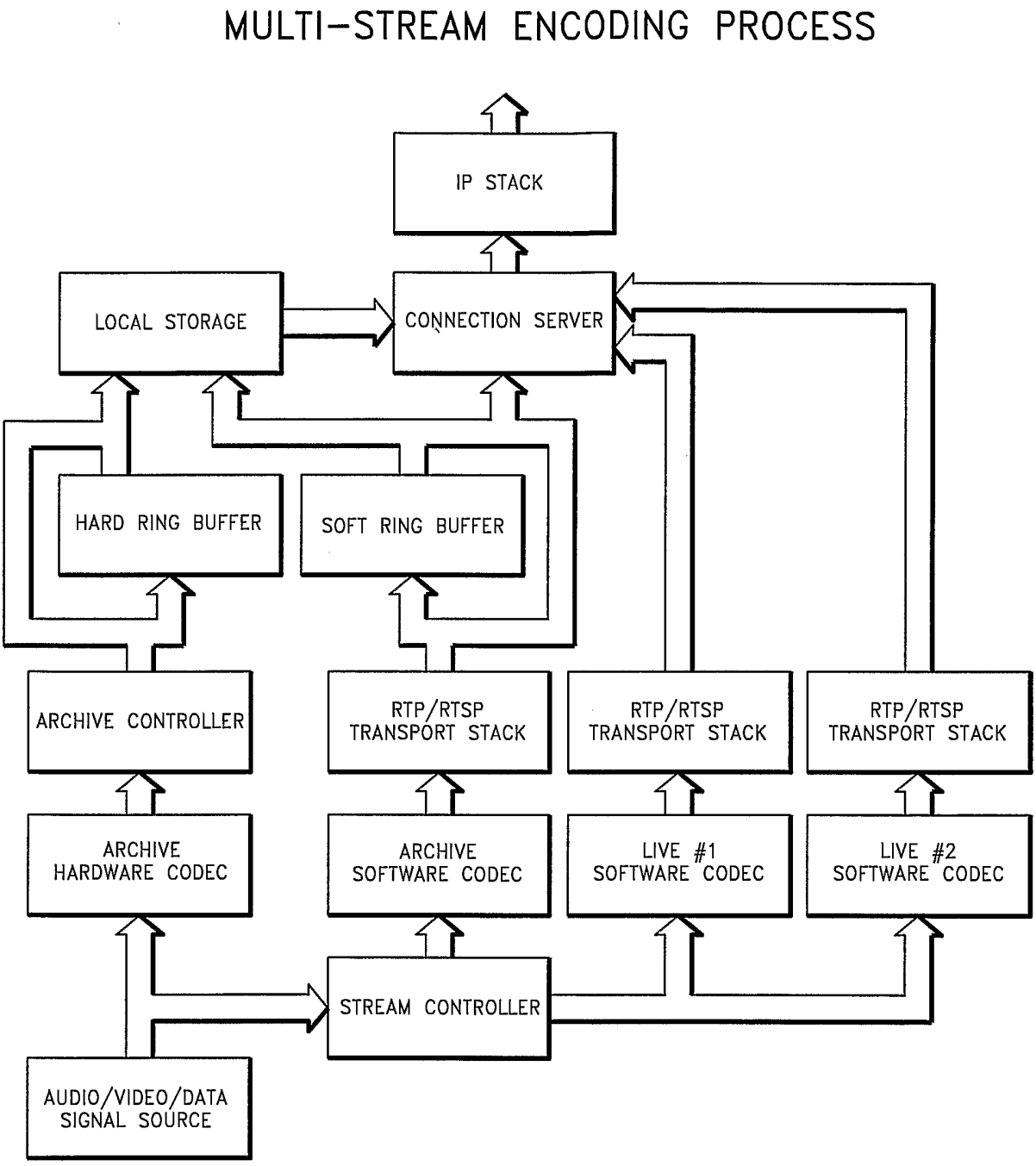

MULTI-STREAM ENCODING PROCESS
IP STACK
LOCAL STORAGE
CONNECTION SERVER
HARD RING BUFFER
SOFT RING BUFFER
ARCHIVE CONTROLLER
RTP/RTSP TRANSPORT STACK
RTP/RTSP TRANSPORT STACK
RTP/RTSP TRANSPORT STACK
ARCHIVE HARDWARE CODEC
ARCHIVE SOFTWARE CODEC
LIVE #1 SOFTWARE CODEC
LIVE #2 SOFTWARE CODEC
STREAM CONTROLLER
AUDIO/VIDEO/DATA SIGNAL SOURCE

FIG. 10

Appendix Y

US006690294B1

(12) **United States Patent**
Zierden

(10) **Patent No.: US 6,690,294 B1**
(45) **Date of Patent: Feb. 10, 2004**

(54) **SYSTEM AND METHOD FOR DETECTING AND IDENTIFYING TRAFFIC LAW VIOLATORS AND ISSUING CITATIONS**

(76) Inventor: **William E. Zierden**, 123 Spa View Ave., Annapolis, MD (US) 21401

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 140 days.

(21) Appl. No.: **09/901,005**

(22) Filed: **Jul. 10, 2001**

(51) **Int. Cl.**[7] **G08G 1/017**
(52) **U.S. Cl.** **340/937**; 340/933; 340/936; 348/148
(58) **Field of Search** 340/937, 933, 340/936, 905, 540, 541, 995; 348/148, 149, 153; 382/224, 228, 181, 104; 701/215, 301, 119

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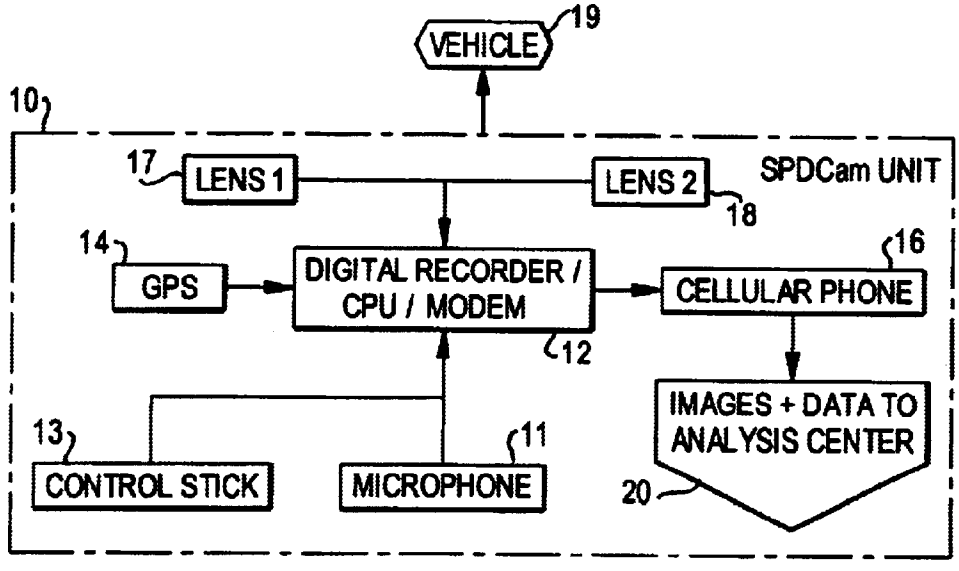
* cited by examiner

Primary Examiner—Benjamin C. Lee
Assistant Examiner—Phung Nguyen
(74) *Attorney, Agent, or Firm*—Blank Rome, LLP

(57) **ABSTRACT**

The present invention is directed to a mobile or stationary traffic monitoring system for detecting violations of speed limits or other traffic laws by vehicle operators and issuing citations to an operator and/or vehicle owner suspected of a violation using a digital camera to capture images of the operator and/or the vehicle, transmitting the captured images and other relevant data to an analysis center where the images and data are analyzed to determine whether to issue a citation and, if so, to issue the citation or take other appropriate law enforcement measures. The invention is also directed to a method for capturing images of a vehicle and /or vehicle operator suspected of a traffic violation, determining the time and geographic location of the suspected violation, transmitting the images and other data to an analysis center, issuing citations to violators and deriving revenue therefrom.

24 Claims, 4 Drawing Sheets



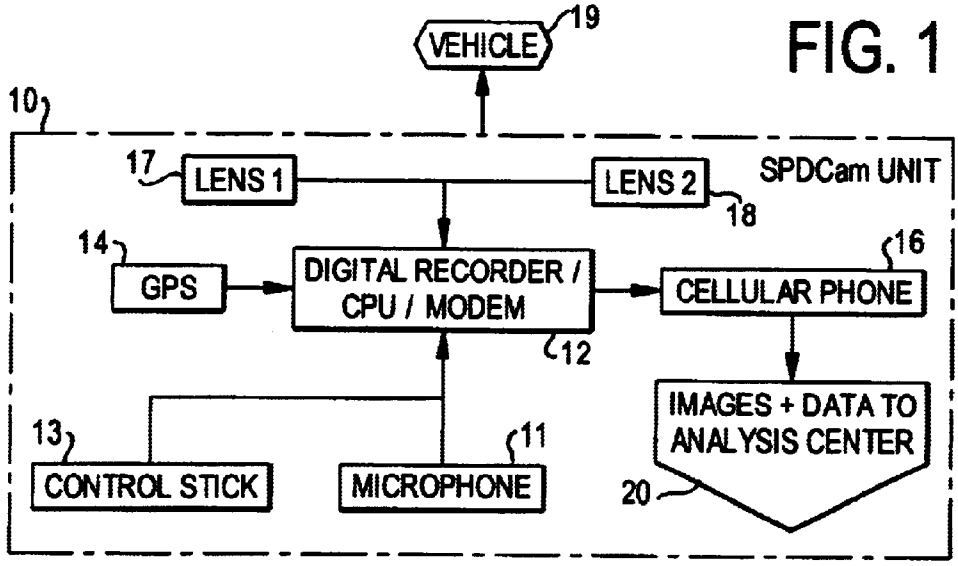

VEHICLE
19
10
17
LENS 1
LENS 2
18
SPDCam UNIT
14
GPS
DIGITAL RECORDER / CPU / MODEM
12
16
CELLULAR PHONE
IMAGES + DATA TO ANALYSIS CENTER
20
13
CONTROL STICK
11
MICROPHONE

FIG. 1

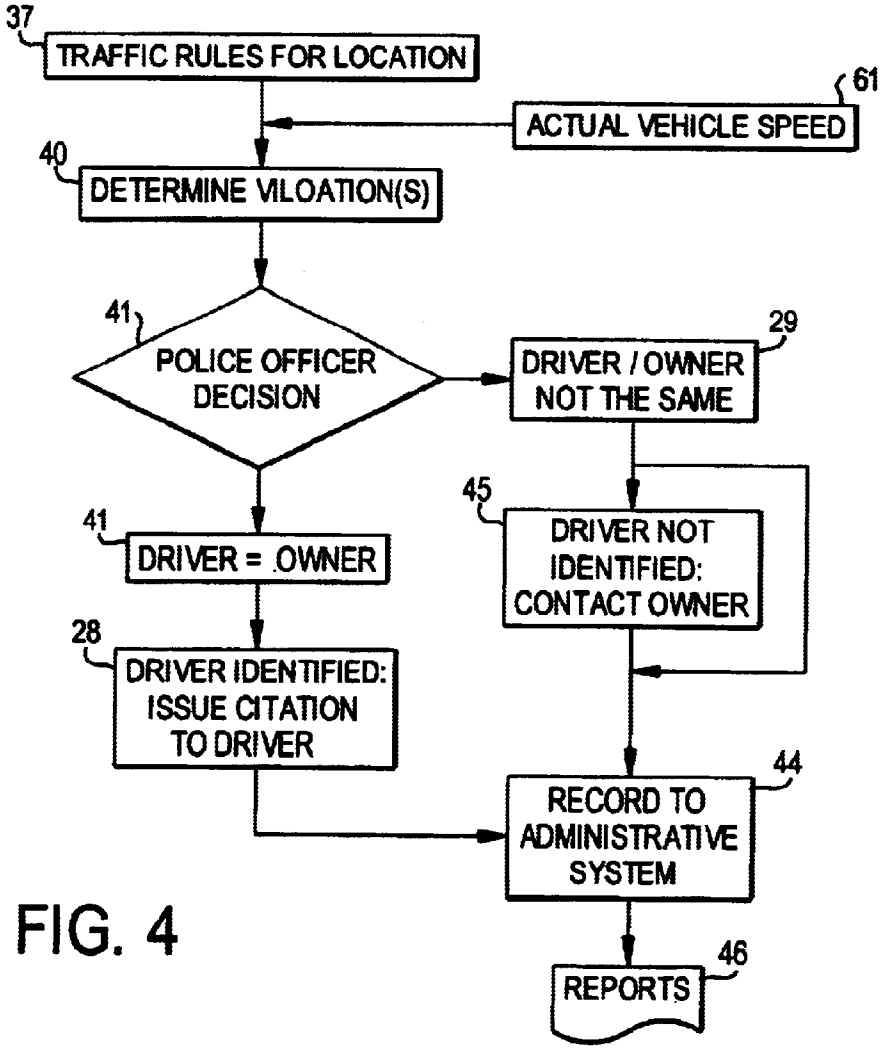

37
TRAFFIC RULES FOR LOCATION
61
ACTUAL VEHICLE SPEED
40
DETERMINE VILOATION(S)
41
POLICE OFFICER DECISION
29
DRIVER / OWNER NOT THE SAME
45
41
DRIVER = OWNER
DRIVER NOT IDENTIFIED: CONTACT OWNER
28
DRIVER IDENTIFIED: ISSUE CITATION TO DRIVER
44
RECORD TO ADMINISTRATIVE SYSTEM
46
REPORTS

FIG. 4

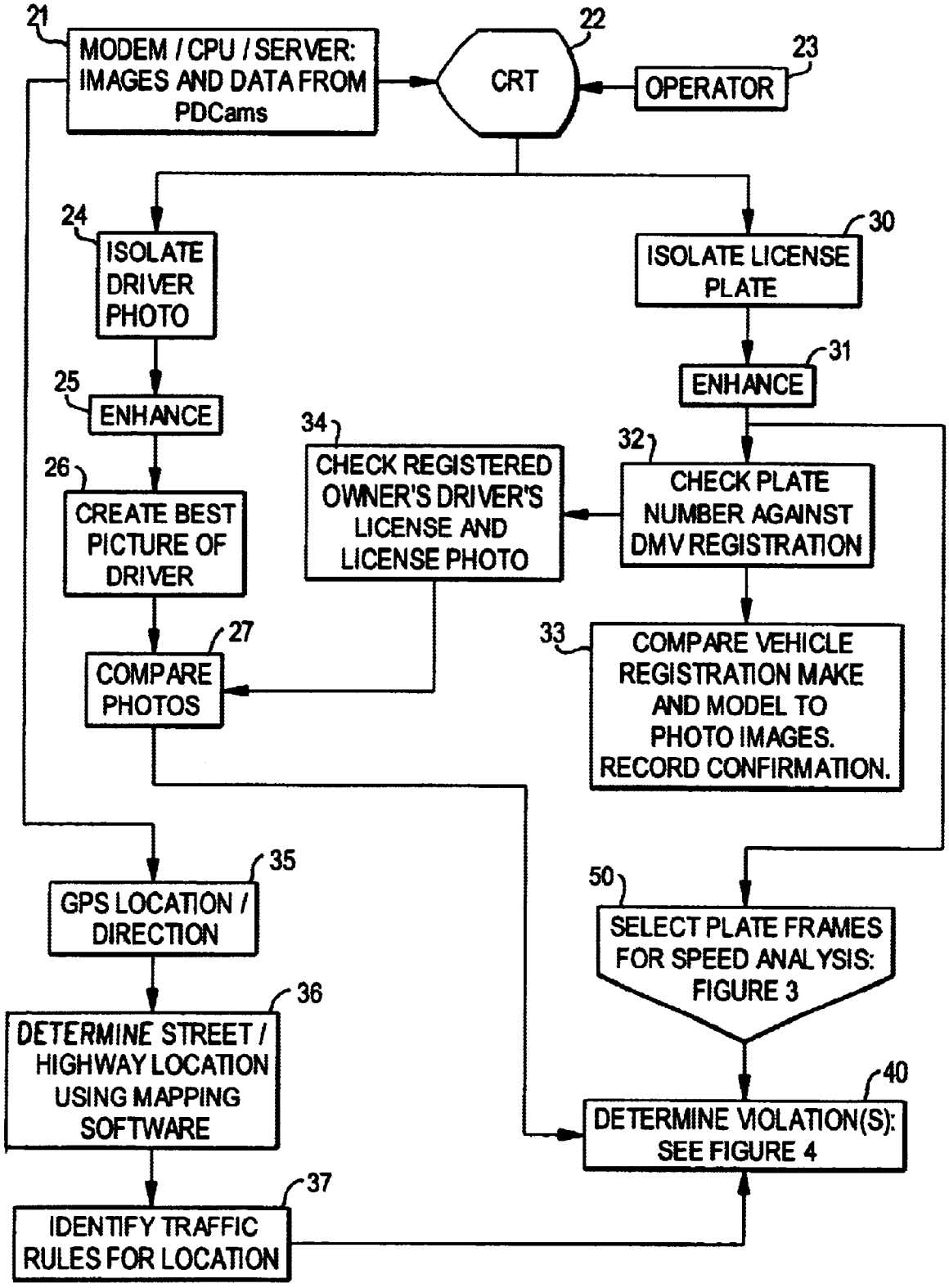

21
MODEM / CPU / SERVER: IMAGES AND DATA FROM PDCams
22
CRT
23
OPERATOR
24
ISOLATE DRIVER PHOTO
25
ENHANCE
26
CREATE BEST PICTURE OF DRIVER
27
COMPARE PHOTOS
30
ISOLATE LICENSE PLATE
31
ENHANCE
32
CHECK PLATE NUMBER AGAINST DMV REGISTRATION
33
COMPARE VEHICLE REGISTRATION MAKE AND MODEL TO PHOTO IMAGES. RECORD CONFIRMATION.
34
CHECK REGISTERED OWNER'S DRIVER'S LICENSE AND LICENSE PHOTO
35
GPS LOCATION / DIRECTION
36
DETERMINE STREET / HIGHWAY LOCATION USING MAPPING SOFTWARE
37
IDENTIFY TRAFFIC RULES FOR LOCATION
50
SELECT PLATE FRAMES FOR SPEED ANALYSIS: FIGURE 3
40
DETERMINE VIOLATION(S): SEE FIGURE 4

FIG. 2

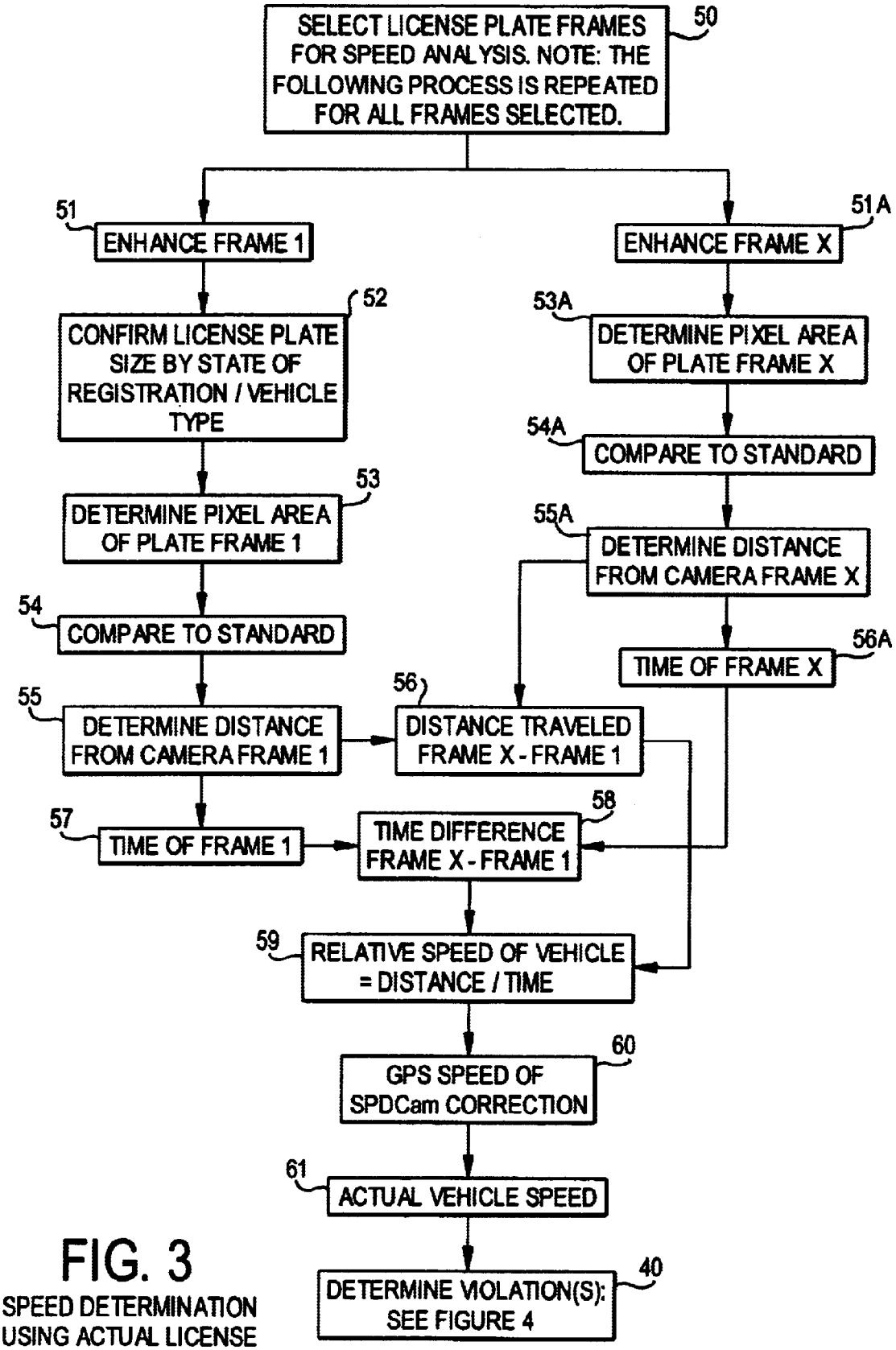


FIG. 3

SPEED DETERMINATION USING ACTUAL LICENSE PLATE SIZE

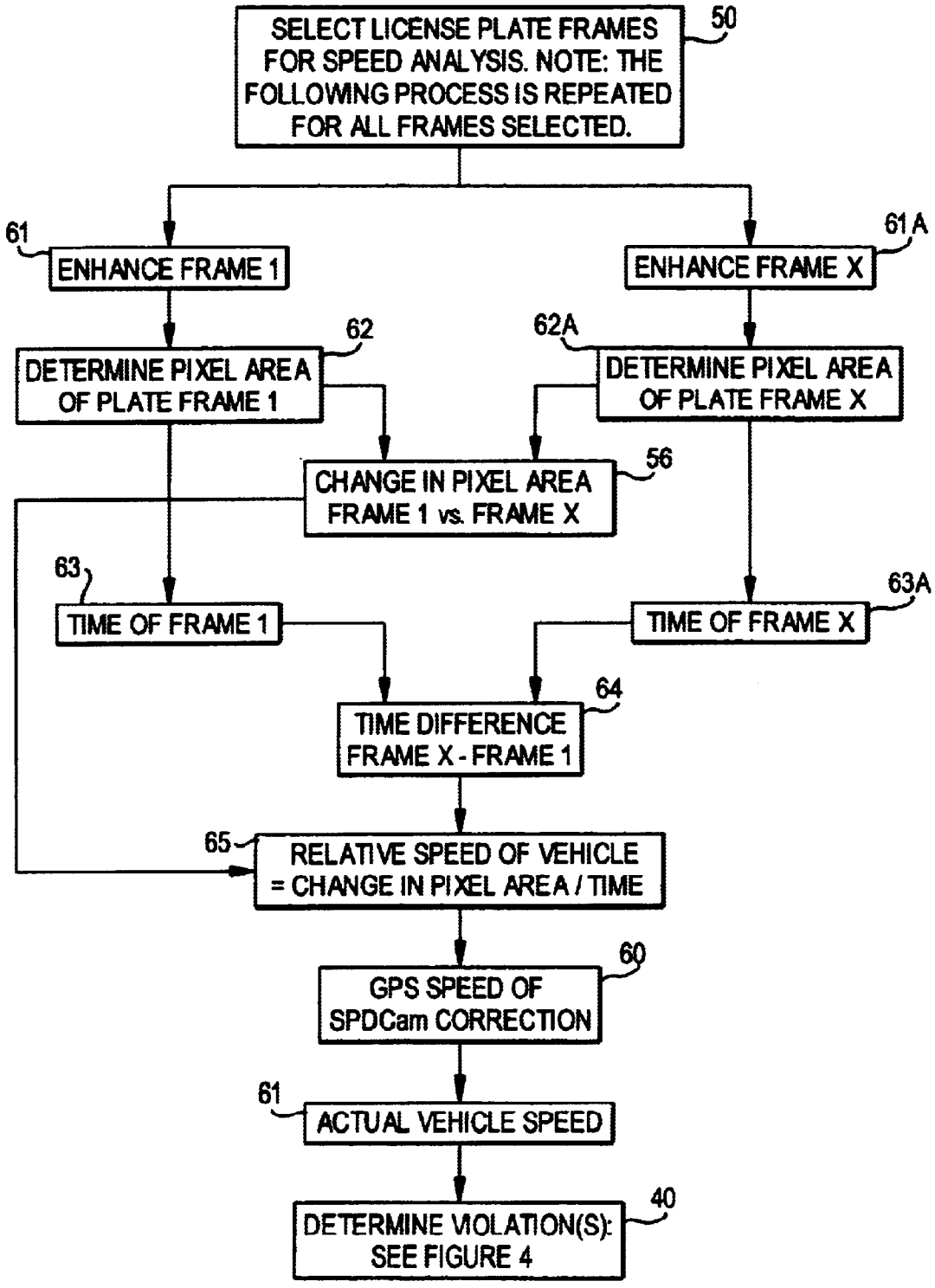


FIG. 3A

SPEED DETERMINATION USING RELATIVE CHANGE IN LICENSE PLATE SIZE

SYSTEM AND METHOD FOR DETECTING AND IDENTIFYING TRAFFIC LAW VIOLATORS AND ISSUING CITATIONS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is directed to a mobile or stationary traffic monitoring system for detecting violations of speed limits or other traffic laws by vehicle operators and issuing citations to an operator and/or vehicle owner suspected of a violation using a digital camera to capture images of the operator and/or the vehicle, transmitting the captured images and other relevant data to an analysis center where the images and data are analyzed to determine whether to issue a citation and, if so, to issue the citation or take other appropriate law enforcement measures. The invention is also directed to a method for capturing images of a vehicle and /or vehicle operator suspected of a traffic violation, determining the time and geographic location of the suspected violation, transmitting the images and other data to an analysis center, issuing citations to violators and deriving revenue therefrom.

2. Description of the Prior Art

Traffic violations, particularly speeding, are a major cause of accidents on roads and highways. A common method to catch speeders is to set up a stationary radar or laser site along a roadway to identify speeders and issue citations. According to this method, a police officer uses a radar or laser gun to determine the speed of an approaching vehicle. If the officer determines that the approaching vehicle is speeding, he directs the driver to pull over to the side of the road and issues a citation. A similar method is for a police officer to place the radar/laser gun in his police vehicle, use it to detect whether vehicles are speeding and then pursue and pull over any vehicle he observes speeding. Both methods require the police officer to stop the vehicle primarily to identify the operator for purposes of issuing a citation.

More recently, traffic control systems using cameras have been placed at traffic-lighted intersections to capture vehicle and license plate images of a vehicle running a red light and issue a citation by mail without having to stop the vehicle. However, the use of such traffic control systems requires legislation that specifically sanctions the practice of issuing a citation to a vehicle owner based on license plate information without identifying the vehicle operator.

Apart from the need to pull a vehicle over to issue a citation to the driver, the use of a radar/laser gun by a police officer, whether stationary or mobile, has many other drawbacks. For instance, when a vehicle is stopped along the side of a road by a police officer to issue a citation to the driver for a traffic violation, both the officer and the occupants of the stopped vehicle are at risk of being hit by other passing vehicles. When a police officer pursues a speeding vehicle in what has become known as a "high speed chase," the officer's vehicle and the fleeing vehicle pose a serious danger to other travelers on the road. The police officer is also at risk when confronting an unknown and potentially dangerous driver and attempting to issue a citation to that driver. Moreover, large numbers of drivers have purchased detectors to alert them of the use of a radar/laser guns, and when alerted, a driver may quickly decelerate creating a danger of collision for vehicles traveling behind the decelerating vehicle. The use of CB radios to warn other drivers of a "speed trap" may have a similar result. The widespread use of such devices also diminishes the overall effectiveness of police use of radar/laser guns to detect speeding violations.

Additionally, the use of radar/laser guns place an added burden on the strained resources of a police department because officers must appear in court if a driver elects to contest or otherwise question the validity of a traffic citation. The primary reason for the officer's presence in court is to confirm the identity of the driver and to testify about the circumstances of the issuance of the citation.

The use of a high resolution-digital imaging system to capture images and provide documentation of a variety of traffic violations provides a far safer and more productive alternative to the foregoing systems and methods currently in use. Such an imaging system is capable of taking digital images of a vehicle and the operator with sufficient resolution for identification purposes so that citations may be issued without having to pursue and stop the vehicle of a suspected violator. The images also serve as compelling evidence that may result in fewer court challenges and should relieve a police officer from court appearances merely to identify the vehicle operator.

Digital imaging and photographic technologies and imaging analysis technologies that are capable of capturing high resolution vehicle images from long distances for traffic monitoring and enforcement systems are known in the prior art. An example of such a system is disclosed in U.S. Pat. No. 5,515,042 to Nelson. The system of the Nelson patent comprises an apparatus that includes a camera for recording still or video images, an audio information recorder, a laser or radar speed detector, and a GPS receiver. The apparatus is mounted to the dashboard of a law enforcement vehicle and is operative to record photo images of the vehicle and vehicle license plate of a suspected speeder and imprint the vehicle speed, time and GPS-determined location onto the photo, all of which is stored for later evaluation. The operator of the apparatus in the law enforcement vehicle also records his or her observations on the audio recording device of the apparatus. At the end of a shift, the photos and audio recordings are recovered and reviewed to determine whether violations have occurred and citations should be issued.

U.S. Pat. No. 5,938,717 to Dunne et al. discloses a traffic control system that automatically captures an image of a vehicle and speed information associated with the vehicle and stores the image and information on a hard disk drive. The system uses a laser gun to determine whether a vehicle is speeding. The hard drive is later connected to a base station computer which is, in turn, connected to a LAN at which the information from the hard drive is compared with databases containing data such as vehicle registration information and the like. The system automatically prints a speeding citation and an envelope for mailing to the registered owner of the vehicle

U.S. Pat. No. 5,734,337 to Kupersmit discloses a stationary traffic control method and system for determining the speed of a vehicle by generating two images of a moving vehicle and calculating the vehicle speed by determining the distance traveled by the vehicle and the time interval between the two images. The system is capable of automatically looking up vehicle ownership information and issuing citations to the owner of a vehicle determined to be speeding.

U.S. Pat. No. 5,948,038 to Daly et al. discloses a method for processing traffic violation citations. The method includes the steps of determining whether a vehicle is violating a traffic law, recording an image of the vehicle

committing the violation, recording deployment data corresponding to the violation, matching the vehicle information with vehicle registration information to identify the owner, and providing a traffic violation citation with an image of the vehicle, and the identity of the registered owner of the vehicle.

It would be desirable to provide a traffic violation monitoring system and method operable by law enforcement personnel as well as private citizens that captures high resolution digital images of a vehicle operator as well as digital images of the vehicle and vehicle license plate so as to positively identify the operator and vehicle involved in a traffic violation, not limited to speeding. It would also be desirable to provide such a system and method that uses advanced communications and GPS location technology to provide comprehensive violation data for transmission to a remote evaluation center for data analysis and issuance of citations. Such a system and method should desirably collect all the evidence needed to support a traffic citation against a court challenge with minimal involvement of law enforcement personnel and provide a financial incentive to private citizens to become involved in traffic monitoring.

SUMMARY OF THE INVENTION

The present invention is directed towards a system for identifying and issuing citations to speeders or other traffic law violators (hereinafter referred to as the SPDCam system), and a method for permitting private citizens to use the SPDCam system to record evidence of suspected traffic violations for submission to law enforcement personnel.

The SPDCam system comprises a color digital imaging device (SPDCam device) connected to a global positioning satellite (GPS) system and a cellular telephone network. The imaging device is composed of two lenses or cameras, one facing a forward direction and the other facing a rearward direction so that images of both the front and rear of a vehicle may be recorded as the vehicle passes the imaging device. The image of the front of the vehicle records both the driver's face and a front license plate, and the rear image records the rear license plate. The two lenses can take either still or continuous images of the vehicle. Information obtained from the GPS system such as the imaging device's location, its speed and its direction of travel are attached to the images and sent by the cellular telephone to an analysis center where the images are reviewed. At the analysis center the images of the vehicle are analyzed to determine whether a traffic violation has occurred, and whether a citation or citations should be issued.

Also disclosed is a method for allowing private citizens to use the SPDCam system to capture images of vehicles violating traffic laws, submit the images to an analysis center and collect a percentage of the revenues generated from the fines.

With the foregoing and other objects, advantages and features of the invention that may become hereinafter apparent, the nature of the invention may be more clearly understood by reference to the following detailed description of the invention, the appended claims and to the several drawings forming a part hereof.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of the SPDCam system of the present invention;

FIG. **2** is a flow chart showing the process of analyzing an image of a vehicle to determine whether a traffic violation has occurred;

FIG. **3** is a flow chart showing a method of calculating the speed of a vehicle by comparing the size of a license plate in an image to a standard size license plate;

FIG. **3A** is a flow chart showing a method of calculating the speed of a vehicle by comparing the size of a license plate in successive images of the vehicle; and

FIG. **4** is a flow chart of the method of the invention showing the steps taken after a determination is made that a traffic violation has occurred.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the detail in the drawings, FIG. **1** is a block diagram of a digital imaging device (SPDCam device) **10** for capturing the image of a target vehicle **19** that is suspected of violating a traffic law. The SPDCam device **10** comprises two cameras, identified as lenses **17** and **18**, for capturing the image of the target vehicle **19**. A computer **12** comprising a digital recorder, a central processing unit (CPU), and a modem receives images from the lenses **17**, **18** through a fiber optic or other cable. Geographic position information from a global positioning satellite (GPS) receiver **14** and recorded audio information from a microphone **11** are stored with the images from the lenses **17**, **18** on the computer **12**. The computer **12** processes, stores, and transmits the images and the geographic and audio data to an analysis center **20** via a cellular telephone **16**. A control stick **13**, which may be a keyboard or other conventional input device, is attached to the computer **12** and is used by the operator to control the various functions of the SPDCam device **10**. The microphone **11** permits the operator to attach contemporaneous voice messages to the images recorded on the computer **12**, for example, a description of the circumstances surrounding the recording of the images.

In the preferred embodiment of the invention, the SPDCam device **10** is mounted to a source vehicle, normally a motor vehicle, such as a police car or private automobile, which can be either mobile or stationary. The SPDCam device **10** can also be placed on a stationary or movable support alongside a road or can be constructed as a handheld device without altering its mode of operation. The two lenses **17** and **18** are pointed in opposite directions so that a rearward facing lens **18** records one or more images of a target vehicle **19** as it approaches the SPDCam device **10**, thereby capturing images of the vehicle driver's face and front license plate. The other lens **17** is a forward facing lens that records one or more images of the vehicle as it moves away from the SPDCam **10**, in particular, capturing an image of the rear license plate of the vehicle. The lenses are high resolution wide-angle lenses that are capable of recording images in at least one lane of traffic to either side of the lane in which the source vehicle is traveling.

The SPDCam device **10** can be configured as a video camera or a photographic camera, or both, and thus can record both continuous and still images of a target vehicle. In either mode of operation, the images of the target vehicle are preferably used to calculate the speed of the target vehicle as well as identify the target vehicle and its driver as described in more detail hereinafter.

The two modes of operation are similar except that the number of frames per second in the video mode of operation is higher, typically 24 frames/second or more, than in the photographic mode of operation. The video mode captures images at a rate of at least about 24 frames per second, which is approximately the minimum frame rate required to give the illusion of motion. The photographic rate is set lower, for example, a rate of about 2 to 5 frames per second to conserve memory in the device **10**. The rate of 2–5 frames per second

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is for illustrative purposes only and is not meant to limit the scope of the invention. The frame rate may be adjusted depending on the amount of memory available and the number of images that are necessary to accurately calculate the speed of a target vehicle. In other respects, the operation of the SPDCam device **10** is the same in both image-capturing modes.

In operation, the lenses **17** and **18** constantly record images, with the most recent time period, e.g., 120 seconds, of images being retained in the computer memory at any given time. As new images are acquired, older ones are erased. When a target vehicle is identified, the system operator activates an "Event" on the SPDCam device **10** to begin collecting data for the target vehicle. When the "Event" is initiated, the prior 120 seconds of images are permanently stored, and subsequent images of the target vehicle are continuously captured and stored in the computer memory until the operator "Ends" the event. GPS data and the entirety of the audio recording is retained from the start of the event to the end thereof, and stored with the images.

The control stick **13** may be a conventional manual input device with switches and/or keys (not shown) that control the various functions of the SPDCam device **10**. For example, switches may be provided for selecting between the video mode and the photographic mode of operation or selecting between one or both of the lenses **17**, **18** so that a single lens may be used when necessary or, as in the preferred embodiment, so that both lenses are used simultaneously. A "Power" key turns the device **10** on and initiates the recording of the 120 second loop of images. An "Event" key permanently stores the most recent 120 seconds of images while continuing to record until an "End/Store" key is pressed to stop the recording of the images. All the images are stored in the memory of the computer **12**. A "Microphone" key activates the audio recorder attached to the microphone **11** and initiates the recording of contemporaneous voice recordings for transmission to the computer **12**. An "Erase" key may be used to erase the images and other data stored in the computer memory. A "Submit" key activates the cellular telephone **16** connected to the computer **12** which transmits the images and other collected data to the analysis center **20**. An "Emergency" key may be provided to activate the cellular telephone **16** and automatically dial "911" or other emergency number to contact an emergency response unit and transmit voice and/or GPS data to that unit. The cellular telephone **16** may also be programmed to dial other numbers set by the user of the SPDCam device.

The foregoing features facilitate the use of the SPDCam device **10** in a source vehicle, such as a police car, where one lens is mounted on the police car pointing in a rearward direction and the other lens is mounted pointing in a forward direction. When a target vehicle overtakes the police car from behind at a high speed, the system operator activates the SPDCam device which captures images of the overtaking vehicle from the rearward-facing lens for the last 120 seconds of the approach so that, inter alia, images of the driver's face are in the field of view and can be recorded. The forward facing lens then captures the image of the target vehicle, including the license plate and any other identifying indicia, as the vehicle passes the source vehicle. Both lenses **17** and **18** are recording simultaneously so that a continuous image of the vehicle is recorded as it passes from the rear to the front of the source vehicle.

The recorded images of the target vehicle are stored in the memory of the computer **12**, and are each labeled with a unique serial number assigned to the SPDCam device **10**, a unique frame number, a unique event designator, the date and time, and the location, speed and direction of the source vehicle obtained from the GPS system. Any related audio recording is preferably identified at the beginning of the recording by the operator's voice recording of the event designator and SPDCam device serial number, and preferably includes periodic time marks. The audio recording may be linked to the images and other vehicle data by other suitable means, e.g., a synthetic voice recording or the like.

The images are transmitted by cellular telephone **16** to the analysis center **20** at the end of each event or other appropriate time. The rate of transmission will be a function of the upload bandwidth capabilities of the existing cellular system, and will change as the cellular technologies develop, or will vary according to the cellular capabilities in a given geographic location. The cellular telephone **16** is programmed to automatically call the local analysis center **20** based upon its GPS coordinates, a national "800" number or other preprogrammed number. The cellular telephone may also be used by the SPDCam operator to call the analysis center to discuss any issues related to the images. The microphone **11** allows the SPDCam operator to use the cellular telephone in a "hands-free" mode. Similarly, the cellular telephone provides a means for the analysis center **20** to reach the operator of the SPDCam device **10**. In addition to the cellular telephone **16**, other transmission means may be used with the SPDCam device **10**. For example, the images and data may be transmitted to the analysis center **20** by satellite, by connecting the computer **12** to a local telephone line, or by physically transporting the memory component of the computer **12** to the nearest analysis center **20**.

In addition to being mounted in a vehicle, the SPDCam device **10** can also be set up adjacent the side of a road, with one lens facing one direction to capture frontal images of approaching vehicles and drivers, and the other lens facing the opposite direction to capture rear images of vehicles that have passed the device **10**. The SPDCam device **10** can be mounted on a stationary support, such as a typical camera tripod, or can be miniaturized and configured as a handheld device.

FIG. **2** illustrates the process of analyzing the images after they are received from the SPDCam device **10**. The images and other data are first received by a computer **21** at the analysis center **20**. The analysis computer **21** displays the images on a monitor **22** to be reviewed by an operator **23**, who is typically a police officer trained in the operation of the overall system and analysis of the data received from the SPDCam device. The images are preferably displayed in a split screen format so that the images from the two lenses **17**, **18** can be viewed simultaneously. Since the lenses may have captured more than one vehicle, the operator **23** selects and isolates the target vehicle based on other available data and information, e.g., the audio recording, and proceeds with further analysis.

The operator modifies the original images of the target vehicle so that images of the driver and the target vehicle license plate are obtained as isolated images **24** and **30**, respectively. These modified images are then enhanced using conventional digital image enhancement techniques in steps **25** and **31** to improve the quality of the images of the driver and license plate. Several images of the driver are modified and enhanced in this manner to obtain the best picture of the driver **26** for later comparison with records from the Department of Motor Vehicle (DMV) or other database containing driver photographic information.

The enhanced image of the license plate **31** is checked against DMV records in step **32** to identify the registered

owner of the vehicle. A photograph of the registered owner is retrieved in step **34** by accessing DMV records and comparing registered owner records with driver's license records or other databases containing driver photographs. This photograph is then compared in step **27** with the best enhanced photo image obtained from the SPDCam device **10** in step **26** to determine whether the driver of the target vehicle is the registered owner of the target vehicle. As a backup measure, the make and model of the vehicle associated with the license plate number is compared to the make and model of the target vehicle in the image in step **33**.

If the image of the driver of the target vehicle does not match the image of the registered owner of the target vehicle, the analysis process may include a further analysis step (not shown) of comparing the target vehicle driver image with photographs of licensed drivers having the same residence address as the registered owner of the target vehicle to determine whether, for example, a member of the family of the registered owner was the driver of the target vehicle. If that step does not produce an image match, then the analysis proceeds as described below in connection with FIG. **4**.

The analysis center operator **23** also selects the speed analysis method in step **50** as will now be described. FIGS. **3** and **3A** show alternative methods for determining the speed of a vehicle from the enhanced images of the license plate. According to one method, the speed of the target vehicle can be determined by comparing the size of the license plate in the image to a known standard size license plate, as shown in FIG. **3**. According to the other method, the speed of the target vehicle is determined by comparing the relative change in the size of the license plate in successive images, as shown in FIG. **3A**. One or both methods may be used for determining speed.

Referring first to the method depicted in FIG. **3**, each SPDCam device **10** is manufactured and calibrated such that the size of a standard automobile license plate (12×6 inches) covers a fixed number of image pixels at a predetermined distance from the lenses **17**, **18**. After image enhancement in steps **51** and **51A** of two time-separated frames, Frame **1** and Frame X, and confirmation of license plate size for the particular state that issued the license plate in step **52**, the standard 12-inch by 6-inch license plate is used as a reference for further analysis. The pixel area of the license plate in Frame **1** is determined in step **53** and compared to the standard plate size in step **54**. From that comparison, the distance from the license plate of the target vehicle to the SPDCam device lens **17** or **18** is calculated in step **55**. The time of the Frame **1** is also recorded in step **57** for speed calculation purposes. The operator then selects and enhances a time subsequent Frame X in step **51A**, determines the pixel area of the license plate in Frame X in step **53A**, compares it to the known standard in step **54A**, and calculates the distance between the target vehicle license plate and the lens **17** or **18** of the SPDCam device in step **55A**. The time of Frame X is also recorded in step **56A**. The relative speed of the target vehicle is then obtained in step **59** by dividing the distance traveled between Frame **1** and Frame X determined in step **56** by the time difference between Frame **1** and Frame X determined in step **58**.

If the SPDCam device is stationary the relative speed determined in step **59** is the actual target vehicle speed. If the SPDCam device **10** is installed on a moving source vehicle, the relative speed of the target vehicle must be adjusted to determine the actual speed of the target vehicle by compensating for the speed of the source vehicle. The speed of the source vehicle is determined by averaging the GPS-determined speed of the source vehicle at Frame **1** and at Frame X or by averaging the GPS speed for all frames between Frames **1** and X, or by other speed determination means. The actual speed of the target vehicle **61** is then calculated in step **60** by either adding or subtracting the speed of the source vehicle to the target vehicle, depending on whether the target vehicle is overtaking or pulling away from the source vehicle. The actual target vehicle speed **61** is used to determine whether a violation has occurred in step **40** as described in more detail below in connection with FIG. **4**.

A second method for calculating the speed of the target vehicle is shown in FIG. **3A**. According to this method, an enhanced Frame **1** is selected in step **61** and its pixel area is determined in step **62** and the time of Frame **1** is recorded in step **63**. A second Frame X is selected, its image enhanced in step **61A**, its pixel area is determined in step **62A** and its time is recorded in step **63A**. The proportional change in pixel area of the license plate between Frame **1** and Frame X is related to the distance traveled by the target vehicle so that the distance traveled is calculated in step **56**. The distance traveled from step **56** is divided by the time difference between Frame **1** and Frame X calculated in step **64** to yield the relative speed of the target vehicle in step **65**. Stated another way, the calculation of the proportional reduction in the pixel size of the license plate per unit of time as the vehicle moves away from the SPDCam device (or enlargement of the plate as it moves toward the SPDCam device) yields the speed of the vehicle relative to the SPDCam device **10**. In the same manner as in the FIG. **3** method, if the SPDCam device is mounted on a moving source vehicle, the relative speed of the target vehicle calculated in step **65** is corrected by the GPS-determined speed of the source vehicle in step **60** yielding the actual target vehicle speed **61**. Also as in FIG. **3**, the actual target vehicle speed **61** is used to determine whether a violation has occurred in step **40** as described in more detail below in connection with FIG. **4**.

If the target vehicle is not directly in front of or behind the lenses **17** and **18** of the SPDCam device **10**, for instance, if the target vehicle is in an adjacent lane to the source vehicle, the offset will affect the distance calculations and the speed determination. U.S. Pat. No. 5,734,337 to Kupersmit, the disclosure of which is incorporated by reference herein, discloses a method of compensating for the angular offset between the lens of a camera and a target vehicle. Other methods of correcting errors resulting from such an angular offset will be apparent to the skilled artisan.

Referring again to FIG. **2**, the geographic location information and direction of movement of the source vehicle obtained from the GPS system in step **35** is used in conjunction with conventional mapping software to determine in step **36** the street or highway location where the images of the suspected traffic violation were recorded. The traffic laws for that location, particularly the speed limits, are then retrieved in step **37** and compared with the actual speed of the target vehicle to determine whether a violation has occurred in step **40**, and what sanction, if any, is warranted.

FIG. **4** illustrates the violation-determination process of the invention. The analysis operator **23** reviews all the available information to determine whether one or more traffic violations has occurred. For example, images of a vehicle may show that the driver of the vehicle ran a stop sign or was weaving in-and-out of traffic or otherwise driving dangerously. With respect to speed violations, comparison of the actual target vehicle speed **61** with the speed limit for the GPS-determined location of the target vehicle

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in step **37** may establish that a speeding violation has occurred. If the police officer/operator **23** determines that a violation has occurred in step **40**, he then compares the photograph of the licensed driver and the driver of the speeding target vehicle in step **27** of FIG. **2** to determine if there is a match between the owner of the vehicle and the driver designated **28** in FIG. **4**. If there is a match, the police officer/operator **23** makes a decision in step **41** to issue a citation to the driver/registered owner in step **42**.

If the driver of the speeding target vehicle is unrecognizable from the image, or no match occurs in step **29**, or if the driver has no association with the target vehicle or the registered owner, the registered owner may be contacted by police for further investigation in step **45**. Whether or not the driver is identified, a machine-accessible electronic file and administrative record is created in step **44** of the circumstances of the violation for future use. The file created in step **44** is then used to generate reports in step **46** and to otherwise ensure proper supervision of the SPDCam system.

The use of the SPDCam system enhances the use of police manpower by leaving the analysis of the images to trained officials at the analysis center **20**, permitting patrol officers to record and submit traffic violations without having to stop a driver and issue a citation. Furthermore, because the SPDCam system records images of both the vehicle and the driver, the images can be used as evidence in court for identification purposes. Alternatively, analysis center personnel may appear with the photographic evidence to support the charge of a violation.

It is also envisioned that the SPDCam device **10** will be used by both law enforcement officials as well as private citizens. Law enforcement officials would use the SPDCam system in much the same manner as other similar traffic enforcement systems currently in use, with the exception that a law enforcement officer would freed from the burden of having to stop vehicles suspected of violating a traffic laws and, in most cases, from having to appear in court.

The SPDCam device could be registered to and used by private citizens to capture images of vehicles and drivers violating traffic laws in a special SPDCam program. A private citizen would submit the images and other data to law enforcement officials using the SPDCam system of FIG. **1**. Private citizens may be encouraged to purchase or lease the SPDCam device **10** by providing a financial incentive for any event they record that results in a conviction or payment of a fine. Criteria are established for any private citizen who wished to participate in the SPDCam program, including a rigorous application process involving criminal and driving background checks. Furthermore, in the event of a criminal conviction or other decertifying event, the private citizen may be denied further participation in the program.

Upon acceptance in the SPDCam program, a special credit account is established for each private citizen provided with the SPDCam system. A fee is charged for each submission of an event to the analysis center against the credit account to discourage private citizens from submitting frivolous events and unreliable data. Also, a limit is placed on the number of submissions an individual is allowed to submit on a monthly basis, for example, to encourage the submission of only the most egregious traffic violation events, and to discourage full-time vigilantism. The individual SPDCam operator then receives a percentage of any fees received by the jurisdiction from the issuance of a citation, which is credited to the individual's account. At the end of each month, the individual receives a monthly report of event submissions of his assigned system and the analysis center disposition of the event submissions.

Analysis centers **20** are established to receive the images sent from the SPDCams (operated by both law enforcement and private citizens). Depending on the laws of a particular state, the analysis centers **20** may be operated and managed by an independent contractor, along with sworn law enforcement personnel who conduct all image analysis and make all determinations as to appropriate police follow-up, including whether citations should be issued. The contractor receives a percentage of the citation fees received for operating the center.

Service Centers that sell, lease, install, inspect, test, certify and remove SPDCams are established in those jurisdictions that implement the SPDCam system. Service Centers are licensed by governmental jurisdictions and derive revenue from the sales and services provided.

Although certain preferred embodiments of the present invention have been specifically described herein, it will be apparent to those skilled in the art to which the invention pertains that variations and modifications of the various embodiments shown and described herein may be made without departing from the spirit and scope of the invention. Accordingly, it is intended that the invention be limited only to the extent required by the appended claims and the applicable rules of law.

What is claimed is:

1. A mobile digital imaging device to be used by non-governmental personnel for identifying traffic violators comprising:

a camera mounted on a mobile platform and having a first lens and a second lens aimed in different directions for recording digital images of a target vehicle;

a memory component for storing the recorded images from the first and second lenses;

a global position satellite receiver for determining the location and speed of the mobile digital imaging device;

an information transmission system for sending the recorded images to an analysis center; and

means at the analysis center for receiving the images and for calculating the speed of the target vehicle based on the received images and the speed of the mobile digital imaging device.

2. The mobile digital imaging device of claim **1**, wherein the memory component includes means for temporarily storing a plurality of continuous images from the first and second lenses and for permanently storing the most recent images of the plurality of continuous images.

3. The digital imaging device of claim **2**, further comprising a control stick connected to the digital imaging device for controlling the operation thereof.

4. The digital imaging device of claim **2**, wherein the first lens is facing a first direction for capturing frontal images of the target vehicle and the driver's face as the target vehicle approaches the digital imaging device and the second lens is facing a second direction opposite the first direction for capturing images of the rear of the target vehicle as it moves away from the digital imaging device.

5. The digital imaging device of claim **1**, wherein the information transmission system is a cellular telephone system.

6. The digital imaging device of claim **1**, wherein the digital images of the target vehicle are recorded at a predetermined frame rate.

7. The digital imaging device of claim **6**, wherein the frame rate is between about 5 frames per second and about 24 frames per second.

8. A traffic control system for determining a suspected traffic violation by an operator of a target vehicle comprising a mobile digital imaging device having first and second lenses aimed independently of one another for capturing front and rear images of the target vehicle, a global position satellite receiver for determining the geographic location and speed of the mobile digital imaging device, a traffic violation analysis center, a cellular telephone system for transmitting target vehicle information to the analysis center, said information including the images of the target vehicle and the geographic location and speed of the mobile digital imaging device, means at the analysis center for receiving the target vehicle information, for determining the speed of the target vehicle relative to the digital imaging device and for calculating the actual speed of the target vehicle based on the speed of the mobile digital imaging device and the speed of the target vehicle relative to the mobile digital imaging device, and means at the analysis center for issuing a citation if the operator of the target vehicle has committed a traffic violation.

9. The traffic control system of claim 8, wherein said means for determining the speed of the target vehicle relative to the digital imaging device includes means for comparing the difference in size of a given object associated with the target vehicle in successive images of the target vehicle over a time lapse between the successive images.

10. The traffic control system of claim 8, wherein the mobile digital imaging device captures a digital image of a vehicle license plate of the target vehicle for comparing successive images of the vehicle license plate for speed computation.

11. The traffic control system of claim 8, wherein the front images of the target vehicle include images of the face of the operator of the target vehicle, and means at the analysis center for comparing and matching a digital image of the face of the operator with an image from a database of images, the database including digital images of licensed drivers.

12. The traffic control system of claim 8, wherein the first and second lenses comprise one of a digital still camera and a digital video camera.

13. The traffic control system of claim 8, including a display monitor at the analysis center for simultaneously displaying images from the first and second lenses in a split screen format.

14. A method of determining whether an operator of a target vehicle has committed a traffic violation comprising the steps of:

providing a digital imaging device having forward and rearward facing lenses and being mounted on a mobile platform;

recording a front image of an approaching target vehicle using the rearward facing lens as the target vehicle moves toward the rearward facing lens;

recording a rear image of the target vehicle using the forward facing lens as the target vehicle moves away from the forward facing lens;

transferring the images recorded by the forward and rearward facing lenses to an analysis center; calculating a distance traveled by the target vehicle using an object of known dimensions on the target vehicle as a reference dimension and comparing the reference dimension in a first image of the object to a corresponding dimension in a successive image of the object to determine the change in dimension of the object between the dimensions in the first and successive images; and

calculating the speed of the target vehicle from the distance traveled and the difference in time between the first and successive images of the target vehicle.

15. The method of claim 14, wherein the object is a front or rear license plate of the target vehicle.

16. The method of claim 14, further comprising the steps of:

determining a geographic location where the images are recorded using a global positioning satellite receiver;

determining the speed limit for the geographic location; and

issuing a citation to the registered owner of the target vehicle if the calculated speed of the target vehicle exceeds the speed limit for the geographic location.

17. The method of claim 14, further comprising the steps of: recording an image of the face of the operator and an image of the license plate number of the target vehicle;

retrieving from a database of photographic images of registered vehicle owners a photographic image of the registered owner of the target vehicle based on the recorded license plate number of the target vehicle;

comparing the image of the operator's face with the photographic image of the registered owner; and

determining whether the image of the operator's face matches the photographic image of the registered owner.

18. The method of claim 17, further comprising the steps of:

determining a geographic location where the images are recorded using a global positioning satellite receiver;

determining the speed limit for the geographic location; and

issuing a citation to the registered owner of the target vehicle if the image of the operator's face matches the photographic image of the registered owner and the calculated speed of the target vehicle exceeds the speed limit for the geographic location.

19. A method of determining whether an operator of a target vehicle has committed a traffic violation comprising the steps of:

recording a front image of an approaching target vehicle using a first digital camera;

recording a rear image of the target vehicle using a second digital camera as it moves away from the second digital camera;

transferring the images recorded by the first and second cameras to an analysis center;

isolating an image of a license plate of the target vehicle at the analysis center;

determining the dimensions of the license plate of the target vehicle based on the jurisdiction of registration of the target vehicle;

calculating the distance traveled by the target vehicle using a known dimension of a license plate from the jurisdiction of the target vehicle as a reference dimension by comparing the reference dimension in a first image of the license plate to the reference dimension in a successive image of the license plate to determine the change in the reference dimension between the first and successive images; and

calculating the speed of the target vehicle from the distance traveled and the difference in time between the first and successive images of the license plate.

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20. The traffic control system of claim 8, wherein said operator is non-governmental personnel.

21. The method of claim 14, wherein the method is practiced by non-governmental personnel.

22. The method of claim 14, further comprising a global positioning satellite receiver for determining the speed of the digital imaging device, wherein the actual speed of the target vehicle is calculated by determining the speed of the target vehicle relative to the digital imaging device and incorporating the speed of the digital imaging device to determine the actual speed of the target vehicle.

23. The method of claim 19, wherein the method is practiced by non-governmental personnel.

24. The method of claim 19, further comprising a global positioning satellite receiver for determining the geographic speed of the digital imaging device, wherein the actual speed of the target vehicle is calculated by determining the speed of the target vehicle relative to the digital imaging device and incorporating the speed of the digital imaging device to determine the actual speed of the target vehicle.

* * * * *

Appendix Z

US006831556B1

(12) **United States Patent**
Boykin

(10) **Patent No.: US 6,831,556 B1**
(45) **Date of Patent: Dec. 14, 2004**

(54) **COMPOSITE MOBILE DIGITAL INFORMATION SYSTEM**

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(73) Assignee: **Digital Safety Technologies, Inc.**, Nashville, TN (US)

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(22) Filed: **May 16, 2001**

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(52) **U.S. Cl.** **340/539.1**; 340/937; 348/143; 348/148; 701/35
(58) **Field of Search** 340/539.1, 426.1, 340/426.13, 426.16, 426.19, 426.2, 426.25, 937; 348/143, 148; 701/35, 36

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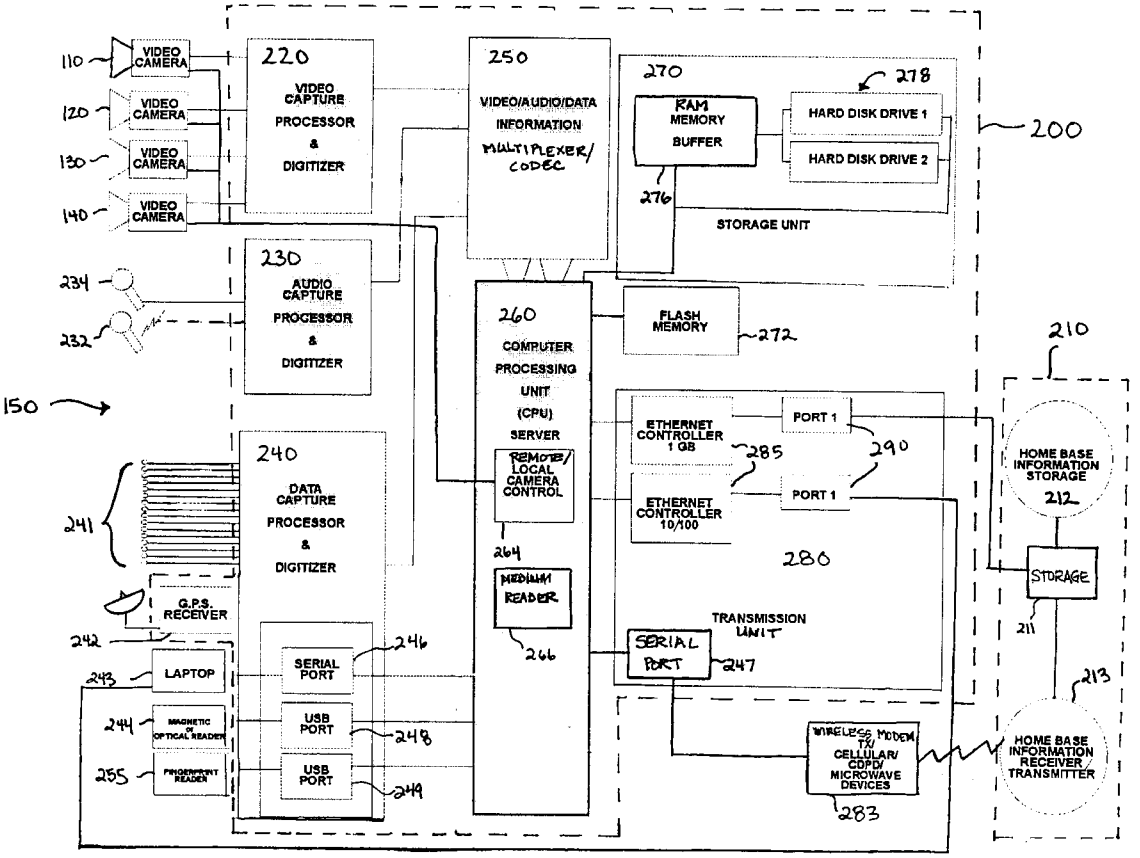
* cited by examiner

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(57) **ABSTRACT**

A surveillance system includes a device for capturing video, audio, and data information. The device is provided in a first location, such as a vehicle. A server is provided for integrating and storing the captured information in the vehicle. The server may be a mobile server which is capable of transmitting the captured information from the vehicle to a second location, such as a building.

25 Claims, 2 Drawing Sheets



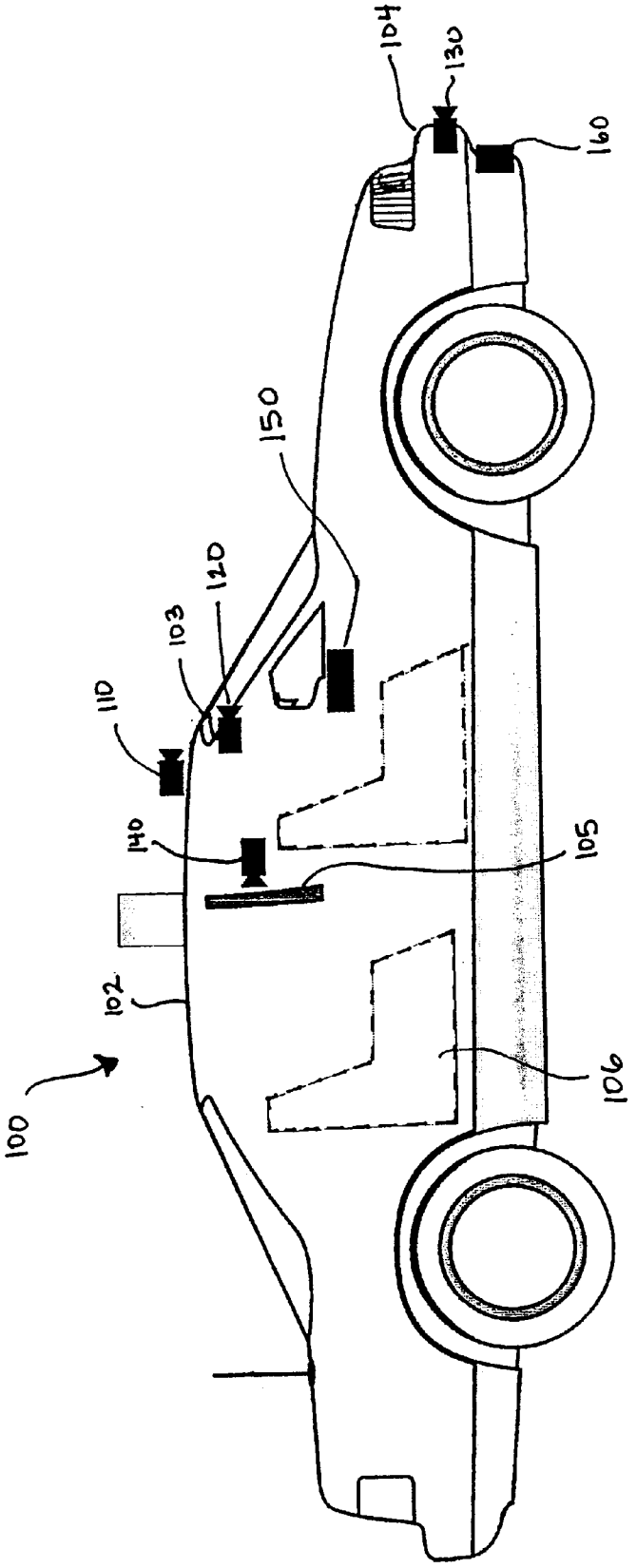


FIG. 1

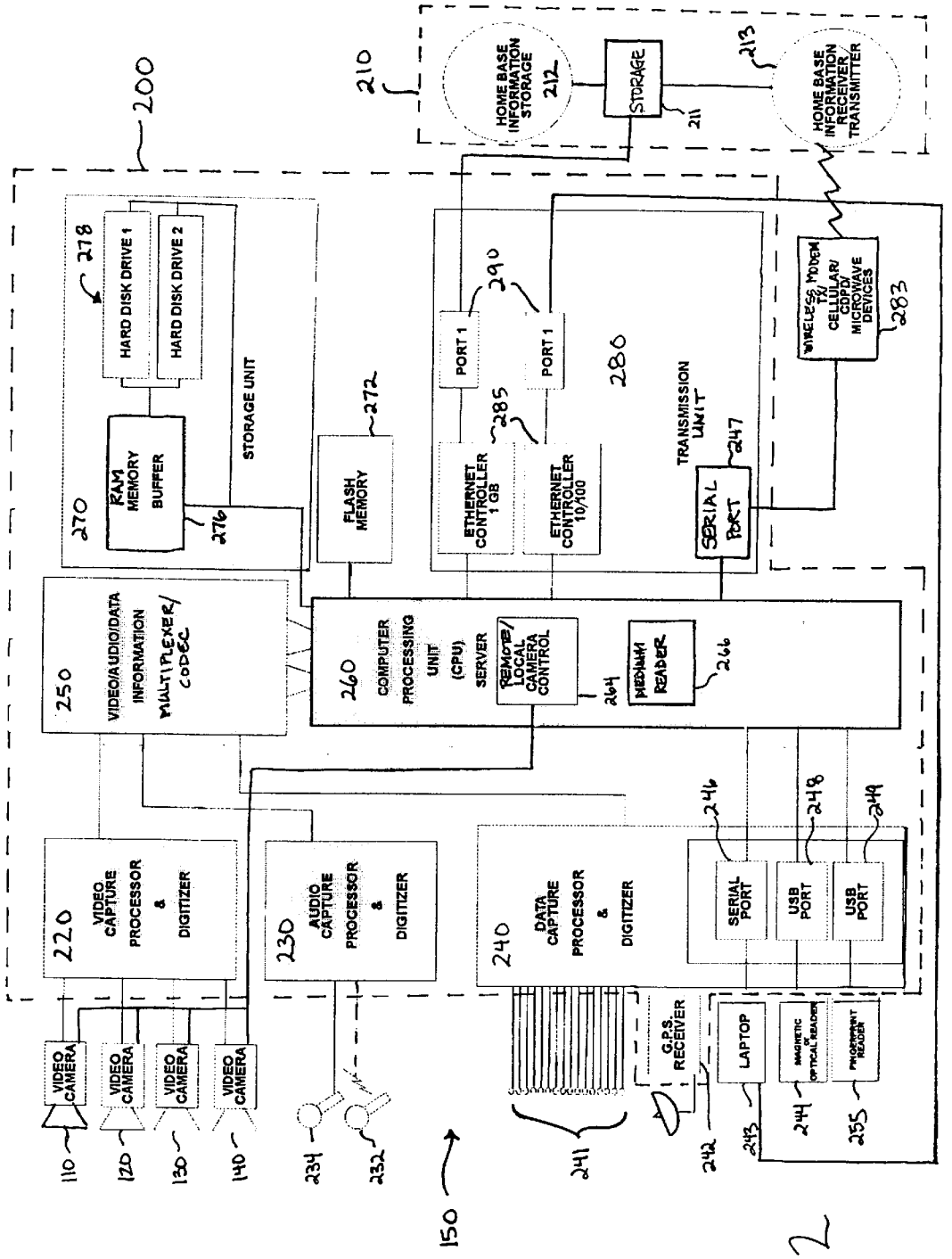

200
210
HOME BASE INFORMATION STORAGE 212
STORAGE
211
213
HOME BASE INFORMATION RECEIVER/ TRANSMITTER
278
HARD DISK DRIVE 1
HARD DISK DRIVE 2
STORAGE UNIT
270
RAM MEMORY BUFFER
276
272
FLASH MEMORY
290
PORT 1
PORT 1
285
ETHERNET CONTROLLER 1 GB
ETHERNET CONTROLLER 10/100
286
TRANSMISSION UNIT
247
SERIAL PORT
WIRELESS MODEM TX/ CELLULAR/ CDPD/ MICROWAVE DEVICES
283
250
VIDEO/AUDIO/DATA INFORMATION MULTIPLEXER/ CODEC
260
COMPUTER PROCESSING UNIT (CPU) SERVER
REMOTE/ LOCAL CAMERA CONTROL
264
MEDIUM READER
266
220
VIDEO CAPTURE PROCESSOR & DIGITIZER
230
AUDIO CAPTURE PROCESSOR & DIGITIZER
240
DATA CAPTURE PROCESSOR & DIGITIZER
246
SERIAL PORT
248
USB PORT
249
USB PORT
VIDEO CAMERA
VIDEO CAMERA
VIDEO CAMERA
VIDEO CAMERA
G.P.S. RECEIVER
LAPTOP
MAGNETIC OPTICAL READER
FINGERPRINT READER
110
120
130
140
234
232
150
241
242
243
244
255

Fig. 2

COMPOSITE MOBILE DIGITAL INFORMATION SYSTEM

TECHNICAL FIELD

The present invention is directed to a composite mobile digital information recording system. In particular, the present invention is directed to a system for use in public and commercial vehicles to capture video, audio, and related information for surveillance and evidentiary purposes.

BACKGROUND

Typical video recording systems, such as those currently deployed in police vehicles, use a standard fixed camera and a videocassette recorder (VCR) recording on a standard videotape, such as a video home system (VHS) tape. The VCR is usually located in the trunk of the vehicle. Recording quality is limited, primarily by the recording speed of the videotape. At standard speed the tape must be changed every two hours. At the slowest speed, a maximum of six hours is possible. Recording at the slowest speed, however, significantly reduces the quality of the recorded material.

Besides quality and capacity issues, VCR problems also include machine failure and tape failure, which require physical replacement and repair, and often occur without the knowledge of the user. Also, with respect to the videotapes, the user must physically remove and replace the videotapes in the VCR, and it is cumbersome to store the videotapes.

The VCR is a technical device nearing the end of its lifecycle; therefore, no serious advancements are on the drawing board that address the numerous technical issues incumbent to videotape recording. On the other hand, digital capture and storage is at the beginning of its technological curve, with rapid development of new devices. The only available means to ensure sufficient quality and control of video recording, access, and storage is an increase in the number of well-trained persons with those responsibilities. On the other hand, advancements of digital technologies are reducing the need for human involvement and even training.

The present invention is an elegant solution to the problems inherent in the current videotape systems deployed by public agencies and private companies for surveillance and evidentiary purposes.

SUMMARY OF THE INVENTION

The present invention provides an effective and efficient method for capturing, transmitting, and storing potential evidentiary video and related information in mobile environments. The captured data is stored in onboard hard drives, or other storage facilities, such as flash memory, solid state memory, etc., and transferred to a home base data repository for archival, retrieval, and evidentiary use.

The present invention provides a surveillance system which includes a device for capturing video, audio, and data information. The device is provided in a first location, such as a vehicle. A mobile server is provided for integrating and storing the captured information in the vehicle. The mobile server is capable of transmitting the captured information from the vehicle to a second location, such as a building.

In addition, the present invention involves a method for managing video, audio, and data information which includes capturing the information, integrating the information into one data stream, and storing the data stream.

The invention also involves a computer system, interface, and computer program product for implementing the foregoing method.

BRIEF DESCRIPTION OF THE DRAWINGS

The above objects and advantages of the present invention will become more apparent by describing in detail preferred embodiments thereof with reference to the attached drawings, in which:

FIG. **1** illustrates the present invention in a police car example; and

FIG. **2** illustrates a schematic diagram of the present invention.

DETAILED DESCRIPTION

The present invention simultaneously captures and stores visual, audible, time, data, and motion-related activities for safety, emergency, and evidentiary purposes. The present invention can be deployed on police, fire, and rescue vehicles and is adaptable for use on transportation and industry vehicles, as well as having rail and airline applications. The present invention is not limited to these applications, and may be used in any environment in which a surveillance system is desired, either mobile or non-mobile.

The system generally operates through the integration of the following components: video capture; audio capture; related-data capture; an information integrator; a computer processing unit (CPU); a storage unit; and a transmission unit. The user has the option of video-only capture, audio-only capture, data-only capture, or any combination of the three information processors.

With the present invention according to the preferred embodiment, there is no limitation due to the tape speed or quality because digital video and related information are recorded on the hard drive of an onboard computer. The capacity of the present invention to capture, store, and transmit streams of video/audio/event information data significantly expands the value and the capacity of an onboard videotape surveillance system.

The embodiment disclosed herein is used in a police car wherein the information is captured, stored and can be transmitted back to a home base (e.g., a station precinct); however, the present invention is not limited to this example and may be used in any type of environment in which a surveillance system is desired.

FIG. **1** illustrates the present invention embodied in a police car **100**. In particular, a composite mobile digital information system (CMDIS) unit **150** is provided in the police car **100** for storing and transmitting captured information. In this example, up to four video cameras are strategically mounted in four locations on the police car **100** for use with the CMDIS **150**: a first camera **110** is mounted on a roof **102** facing forward; a second camera **120** is mounted on a rearview mirror **103** facing forward; a third camera **130** is mounted on a bumper (grill) **104** facing forward; and a fourth camera **140** is mounted on a front cage **105** facing towards a back seat **106**. Of course, varying numbers of cameras may be used in these or other desired locations.

The cameras **110–140** may be, for example, high-resolution National Television System Committee (NTSC) analog cameras, digital cameras, or component analog cameras. A multiplexer can be added to the cameras **110–140** to increase the number of views seen at one time.

The cameras located on the police car **100** can be remote controlled by a local user (e.g., officer), a remote user (e.g., precinct personnel), or can be operated to track the officer or specified object. Camera controls permit pan, tilt, record,

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search, playback, focus and contrast adjustments, as well as other features which may be necessary for obtaining a high quality surveillance system. Moreover, one or more of the cameras **110–140** can also be enabled to automatically track the officer, without requiring any human input, if appropriate software is installed in a mobile server **200** (described later).

During recording and playback of the recorded data, digital coding provides tags for future search parameters. For instance, searchable identification code may be embedded in the data which is associated with a particular event. Thus, the data can be easily retrieved for evidentiary purposes at a later time without necessitating labor intensive searches of the recorded material.

With the present invention, data is digitally captured and processed from any one or all of the cameras for integration and storage in the mobile server **200** (see FIG. **2**) of the CMDIS unit **150**. In addition, live views of video/audio/data information may be transmitted from the vehicle **100** to a home base **210** through high speed local links, e.g., cellular devices, as discussed in further detail later. In addition, video/audio/data information can be broadcast or transferred from the home base **210** to the vehicle **100**, or to multiple vehicles in various locations.

With respect to the capture of video information, the resolution of the video capture (or signal) is compressed or decompressed (encoded/decoded (CODEC) for transmission and then decoded once it reaches its destination) to provide the appropriate resolution for storage. Typical resolutions are 720×480, 320×240, or 160×120 pixels. Pixels are the smallest element of a video image. The lower the pixels selected, the lower the quality of the resolution and the higher the capacity for storing images.

In the present embodiment, a video capture processor and digitizer **220** captures, digitizes, and transmits the captured video to a video/audio/data information multiplexer/CODEC **250** of the mobile server **200**. The video/audio/data information multiplexer/CODEC **250** may include a digital signal processor (DSP) (e.g., the Texas Instruments TMS320C6415), or other similar device.

In addition to the video capture described above, an audio capture processor and digitizer **230** captures, digitizes, and transmits captured audio to the video/audio/data information multiplexer/CODEC **250**. In the example shown in FIG. **2**, there is provision for the input of two audio sources **232**, **234** to be digitally captured and processed. For example, a police officer can wear a wireless microphone **234** and one microphone **232** may be configured to capture sound from the rear seat of the vehicle **100**. After the audio is captured, the audio is transmitted to the video/audio/data information multiplexer/CODEC **250** and the appropriate CODEC (compression) is applied. Of course, the present invention is not limited to having two audio sources; an appropriate number of audio sources may be provided in a variety of locations depending on the application requirements.

A data capture processor and digitizer **240** captures various types of data which are also transmitted to the video/audio/data information multiplexer/CODEC **250**. In the present example, capture and processing of sixteen inputs **241** (e.g., time, various event information, and motion related events) are provided. For instance, the surveillance system of the present invention can capture and store the action of removal of a weapon from its rack, a car door opening or closing, the status of the ignition, air bag deployment, presence of an unauthorized individual, and vehicle speed. The various inputs can be configured according to a user need and the particular event.

In addition to the sixteen related-events inputs **241**, other automatically recorded data may include location, using a Global Positioning Satellite (GPS) receiver **242**, time of day, driver name, unit number, and incident number and other types of relevant information.

Various ports are provided for allowing input and output of data. For example, two serial ports **246**, **247** and two universal serial bus (USB) ports **248**, **249** may be provided for additional data input and output. For example, the USB ports **248**, **249** can be used to input information from a magnetic or optical reader **244** and a fingerprint reader **245**. One serial port **246** can be used to input and output data to and from a laptop **243**, and the other serial port **247** can be connected to receiving/transmitting device **283** (one of a variety of wireless modem, cellular, satellite, and microwave devices) that sends radio signals back to the home base or precinct **210**. Of course, the present invention is not limited to this configuration since a variety of ports can be provided depending on the types of data being captured and the parameters required for the specific application in which the present invention is employed. The transmitting/receiving device **283** may comprise any device capable of transmitting at least some of the audio, video, and data information collected by the server **200**. The transmitting receiving device **283** which is employed for a particular surveillance system will depend upon the user's preferences and environmental limitations.

The captured data from the sixteen inputs, GPS **242**, and ports are digitized and relayed to the video/audio/data information multiplexer/CODEC **250** and combined with the video and audio information from the video capture processor and digitizer **220** and the audio capture processor and digitizer **230** to create aggregated documentation that is sent to a storage unit **270** in one data stream. In particular, the stream of data is multiplexed into one final composite compressed stream. Thus, all of the various types of information are aggregated into a single data stream which is then stored in the storage unit **270**. Although in this embodiment the compression is shown in the multiplexer/CODEC **250**, this function can be carried out by software in an alternative embodiment, for example with CPU **260**.

The CPU server **260** runs embedded operating systems, such as Windows NT or a real-time operating system, and functions as a server for all sources of information. The CPU **260** can control the multiplexer/CODEC **250**, the storage unit **270**, and other aspects of the CMDIS **150**. In an alternative arrangement, the CPU **260** can perform the multiplexing function itself, thereby eliminating the need for a separate multiplexer.

The CPU **260** has remote access features that allow technicians to perform system maintenance and repairs at any time, day or night. If a user experiences a malfunction, technicians can examine and resolve it, or ship a repair part quickly. The remote service connection also provides field updating of new software features for the CMDIS **150**.

The CPU **260** may include a remote, local, and/or automatic tracking camera control **264**, for controlling the various functions of the cameras **110–140**, as discussed earlier.

The CPU **260** also commands the multiplexer/CODEC **250** to embed the searchable identification code (tags) which is associated with a particular event or information, into the data stream. The CPU **260** detects the particular events or information, and commands the multiplexer/CODEC **250** to include the tags.

In addition, a flash memory **272** may be provided for storing instructions for execution by the CPU **260**.

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The storage unit **270** contains a random access memory (RAM) memory buffer **276**, and two hard disk storage drives **278** that are driven by the CPU **260**. The combined video/audio/data information stream is first sent to the RAM memory buffer **276** that holds two or more minutes of real-time information. The RAM memory buffer **276** refreshes every time a new record command tells the CPU **260** to transmit the first minutes of the buffered memory onto the hard drives **278**. One purpose of the RAM memory buffer **276** is to provide the operator with a view of the events that initiated the recording process. For instance, when information is being retrieved at a later date, the viewer is able to see the events and/or information which triggered the recording process.

More specifically, the processor CPU **260** commands the RAM memory buffer **276** to transmit the stored information to the permanent storage memory, e.g., the hard drive **278**, upon the triggering of a particular event. Such an event may include, but is not limited to, the activation of a siren on the police car **100**, the removal of a gun from its gun rack, sudden acceleration of the vehicle, etc. All of the information which was recorded during the specified time and saved to the RAM memory buffer **276** is then digitally saved to the permanent storage memory, e.g., one of the two onboard hard disk drives **278**. Thus, the surveillance system records an event, as well as a specified time before the event. This time period of information may be valuable for determining the events that transpired before the triggering event, e.g., removal of gun, acceleration of vehicle.

If the surveillance system is commanded to continuously record onto the permanent storage memory, a triggering event is not required for the CPU **260** to command the RAM buffer memory **276** to transmit captured information to the permanent memory storage. In other words, the RAM buffer memory **276** would continuously transmit information to the permanent memory storage.

The present invention is not limited to the use of hard disk drives. Solid state memory or other types of non-volatile, non-rotating memory devices may be substituted for the hard disk drives, e.g., flash, etc.

Moreover, the present invention is not limited to a RAM memory buffer. The invention may utilize any type of memory buffer, or may be a flash memory, etc.

A transmission unit **280** may house the serial port **247** connected to the wireless modem/cellular/satellite/microwave transmitting/receiving device **283**, allowing live transmission of video/audio information packets back to the home base (or precinct) **210** via a home base information receiver/transmitter **213** or networked computers. An operator located in the home base **210** is able to control which information is transmitted from the mobile server **200** back to the home base **210**. For instance, the operator may view location, and/or listen to audio, and/or access other data which is transpiring at the vehicle location. As broadband technology improves, increased amounts of data will be capable of being transmitted in this manner.

The operator may command the cameras **110–140** via the remote/local camera control **264**, as described above, to improve the composure, framing, and quality of the recorded data. The control **264** can be commanded from the mobile server **200**, or from a home base server **211** of the home base **210** via the home base information receiver/transmitter **213** and wireless device transmitter/receiver **283**. Moreover, the audio or other aspects of the data capture may be controlled from the home base location using the wireless transmission and receiving components. With this aspect of the invention, it is possible to set up a remote surveillance system wherein personnel are not required at the remote location to operate the equipment.

When the vehicle **100** returns to the home base **210**, it is connected via a high-speed, high-capacity Ethernet controller **285** (such as a 3COM 1 GB controller) to the home base server **211** via port **290** and the digitally stored video/audio/related information (i.e., data stream) is data dumped to a home base master storage repository **212**. The data can be dumped through copper wire, wireless transmission, fiber optics, laser or other means. FIG. **1** illustrates an example wherein a data dump outlet **160** is provided on the police car **100** for connecting the port **290** to the home base information storage **212**. Once the data is loaded onto the main home base data servers **211**, it is instantly and readily available for review by authorized personnel (e.g., attorneys, public interest groups, agencies or other parties which may value the recorded information), and for transmission to courtrooms or other desired locations. In addition, the data can be viewed from a web browser or proprietary software. All recorded information data can be encrypted if desired.

In addition, an Ethernet controller **285** (e.g., 10/100 type) may be connected to a port **290** for transmitting information to the laptop **243**. With this configuration, the police officer, or another person who reaches the scene after an event has transpired, is able to view previously recorded information while in the vehicle **100**.

Due to the searchable identification code, i.e., tags, large amounts of information can be easily searched and viewed without requiring viewing irrelevant portions of the data. Moreover, a monitor or liquid crystal display (LCD) (typically provided on the laptop **243** and/or some other display device and/or at the home base) displays all of the recorded information at one time. Thus, for instance, the operator can view video, listen to audio, view time, date, location, and event-related data (e.g., removal of a gun from a weapon rack) simultaneously.

A particular event, such as activation of the light bar on the police vehicle, can initiate the capture and processing of information in the present invention. Alternatively, information can be continuously captured and processed throughout an officer's shift, over a predetermined amount of time, etc., as controlled by the CPU **260**.

One embodiment of the invention resides in a computer system. Here, the term "computer system" is to be understood to include at least a memory and a processor. In general, the memory will store, at one time or another, at least portions of an executable program code, and the processor will execute one or more of the instructions included in that executable program code. It will be appreciated that the term "executable program code" and the term "software" mean substantially the same thing for the purposes of this description. It is not necessary to the practice of this invention that the memory and the processor be physically located in the same place. That is to say, it is foreseen that the processor and the memory might be in different physical pieces of equipment or even in geographically distinct locations.

The computer system, such as the one in the above preferred embodiment, could include the CPU **260** and the flash memory **272** which are shown in FIG. **2**.

The above-identified invention may be embodied in a computer program product, as will now be explained.

On a practical level, the software that enables the computer system to perform the operations described further below in detail, may be supplied on any one of a variety of

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media. Furthermore, the actual implementation of the approach and operations of the invention are actually statements written in a programming language. Such programming language statements, when executed by a computer, cause the computer to act in accordance with the particular content of the statements. Furthermore, the software that enables a computer system to act in accordance with the invention may be provided in any number of forms including, but not limited to, original source code, assembly code, object code, machine language, compressed or encrypted versions of the foregoing, and any and all equivalents.

One of skill in the art will appreciate that "media", or "computer-readable media", as used here, may include a diskette, a tape, a compact disc, an integrated circuit, a ROM, a CD, a cartridge, a remote transmission via a communications circuit, or any other similar medium useable by computers. For example, to supply software for enabling a computer system to operate in accordance with the invention, the supplier might provide a diskette or might transmit the software in some form via satellite transmission, via a direct telephone link, or via the Internet. Thus, the term, "computer readable medium" is intended to include all of the foregoing and any other medium by which software may be provided to a computer.

Although the enabling software might be "written on" a diskette, "stored in" an integrated circuit, or "carried over" a communications circuit, it will be appreciated that, for the purposes of this application, the computer usable medium will be referred to as "bearing" the software. Thus, the term "bearing" is intended to encompass the above and all equivalent ways in which software is associated with a computer usable medium.

For the sake of simplicity, therefore, the term "program product" is thus used to refer to a computer useable medium, as defined above, which bears in any form of software to enable a computer system to operate according to the above-identified invention. Thus, the invention is also embodied in a program product bearing software which enables a computer to perform management of information according to the invention.

The computer readable medium could be read by the CPU **260** through a medium reader **266** as illustrated in FIG. **2**, for example.

The problems of current surveillance systems are eliminated with the present invention because the digital operation and storage is self contained. Also, the system of the present invention is easier to operate and maintain, reduces the risk of data loss, and overcomes data retrieval problems with current surveillance systems.

Digital storage capacity is virtually limitless. In current video systems, when used for evidentiary purposes, videotapes must be stored at appropriate temperatures and climates for up to 18 months. Though there are temperature requirements for digital storage, the range of acceptability is much wider than for videotape storage. Besides the required storage space for videotape, other physical storage issues include proper labeling, inventory control, potential for tampering (destruction, theft editing, or deleting), loss retrieval, and additional human handling errors. With the present invention, these problems are minimized because the data is stored on computer hard drives and/or computer tapes (e.g., back-up tapes) located in the home base data archiving facility along with other important data and computer equipment. These computer equipment rooms tend to be more secure than the typical videotape storage facility.

Also, when the recorded material is transferred from the mobile unit to a storage hard drive at the home base, there is no degradation of the material because there is no loss of image with a digital transfer.

With current systems, at the end of a shift the officer is required to remove all videotapes and turn them into a storage facility. However, with the present invention, the digitally stored material is data dumped via various download devices including wireless transfer, without human contact.

Data retrieval is much easier with the present invention than current systems, and during such retrieval loss of evidence is reduced. In videotape recording systems, it is necessary to conduct time consuming searches for the location of critical evidentiary scene evidence on the videotape. There is also the possibility of degradation of the tape during handling since it can stretch, break or crease. The tape may require handling by several different people to share scenes with other law enforcement officials, district attorneys, defense attorneys, judges, juries, and others.

In contrast, the digital video/audio/data information recorded by the present invention is time coded and can be easily searched without damage to data. The data can be transmitted to others for viewing via the Internet, in digital form on compact disks (CD) and digital video disks (DVD), on videotape, over low power video transmission, and through a variety of other formats without damaging or corrupting the original material.

The system of the present invention will alert the maintenance personnel in case of a system failure or error. A remote technician using a modem can solve most problems immediately. The system is compact and requires no physical contact from the officer to function properly.

While this invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A surveillance system for an emergency response vehicle, comprising:

a device for capturing at least two of video, audio, and data information, said device provided in the emergency response vehicle, and

a server for digitally integrating the captured information into one data stream and storing the data stream in the emergency response vehicle,

wherein said server is operative to transfer the data stream from the emergency response vehicle to a second location.

2. The surveillance system according to claim **1**, wherein said server comprises:

a storage unit for storing the data stream;

a transmission unit for transmitting the data stream to the second location;

a computer processing unit for controlling said storage unit, and said transmission unit.

3. The surveillance system according to claim **2**, wherein said server further comprises a video/audio/data information multiplexer for integrating the captured information into the data stream.

4. The surveillance system according to claim **3**, wherein said capturing device includes a digital video capturing device for capturing video information, an audio capturing

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device for capturing audio information, and a data capturing device for capturing data information, and said video/audio/data multiplexer integrates the video, audio and data information into the data stream.

5. The surveillance system according to claim **2**, wherein said capturing device continuously captures data, said storage unit includes a memory buffer for temporarily storing the continuously captured information and a permanent memory for permanently storing the captured information until said transmission unit transmits the captured information to the second location.

6. The surveillance system according to claim **5**, wherein said computer processing unit commands said memory buffer to transfer the stored information to said permanent memory upon the presence of a triggering event, so that a portion of the stored information, which was captured before the occurrence of the triggering event, is transferred to said permanent memory.

7. The surveillance system according to claim **5**, further comprising:

a wireless device for transmitting at least some of the captured information from the server to the second location when said server is remotely located from the second location; and

an Ethernet controller for transmitting the data stream to the second location when the server is located at the second location,

wherein said wireless device is adapted to receive information from the second location.

8. The surveillance system according to claim **7**, wherein said computer processing unit includes a camera control device, for controlling at least one camera that supplies video information for the video capturing device, said camera control device being controlled by one of said computer processing unit and a computer processing unit of the second location via said wireless device.

9. The surveillance system according to claim **1**, wherein said capturing device is a data capture processor and digitizer for receiving at least one of a plurality of data inputs and other event information which is then integrated, stored and transmitted by said server.

10. The surveillance system according to claim **1**, provided in a police vehicle.

11. The surveillance system according to claim **3**, wherein the multiplexer compresses the captured information.

12. The surveillance system according to claim **6**, wherein said triggering event includes at least one of activation of a siren, removal of a gun from a gun rack, sudden acceleration of the vehicle.

13. The surveillance system according to claim **1**, wherein each of said video, audio and data information is captured, integrated and stored in said server.

14. A surveillance system for an emergency response vehicle, comprising:

means for capturing at least two of video, audio, and data information;

means for storing the information in the emergency response vehicle;

means for digitally integrating the information into one data stream; and

means for transmitting the one data stream from the emergency response vehicle to a remote location.

15. A surveillance system for an emergency response vehicle, comprising

means for capturing at least two of video, audio, and data information;

means for storing the information in the emergency response vehicle;

means for integrating the information into one data stream;

means for transmitting the one data stream from the emergency response vehicle to a remote location;

a digital video camera; and

means for controlling said digital video camera from the remote location.

16. The surveillance system according to claim **15**, further comprising means for automatically controlling said digital video camera to track movements of an object.

17. A process for managing information obtained from a vehicle, the information including at least two of video, audio, and data information, comprising:

capturing the information;

digitally integrating the information into one data stream; and

storing the data stream in the vehicle.

18. The process for managing information according to claim **17**, further comprising:

transmitting the data stream to a storage device in a remote location.

19. A process for managing information obtained from a vehicle, the information including at least two of video, audio, and data information, comprising:

capturing the information;

integrating the information into one data stream;

storing the data stream in the vehicle;

embedding searchable identification codes in the data stream during the integrating of the information; and

transmitting at least a portion of the data stream via a wireless device to a receiving device in the remote location.

20. A computer system adapted to manage information from a vehicle, the information including at least two of video, audio, and data information, comprising:

a processor, and

a memory including software instructions adapted to enable a computer to perform the steps of:

capturing the information;

digitally integrating the information into one data stream; and

storing the data stream in the vehicle.

21. The computer system according to claim **20**, wherein the software instructions are adapted to enable the computer to perform the additional step of: compressing the information captured in the capturing step.

22. A computer program product for enabling a computer to manage information from a vehicle, the information including at least two of video, audio, and data information, comprising:

software instructions for enabling the computer to perform predetermined operations, and

a computer readable medium bearing the software instructions;

the predetermined operations including the steps of:

capturing the information;

digitally integrating the information into one data stream; and

storing the information in the vehicle.

23. The computer system according to claim **20**, wherein the step of capturing the information is performed by at least

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one of a digital video capturing device, an audio capturing device and a data capturing device, and the step of integrating the information is performed by a video/audio/data multiplexer.

24. The computer program product according to claim **22**, wherein the step of capturing the information is performed by at least one of a digital video capturing device, an audio capturing device and a data capturing device, and the step of integrating the information is performed by a video/audio/data information multiplexer.

25. The computer program product according to claim **22**, wherein the predetermined operations further includes the step of: compressing the information captured in the capturing step.

* * * * *

Appendix AA

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A Practical Home Security System via Mobile Phones

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Abstract: - This manuscript addresses the design and implementation of a practical home security system (PHSS). This system realizes its mobile surveillance via mobile phones by the planted Java applet. The challenge is that PHSS works independently under the existing Internet Service Providers (ISP) and telecoms. End-users can monitor their home and properties anywhere and anytime on the screen of their mobile phone. Furthermore, PHSS can be also applied to vehicle surveillance without the restrictions of ISPs. This system has been completed and verified in houses and vehicles.

Key-Words: - Home security, mobile surveillance, PHSS

1 Introduction

The importance of home security has greatly increased in recent years. Relying on huge computing power and friendly user interface, the most recent surveillance systems are primarily PC-based ones. To satisfy the application in different conditions, surveillance systems have also been implemented in many ways to accomplish the objectives. The DSP-based real-time surveillance system has been realized in [1, 2]. Sato et al. [3] presented a hybrid intelligent surveillance system consisted of an embedded system and a PC. [4], [5] and [6] addressed the web-based monitoring system with Java applet. However, these surveillance systems perform surveillance jobs without mobility. That is the monitoring works cannot be carried out unless the user is near a PC or some embedded computer system.

Since mobile phones have become prevailing, while house and property security demands are continually increasing, the integration of the mobile phone and a surveillance system becomes more meaningful so that people can know the security of their properties anytime, anywhere. Mobile phones are at present, quite ubiquitous and increasingly sophisticated. A mobile phone can not only be treated as a communication unit, but as a camera, a web browser, a music box, a game platform, or even a wireless remote controller, since so many services are provided on a mobile phone. Corcoran et al. proposed a photography service which offered the possibility to access and manipulate uploaded pictures directly by Wireless Application Protocol (WAP) or iMode services via mobile phone [7]. They also presented a combined battery-charger and picture upload unit to solve the two-hour talk-time limitation of a fully charged mobile phone in their investigation. Nikolova et al. developed a gateway to enable the control of consumer electronics devices connected to the home network from a mobile phone. The gateway intermediates are wired between the home network and a wireless communication network using Home Audio Video interoperability (HAVi) and WAP specification, respectively [8], named HAVi-WAP UI.

Recently, a video clip system [9] has developed a way to transfer the video stream to a mobile phone through Ethernet from PCs. A new kind of wireless image system [10] provides users the image information by multimedia message service (MMS). However, for the users, to read a MMS in mobile phone need several operational steps. Although [9] and [10] still have a lot of room to improve, it can be found that the mobile phone is exactly a nice solution for a remote surveillance appliance.

In this paper, a practical home security system (PHSS) is addressed and has been realized via mobile phones. PHSS is a RISC-based embedded system. μCLinux is chosen as the embedded OS on the low cost server of PHSS. The doorbell, Infrared sensors, and other motion sensors play the roles of trigger sources to enable PHSS to carry out its surveillance job. End-users can monitor their properties in house or on vehicle anywhere and anytime by the mobile phone in hand. Once PHSS was triggered, users receive a notification and browse the desired images captured from the CCD/CMOS cameras connected to the embedded surveillance server (ESS) of PHSS on the screen of their mobile phone.

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The challenge of this security system is that PHSS must work independently under the existing Internet Services Provider (ISP) and telecom. In particular, the ESS of PHSS can be installed in houses or outdoors without a physical IP address supporting. Besides house surveillance, PHSS can also be applied to vehicle security. Recent vehicle surveillance systems, [11-12], provide real-time short messages to notify users when something has happened to their car. Nevertheless, the users just know something has happened but understand what happened on their cars. Because [11, 12] do not provide real-time images. PHSS can fully support this requirement.

This paper consists of six sections and is organized as follows: Section 2 presents the system overview and the software of PHSS is described in Section 3. The mobile phone programming is addressed in Section 4. Section 5 gives the experimental results and potential applications. Finally, Section 6 discusses the conclusions.

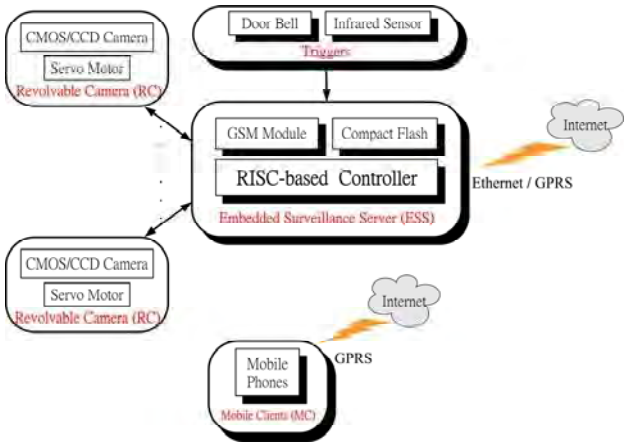


Fig.1 PHSS system overview

2 The System Overview of PHSS

PHSS, as shown in Fig.1, consists of four parts; embedded surveillance server (ESS), triggers, mobile clients (MCs), and revolvable cameras (RCs). ESS is composed of a RISC-based controller, a GSM module, and a CompactFlash card. The Linux kernel, related device drivers and the applications are implanted on ESS. The GSM module enables the mobility of this surveillance system.

The motion sensors and doorbell are assigned as the triggers in PHSS. The doorbell is integrated to build a communication link between users and the visitors to avoid intruders, whom might try to determine if the house empty by pressing the doorbell and receiving no answer.

Furthermore, ESS is also triggered by an infrared sensor or other motion sensors, when someone moves within its sensing scope. The RCs will begin capturing successive images, if it receives a trigger signal from the ESS. These images were compressed into JPEG format and stored in storage units, i.e., CompactFlash card. The notifications for these events will be sent to the users by short messages through the GSM module on ESS.

Besides, MCs offer the users to real time acquire the information about their home condition over the Java program embedded on their mobile phones through GPRS. Moreover, the users can give the rotating commands to ESS for controlling the cameras which are carried by servo carriers. Then, these cameras will capture the pictures at different view angle and the more information can be observed for the users

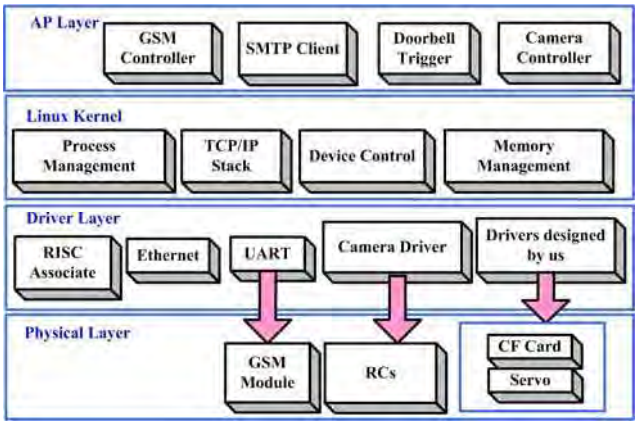


Fig.2 The software architecture of ESS

3 The Softwares on ESS

Figure 2 shows the software architecture of ESS, which is the core technology of PHSS. µClinux is chosen as the embedded OS on ESS. Drivers that correspond to the hardware are developed to control all system components. The OS is divided into three parts; Linux kernel, driver layer and application layer. The detail development is described as follows.

3.1 Linux Kernel

In a UNIX system, several concurrent processes attend to different tasks. Each process asks for computing power, memory, network connectivity, or some other resource from the system resources. The kernel is the largest chunk of executable code responsible for handling such requests. Although the distinction between the various kernel tasks is not always clearly marked, the kernel can be functionally split, into four parts; process management, device control, TCP/IP stack, and memory management [13].

3.2 Driver Layer

Linux kernel can not control the hardware correctly without drivers. There are many drivers in the operating system, such as RISC associates, Ethernet and all kinds of peripherals. Therefore, we only address the used drivers designed for PHSS.

3.2.1 CompactFlash Card Driver

To store compressed images, a CompactFlash card is integrated with the ESS. It is treated as a block device for the Linux OS. The driver is successfully developed to control the CompactFlash card that allows the Linux kernel to read and store data based on the FAT file system.

3.2.2 Servo Carrier Driver

The servo carrier is a kind of character device because it has a serial operating signal. It is controlled by the PWM signals with different duty cycles. The servo carrier driver that generates the PWM signals with corresponding duty ratio using the timer interrupt of RISC is developed.

3.3 Applications

The following applications are designed to enrich the functionality of PHSS.

3.3.1 Camera Capture

This application sends the image capturing request to the RCs connected to ESS, receives the JPEG images from RCs and stores them into the CompactFlash card. This application is written very flexibly to control several RCs. The running flowchart of this application is plotted in Fig.3.

3.3.2 GSM Module Control

The GSM module works with the AT commands and links to the COM port of ESS to make a phone call or send a short message to the user. If the user decides to trigger the system to capture images, he/she can send a short message to ESS and this application will carry out the command. Table 1 lists the codes for the supported function names in the short message sent from the user to ESS.

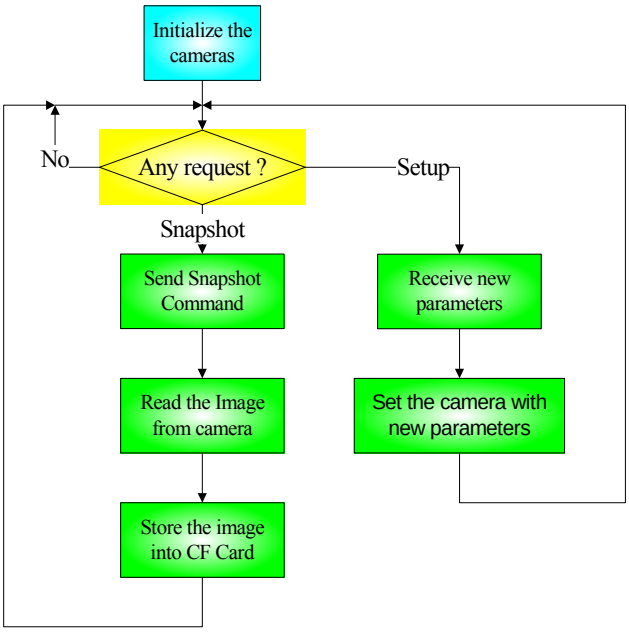


Fig.3. The camera capturing control application flowchart

3.3.3 SMTP Client

ESS will send an E-mail to users when something occurs. The captured JPEG images will be attached to the E-mail to provide complete information to the user.

3.3.4 Doorbell Trigger

The doorbell is integrated in PHSS to check visitors' purpose for coming. PHSS is trigged by the pressed doorbell and dials the house owner's mobile phone automatically. The voice channel between the visitor and the owner is quickly established. As shown in Fig.4, the house owner can see the visitor's image on their mobile phone and talk to him/her directly between the intercom and the

Table 1: Code list for the supported functions in short message.

Functionalities	*Commands*	*Formats*	*Descriptions*
Enable Camera 1	'A'	"A[num]"	Enable camera 1 to capture and transfer [num] images to the user.
Enable Camera 2	'B'	"B[num]"	Enable camera 2 to capture and transfer [num] images to the user.
Enable both cameras	'C'	"C[num]"	Enable both cameras to capture and transfer [num] images to the user.
Image resolution setting	'X'	"X[num]"	Set the capturing image resolution. 1. VGA (640x480) 2. QVGA (320x240) 3. QCIF (176 x 144)
User's phone number setting	'P'	"P[num]"	Set the user's mobile phone number so that PHSS can dial or send the warning messages to the user.
User's email address setting	'E'	"E[address]"	Set the user's email address so that PHSS can send a warning email with the attached JPEG images to the user.
Reset	'R'	"R"	Reset the system.

mobile phone, respectively. PHSS not only monitors house properties, but also prevents thieves from breaking into the user's house, since the house owner talks to visitors directly even when he is not at home.



Fig.4 The doorbell integration in PHSS

4 Mobile Phone Programming

The development kit we used to build Java programs for a mobile phone is Wireless Tool Kit (WTK) provided by Sun. The elementary program is verified by the simulator that WTK provides, as shown in Fig.5.



Fig.5 Mobile phone simulator provided by WTK

Since more and more mobile phones support Java programming, the J2ME Java version is addressed for developing applications on mobile devices. But the API of J2ME is not as complete as that of J2SE. There are still many restrictions in developing the Java program. The socket programming is used to establish the connection between ESS and the mobile phone. The server-push method is applied in the data transmission between them. That is, the mobile phone will not download the files until the server is ready for the downloading. Figure 6 shows the state chart of this method and Fig. 7 is the processing flowchart of this program on a mobile phone.

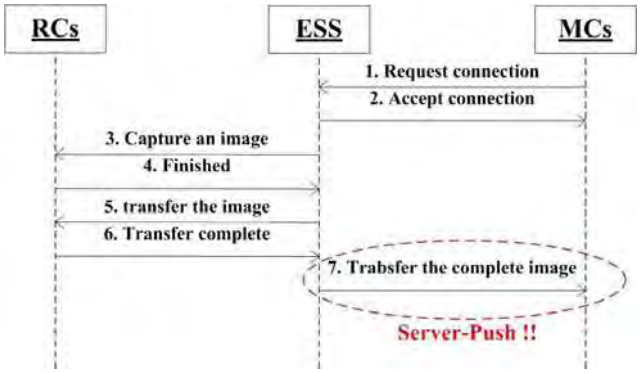


Fig. 6 The state chart of server-push we addressed.

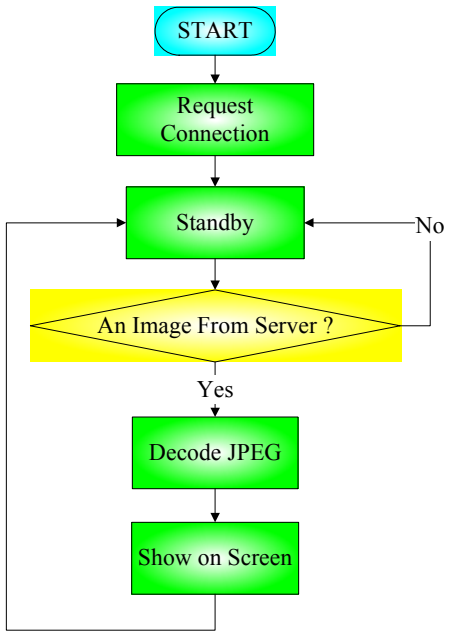


Fig. 7 The processing flowchart of the program on a mobile phone

To guarantee the workability of this program, the simulators provided by the mobile phone manufacturers are necessary since not all mobile phones can fully support the J2ME. Figure 8 shows one of the simulators.

Users can download the continuous real-time images to their mobile phones from ESS anywhere if this Java applet has been embedded in their mobile phones. The computing power and memory size of the mobile phone are both much lower than other peripherals so that software decoding of the received JPEG images relies on the J2ME API, createImage (DataInputStream in), to decode the JPEG images on mobile phones.

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Fig. 8 The simulator provided by some manufacturers

The GUI developed on mobile phones is shown in Fig. 9. The top of the screen in Fig. 9 displays the date and time of the captured image, and the two buttons on the bottom are "Option" in Chinese and "Stop", respectively. The "Stop" button can suspend the image transmission, as illustrated in Fig. 10, and resume transmission by pressing the "Resume" button.

5 Experimental Results

PHSS has been completely implemented with the functions mentioned above. Users promote their surveillance systems with mobility so that they know the circumstances of their properties anytime and everywhere. The Java program developed for mobile phones enables users to see real-time images through GPRS protocol. Images are transmitted from the triggered ESS so that if someone is sensed by the settle sensors, a short message is sent to the user to notify of an emergency. The Java applet on their mobile phone shows the real-time continuous QCIF images on the screen

The actual average bandwidth of GPRS is approximately 8K to 10K bits per second for the downloading data transmission rate. The QCIF JPEG image size is approximately 1K Bytes so that the mobile phone can download the compressed image data from ESS display the decoded JPEG image in three seconds per image by our developed Java applet. The processing time will be reduced if GPRS can gain a faster download speed. Table 2 shows the performance comparisons between PHSS, [9], and [10]. PHSS owns more widespread applications than others with its mobility. PHSS supports multi-camera service and friendly one-key-operation interface that [9] and [10] cannot.



Fig. 9 The GUI developed on mobile phones



Fig. 10 The GUI on suspended mode on mobile phones

PHSS is a low cost multipurpose embedded surveillance appliance especially developed for home security demands. Similar to house surveillance, PHSS can be installed in vehicles, as shown in Fig. 11, to notify the car owner by a short message and real-time images if someone violates his car. ESS can transmit images to the owner through GPRS and these images serve as evidence for the police.

Table 2: Units and corresponding symbols

	PHSS	*[9]*	*[10]*
Continuous Snapshot	Yes	No	Yes
Server System	Embedded System	Embedded System	Personal Computer
Number of Cameras	Not Limited	1	Not Limited
Operating Convenience	One Key	More than One Key	More than One Key
Extension Ability	Excellent	Good	Good
Image Transmission Path	GPRS / Ethernet	GPRS	Ethernet

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In this application, PHSS can also integrate the GPS navigation module into a mobile phone so that the car owner can hold the robbers' images and the car position on the screen of their mobile phones without the call center.



Fig. 11 The PHSS installed in the vehicle

Furthermore, PHSS can also be applied to the homecare systems and the assist in accidents with tele-consultation. When children or aged persons get hurt at home, PHSS can be the bridge between the patients and the medical station. The patient's family can then receive important instructions from doctors. Because time before the ambulance arrives is critical, communications with medical personnel is vital.

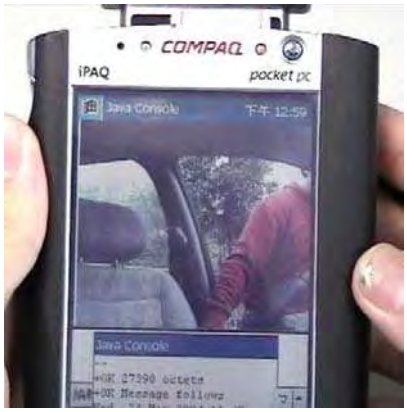


Fig. 12 The processed Java program on PDA

The Java program can also be installed to PDA with little modification since the computing power is stronger than that in a mobile phone. The functions mentioned above are all realized through Wi-Fi, as shown in Fig. 12.

6 Conclusions

This paper addresses the design and implementation of a practical home security system via mobile phone through GPRS communication protocol. PHSS realizes the mobile surveillance concept and is successfully verified. PHSS works under existing telecom infrastructures and ISPs without any modification, so that a new popular application on a mobile phone is created. Moreover, PHSS not only can be applied in home surveillance and vehicle security, but also to tele-consultation and homecare systems with little modifications.

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Appendix BB

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Remote Video Monitoring Over the WWW

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Abstract. Remote video monitoring has become increasingly important for monitoring the security of destined locations. Traditional security monitoring systems using coaxial cables and VCR recording systems are expensive and ineffective. With the rapid growth of the Internet, it is now possible to use it as an intermediate transmission medium to support real-time video transmission. This paper proposes a web-based remote monitoring system known as iSecure. Apart from the essential live or stored video transmission, intelligent monitoring and web-based monitoring are also supported. As the transmission of live video data through the packet switched network environment of the Internet can result in packet loss and quality degradation, the iSecure system has implemented an adaptive transmission and recovery mechanism to enhance the quality of real-time video transmission. Intelligent monitoring for elevator security and face-based door access control applications has been incorporated. The iSecure system can be used as a framework for developing other intelligent remote monitoring applications.

Keywords: remote video monitoring, web-based monitoring, intelligent monitoring, real-time video transmission, world wide web

1. Introduction

Traditional monitoring systems have been widely used for security purposes for bank, elevator, entrance to apartment, etc. In such systems, a video camera is usually installed at the destined location and connected to a security console where the security operator can monitor for suspicious activities. The video images from the camera can also be recorded and played back on a VCR machine. However, the picture quality of the video-tape is low. It is also impossible to search the recorded images for any desired information. In addition, the installation of such systems is very expensive due to the use of coaxial cables and other controller equipment.

Recently, the Internet has provided an intermediate transmission medium to support remote video monitoring. A number of Internet-based remote monitoring systems such as DigiEye [28], TeleEye Pro [26], Digital Surveillance [13] and Vision-Based Traffic Surveillance System [20] have been developed and marketed. These systems can connect to the Internet through a phone line or Local Area Network (LAN), and provide multiple remote monitoring functions such as live video viewing, digital video recording and motion detection. Compared with traditional monitoring systems, the Internet-based monitoring systems have some obvious advantages. It is more cost effective to use existing network cables instead of installing separate video cables and controller equipment. Digital images can be recorded and stored, and it is also possible to search the recorded images efficiently and effectively. Moreover, multiple locations can be monitored remotely through the Internet.

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Some monitoring systems such as the Vision-Based Traffic Surveillance System can further support the remote monitoring function over the web and deliver live video over a web browser. Besides this, web video systems such as Webcam32 [27], SpyCam [19] and WebMedia [31] are also able to support live video transmission over a web browser. These systems can be used for video monitoring purposes. The web-based monitoring function has some additional benefits. No extra software is needed to be installed for the monitoring consoles, and the use of a web browser such as Netscape's Navigator or Microsoft's Internet Explorer for monitoring purpose is very convenient for most users.

In this paper, we propose a web-based intelligent monitoring system known as iSecure. Apart from traditional live video monitoring and web-based functions, the iSecure system also supports intelligent monitoring [1, 11, 12, 16]. Two intelligent monitoring applications on remote elevator monitoring and face-based door access control system have been developed. In this paper, the different mechanisms to support intelligent remote monitoring functions are described. These include the buffering mechanism and the adaptive transmission and video recovery mechanism for enhancing the quality and reliability of real-time video transmission.

2. Remote video monitoring

Figure 1 shows a typical remote monitoring system which consists of the following components: video servers with a set of digital cameras for each location, and security consoles. Digital cameras are installed in the monitored locations, and used to capture video sequences continuously from the monitored locations. A video server performs the functions such as video capture, intelligent analysis (or motion detection), video compression, video storage,

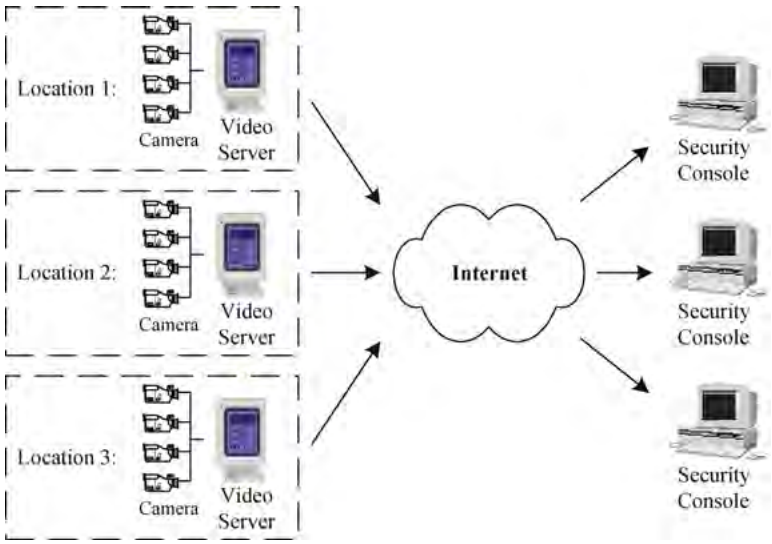


Figure 1. A typical remote monitoring system.

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and video transmission. Security consoles are resided on web browsers. Security operators can activate a web browser and connect it to a video server using its IP address, and view the live video of the monitored location transmitted from the video server.

The major features of a web-based remote video monitoring system include the following:

- *Live video transmission*. Remote monitoring systems are mainly used for security purposes. It is important for security operators to view the monitored locations in real-time. Therefore, supporting real-time (or live) video transmission over the Internet is an important feature. However, the Internet is a relatively harsh environment for real-time video communication. The high packet loss rate and limited bandwidth of the Internet environment have made live video transmission over the Internet difficult. The need for multiple video transmissions has made the situation even worse. Thus, an efficient transmission rate control and packet loss recovery mechanism is necessary to minimize the impact of packet loss.
- *Intelligent monitoring*. Most of the existing security monitoring systems are passive. The systems only record data and human interpretations are required. In addition to the need of a large storage capacity to record hours of inactivity, the security personnel are often required to attend to the monitor consoles to observe for abnormal activities. Hence, it is useful to support intelligent monitoring to detect human motion or abnormal (crime) scenes to assist security personnel and improve safety. With intelligent analysis, it is possible to detect status change for a monitored location. Automatic video recording can then be triggered for certain events. This also helps to reduce the bandwidth for transmission as only the detected suspicious events are transmitted to the security consoles.
- *Video recording and retrieval*. It is essential to have a record of each event or incident that had happened for subsequent retrieval and review. Security operators can start the video recording when necessary. They can also schedule the time and duration of a particular recording. The recorded video data can be retrieved based on the location and time of the event. However, stored video transmission poses the same problems on packet loss and bandwidth as transmitting live video data over the Internet.
- *Web-based monitoring*. Using web browsers as security consoles, there is no need to preinstall the monitoring software on the machine. In addition, it also supports the distribution and upgrading of the monitoring software automatically over the web. To support this, Java applets can be used to implement the security console. However, Java applets have certain security restriction [9]. The restrictions aim at preventing malicious applets from threatening the client system's security. The most common approach to this problem is to use the code signing method [32].

3. Adaptive transmission and recovery mechanism

TCP/IP [8] is the communication protocol of the packet-switched global Internet. It provides two kinds of network services to application processes: Transport Control Protocol (TCP) which is a connection-oriented protocol with guaranteed delivery of data and User Datagram Protocol (UDP) which is a connectionless-oriented protocol with no guarantee of arrival of data. The TCP/IP protocol applies well for non-temporal data transmission but does not have

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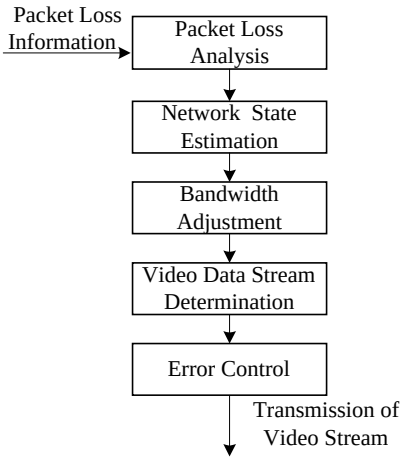


Figure 2. Adaptive transmission and recovery mechanism.

any provision to support the real-time nature of video data. The on-time delivery of data is generally dependent on network performance. Under the varying network load conditions, the video data packets will suffer varying degrees of delay. The variance in delay produces jitters that are undesirable for real-time services. In addition, the unreliability of the network can give rise to packet loss and data duplication that will further deteriorate the video quality.

To resolve these problems, we have developed an adaptive transmission and recovery mechanism for video transmission between a video server and security consoles. The mechanism integrates the dynamic transmission control [2, 4–6] with video recovery [23, 25, 30] to enhance the quality and reliability of real-time video transmission. It minimizes packet loss by controlling the transmission rate dynamically from the source based on the network congestion condition with a video recovery using parity packets at the receivers. The playout time of arriving video packets can be adjusted at the destination to minimize the impact of delay jitters using a buffering mechanism.

Figure 2 shows the adaptive transmission and video recovery mechanism that consists of the following five phases: *Packet Loss Analysis*, *Network State Estimation*, *Bandwidth Adjustment*, *Video Data Stream Determination* and *Error Control*. A video server can be connected to several security consoles during a monitoring session. When a security console requests for video transmission, it will communicate with the video server directly. Therefore, the video server maintains an individual connection with each requesting security console. In the following discussion of the adaptive transmission mechanism, a video server will be represented as a source, each security console as a receiver, and each connection between the video server and security console as a source-receiver link.

3.1. Packet loss analysis

When video packets are transmitted to a receiver, the receiver calculates the number of packets lost from the number of packets received according to their sequence numbers for a

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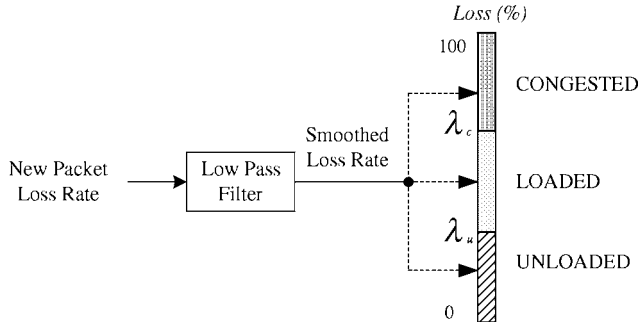


Figure 3. Classification of network congestion state.

given period of time. Based on this loss statistics reported in the receiver report, the source determines the loss rate for each receiver. A low-pass filter is used to smooth out the loss rate. The new smoothed loss rate λ_{new} is computed as $\lambda_{\text{new}} = (1 - \alpha)\lambda_{\text{old}} + \alpha b$, where b is the new loss rate and α is a constant between 0 and 1 which is used to indicate the influence of the new loss rate on the final smoothed loss rate. λ_{old} is the old smoothed loss rate. A moderate value of 0.3 for α has been used as discussed in Busse et al. [6].

3.2. Network state estimation

The new smoothed loss rate (λ_{new}) is then used to measure and determine the network congestion state. Three network states, namely, UNLOADED, LOADED or CONGESTED, are defined based on two pre-defined threshold values, λ_c and λ_u as shown in figure 3. The upper threshold λ_c is defined as the upper limit where the received video quality will be unacceptable if this threshold is exceeded, and the lower threshold, λ_u, is the lower limit such that packet loss rate below this limit will give good video play-out quality. For loss rate between these two thresholds, the quality of received video data is considered acceptable to users. The threshold values of 0.21 and 0.08 are used for λ_c and λ_u based on the JPEG [3, 33] compression technique. They are determined experimentally.

3.3. Bandwidth adjustment

In the proposed mechanism, the source adjusts the bandwidth requirement for each receiver individually according to the corresponding network congestion state. The source reduces the bandwidth for the CONGESTED state, maintains the bandwidth for the LOADED state and increases the bandwidth for the UNLOADED state. A multiplicative decrease σ is used for the CONGESTED state and additive increase ρ is used for the UNLOADED state. The bandwidth is always given to be larger than a minimum bandwidth (i.e. $\text{bandwidth}_{\text{min}}$) to guarantee a minimum quality of the video play-out to be achieved at the receiver. A maximum bandwidth (i.e. $\text{bandwidth}_{\text{max}}$) is also defined. Figure 4 shows the bandwidth adjustment algorithm. The value of 0.75 is used for σ and 8.5 kbps is used for ρ.

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```
if ( network_state = = CONGESTED )
        bandwidth_new = max (bandwidth_old * σ, bandwidth_min);
else if ( network_state = = UNLOADED )
        bandwidth_new = min (bandwidth_old + ρ, bandwidth_max);
```

Figure 4. Bandwidth adjustment algorithm.

3.4. Video data stream determination

MPEG [18, 29] and H.261 [7] are designed for moving images and provide high compression ratio. However, using them to compress video data in real-time applications such as remote monitoring is quite complicated, because they are highly CPU intensive and usually require hardware implementation. Since frames in MPEG or H.261 streams are inter-related, the loss of a single packet might degrade video quality remarkably. Additional mechanism for error recovery is required to minimize the loss rate of intra-coded frames by performing re-transmission or by embedding redundant information, which potentially increases the required bandwidth.

JPEG is becoming more widely accepted due to its better compression ratios and support for full 24 bit images. When used to compress real-time video data, JPEG provides sufficiently high compression ratio to reduce the bandwidth required for transmission of video data across the Internet. Since it does not use temporal redundancy in its compression, it is easier to be incorporated into recovery mechanisms for packet loss. Compared to MPEG, JPEG requires less CPU and does not need complicated error recovery scheme. It is also a popular image format delivered on the web. A number of web video applications have used JPEG to support video transmission over the World Wide Web. In this research, the JPEG compression technique is adopted for video coding.

In figure 5, a two-level coding scheme has been implemented in the JPEG coder. The approach consists of encoding each video frame with two different values of the quantizer. However, the coder only needs to compute the Discrete Cosine Transform (DCT) coefficients for each frame once, and then carries out the quantization calculations and entropy encoding with two different quantizer values. The frame encoded with the higher quantizer value is transmitted as low-quality video stream, and the other is transmitted as high-quality video stream. Thus, a high-quality stream and a low-quality stream can be encoded by the source.

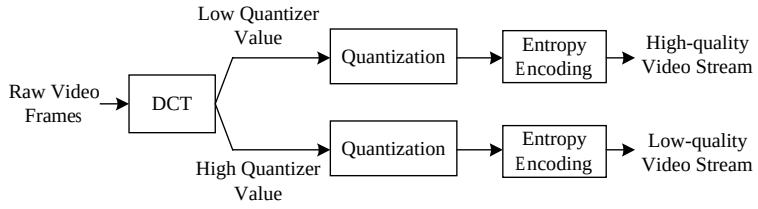


Figure 5. JPEG coder using a two-level coding scheme.

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The high-quality video data stream will be transmitted to the receivers that have good network conditions, and the low-quality video data stream will be transmitted to those that have congested network conditions.

3.5. Error control

In error control, redundancy transmission is used to minimize data packet loss that can occur during the process of transmitting video data from the source to the receivers. Data packets are grouped into blocks of predetermined size, and a parity packet is inserted to each block to contain the error-control bits. The parity packets can be transmitted at different intervals according to the block size, following the data packets in the same block. The redundant parity packets can be used to reconstruct lost data packets from the respective blocks in the receiver. However, a total elimination of the packet loss problem may not be possible if consecutive packets are lost. In this case, parity packets following the data packets will also be lost. Hence, decreasing the size of the block (i.e. increasing the number of parity packets) can increase the resilience to the effects of packet loss.

The construction of the parity packet can be expressed as $P = D_0 \oplus D_1 \oplus D_2 \oplus \cdots \oplus D_{K-1}$, where P is the parity packet and D_i ($i = 0, 1, \ldots K-1$) is the i-th packet. The symbol '$\oplus$' stands for the exclusive-or operation (XOR). If one of the block's data packets is missing, the recipient can reconstruct it using the other $K-1$ data packets and the parity packet. Figures 6 and 7 show an example of generating a parity packet and recovering a lost packet respectively. In this example, the block size is 4.

In parity redundancy transmission, the block size and the construction of the parity packets determine the effectiveness of packet loss recovery. The block size can be adjusted to adapt to the variable network condition by the source. Decreasing the block size will only be justifiable if packet loss rate is escalating. However, smaller block size will result in more redundant parity packets in the video stream transmission. It will consume higher bandwidth and increase the overhead of processing these parity packets for both the source and the receivers. If this is not kept under control, it will even cause higher losses. On the other hand, larger block size leads to increasing play-out delay since K packets have to be

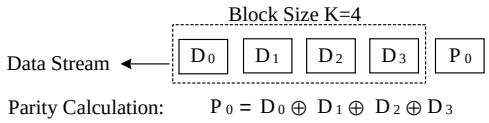


Figure 6. Generating a parity packet.

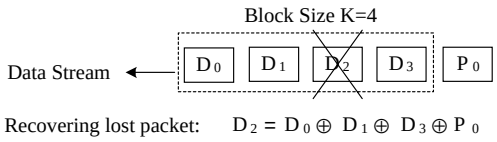


Figure 7. Recovering a lost data packet.

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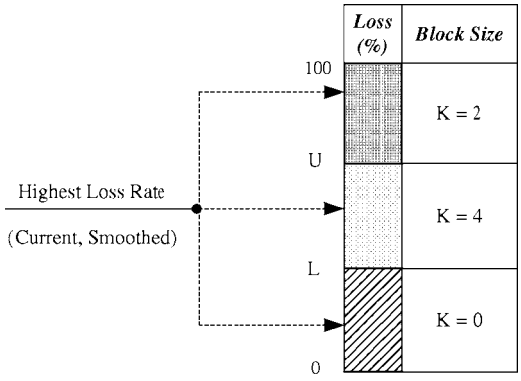


Figure 8. Determination of block size for video packets.

received before the lost packet can be reconstructed. Thus, the block size has been limited to three values, i.e., 4, 2, and 0. The block size 0 represents that no redundant parity packet is needed in video transmission.

The block size for constructing parity packet is determined according to the highest value of the two computed loss rates: the current loss rate and smoothed loss rate. The current loss rate reflects a short-term reception condition. Since smoothed loss rate is computed based on accumulated past loss rates, it reflects a long-term reception condition. A decreasing current loss rate will have the effect of reducing the smoothed loss rate. Therefore, the block size is determined based on the highest value of these two computed loss rates to increase the robustness of the mechanism. The adaptive video transmission mechanism uses parity redundant packets to reduce the packet loss to be within λ_u. When the loss rate is below the threshold, λ_u, it indicates good video quality. Figure 8 shows the determination of the block size that is dependent on two values, the Upper Loss Limit (U) and Lower Loss Limit (L), which are defined in relation with λ_u as follows:

$$L = \lambda_u$$

and

$$(1 - U) + U(1 - U) = 1 - \lambda_u$$
$$\Rightarrow U = \sqrt{\lambda_u}$$

For the Lower Loss Limit, no parity packets are needed to constrain the losses to λ_u. Above this loss limit, parity packets are needed to help recover from the higher losses and the block size is set to 4. However, when packet loss exceeds the Upper Loss Limit, the block size will be set to 2 to maintain the losses within λ_u.

3.6. Performance measurement

Experiments had been carried out to study the performance of the adaptive transmission and recovery mechanism. The main objective was to show the effects of network packet

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loss on the quality of video play-out at each receiver when the mechanism was used for bandwidth adjustment and error control. In the experiments, the values of 0.3, 0.08, 0.21, 0.75, 8.5 kbps, 170.0 kbps and 10.6 kbps were used for the variables α, λ_u, λ_c, σ, ρ, $\text{bandwidth}_{\max}$ and $\text{bandwidth}_{\min}$ respectively. The computers used in the experiment were Pentium II PCs. The distance between the sender and the receivers was 8 hops. The experiments were carried out at two separate periods of the day, one was between 10 a.m. to 11 a.m. when the network was heavily loaded, and the other was between 11 p.m. to 12 a.m. when the network was relatively lightly loaded. In the experiments, the sender was compressing and sending video stream to the receiving computers. One previously captured video sequence consisting of 847 frames was used as the raw video stream for testing. The same video sequence was used for each experiment. Each transmission lasted for ten minutes, during which the receivers periodically sent back to the sender the information of average packet loss rate it observed. The feedback interval was set to ten seconds. Based on the packet loss information, the sender readjusted the video transmissions to the receivers accordingly.

Figure 9 shows the packet loss characteristics when the adaptive transmission and recovery mechanism was used during the heavy network load condition. The experiment was started with the high-quality video stream together with redundant packets having the maximum bandwidth of 170.0 kbps. As expected, the sender responded to the high loss rate by lowering the bandwidth requirement of video transmission upon receiving the feedback from the receiver. As a result, the smoothed loss rate was reduced from 35% to 10%. However, from the 270th second, the receiver detected a higher and fluctuating loss rate around 20%. This high loss rate could be created by an increasing network usage by other users which caused congestion in the Internet. Parity packets had been transmitted along with the primary video data to aid recovery from high packet losses.

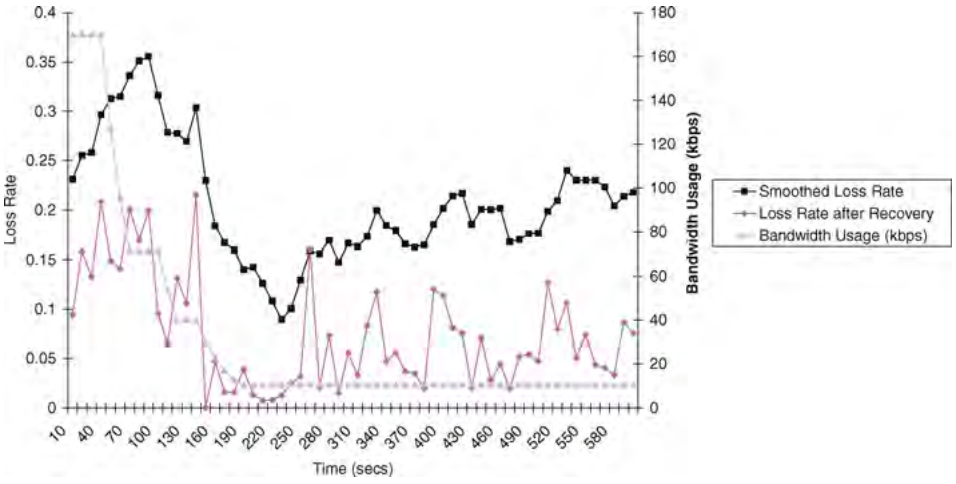


Figure 9. Loss rate and bandwidth usage during heavy network load condition with the adaptive transmission and recovery mechanism.

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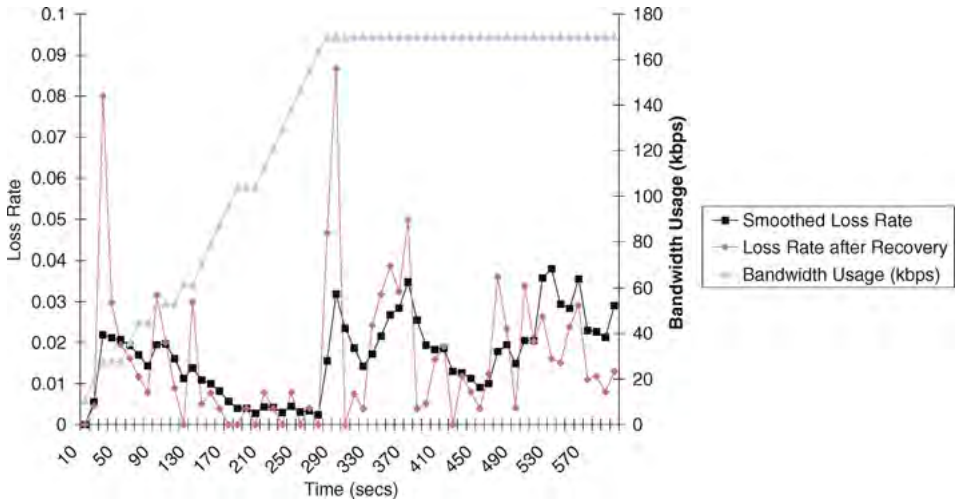


Figure 10. Loss rate and bandwidth usage during low network load condition with the adaptive transmission and recovery mechanism.

Figure 10 shows the packet loss characteristics when the adaptive transmission and recovery mechanism was used during low network load condition. When the network was lightly loaded, the mechanism increased its bandwidth requirement to deliver higher-quality video. Initially, the low-quality video stream with the minimum bandwidth of 10.6 kbps was transmitted. As a result of low packet loss rate which was well below the λ_u limit of 8%, the sender increased its bandwidth to deliver video of better quality. When the increasing bandwidth exceeded the upper bandwidth threshold, the sender used a high-quality video stream for transmission. Although the bandwidth had been increased continuously, the loss rate did not increase significantly, which showed that there was enough network resources for higher bandwidth transmission. Finally, the video stream having the maximum bandwidth without parity packets was sent to the receiver. Throughout the transmission, the packet loss rate did not exceed λ_u for most of the time and thus only the primary video data was delivered. Since there was no recovery from parity redundant packets, the loss rate after recovery reflected the current loss rate.

4. Video monitoring process

Figure 11 shows the system architecture of iSecure. Each Video Server processes the video data and stores them into a video database if required. An Exchange Server is proposed in the system architecture. It provides a directory service of the available Video Servers to Security Consoles, so that a Security Console can connect to a Video Server without the need to remember its IP address. During a monitoring session, the Exchange Server is responsible for relaying the updated information such as suspicious events and the updated scenes from the Video Servers to the connected Security Consoles. However, when the

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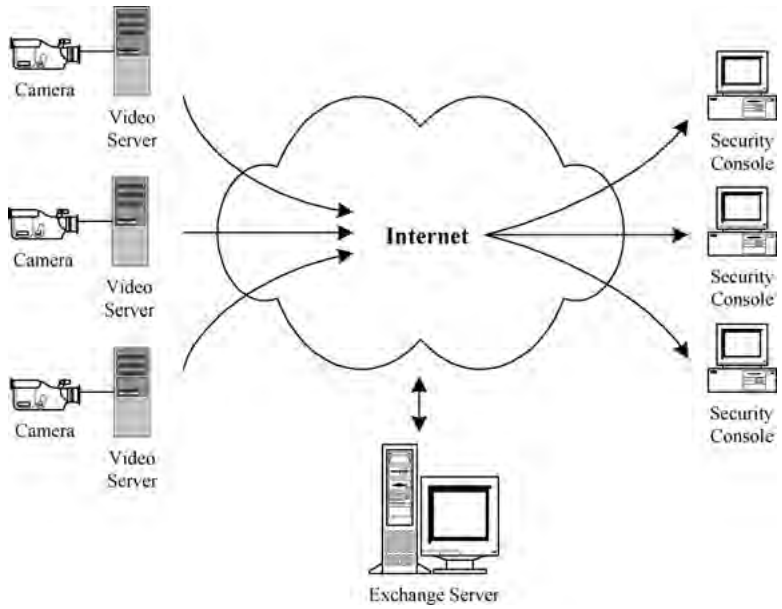


Figure 11. System architecture of iSecure.

Security Console requests for live video monitoring or recorded video data transmission, the Video Server will communicate with the corresponding Security Console directly for video transmission. Figure 12 shows the monitoring process. Four events can occur during a monitoring session. They are Regular Scene Updating, Suspicious Event, Status Change Event and Live/Stored Video Viewing as follows.

- *Regular Scene Updating*. During a monitoring session, each Video Server will transmit the image of the updated scene captured from the monitored location to the Exchange Server at a pre-defined time interval. The Exchange Server will then broadcast the updated images to the connected Security Consoles for refreshing on their monitoring interface. In this way, the user can be kept informed on the latest situation at the monitored locations.
- *Suspicious Event*. When a suspicious event is detected in a Video Server, the Video Server will transmit an alert message to the Exchange Server. Upon reception of the alert message, the Exchange Server will redirect the alert message to all the connected Security Consoles. Once the alert message has been received, the Security Console sounds the alarm.
- *Status Change Event*. The Video Server can be configured to detect any changes in status at the monitored locations. For example, for elevator monitoring, status can be changed from empty to occupy or from occupy to empty. Once detected, a status change signal and the image of the current scene will be transmitted to the Exchange Server which in turn will transmit the information to the connected Security Consoles.
- *Live/Stored Video Viewing*. When there is a need to monitor a particular location in real-time due to a suspicious event that has taken place at that location, the Video Server will

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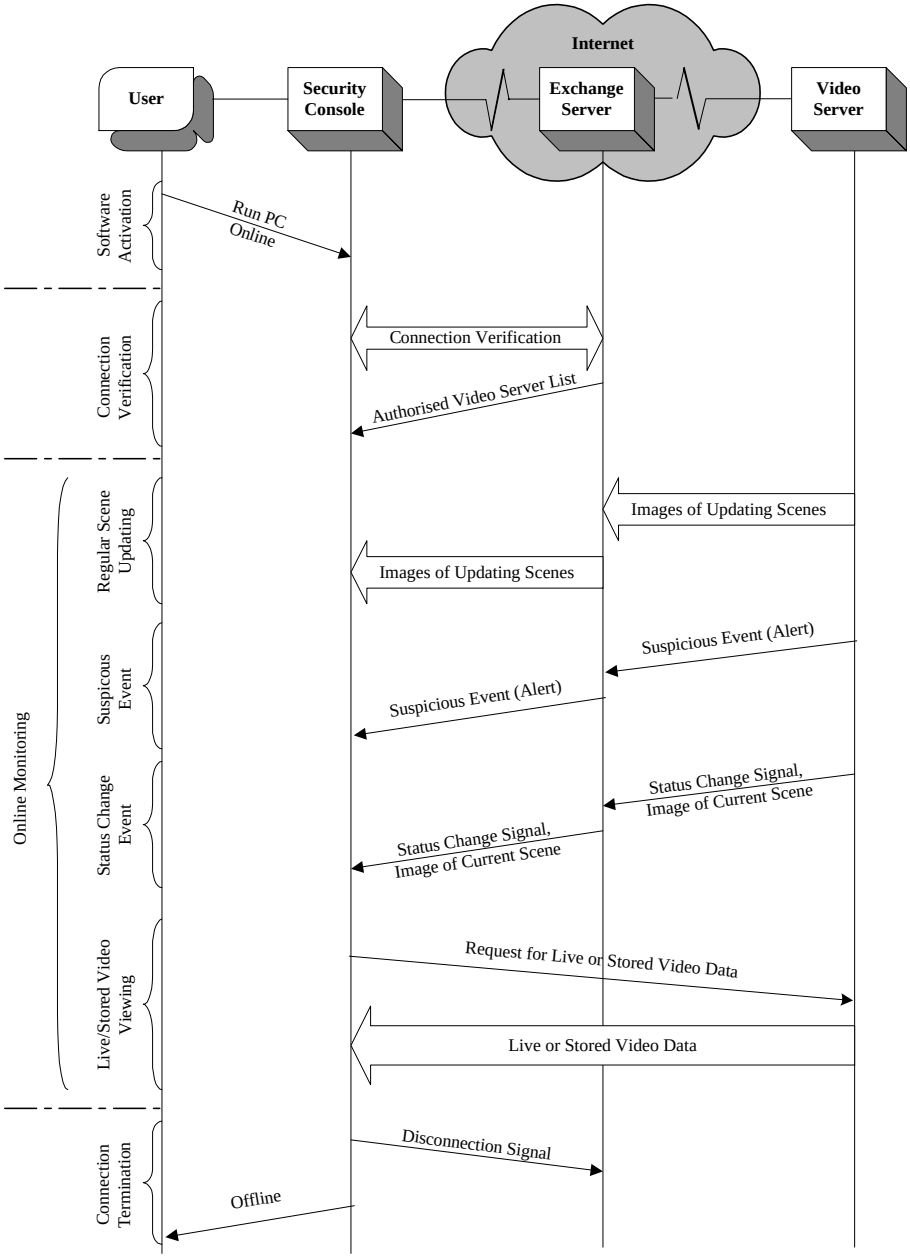


Figure 12. Monitoring process.

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transmit the live video data to the requesting Security Console directly for monitoring. The user can also request for playing back recorded video data. The targeted Video Server will retrieve the video data from its video database, and transmit it to the Security Console for display.

5. System implementation

The implementation of the iSecure system is given in figure 13. It consists of the Video Server, Exchange Server and Security Console as discussed in Section 4.

5.1. Video Server

Video Server performs video capturing, intelligent analysis and recording, and supports live video transmission for remote monitoring. As shown in figure 13, Video Server consists of *Video Capturing*, *Intelligent Analyzer* and *Transmitter*. Video Capturing captures video sequences from its digital camera and performs time stamping for each video frame. The time-stamp is used for the determination of delays between video packets. The time-stamp is stored in the time-stamp field of the RTP [24] header of each video packet.

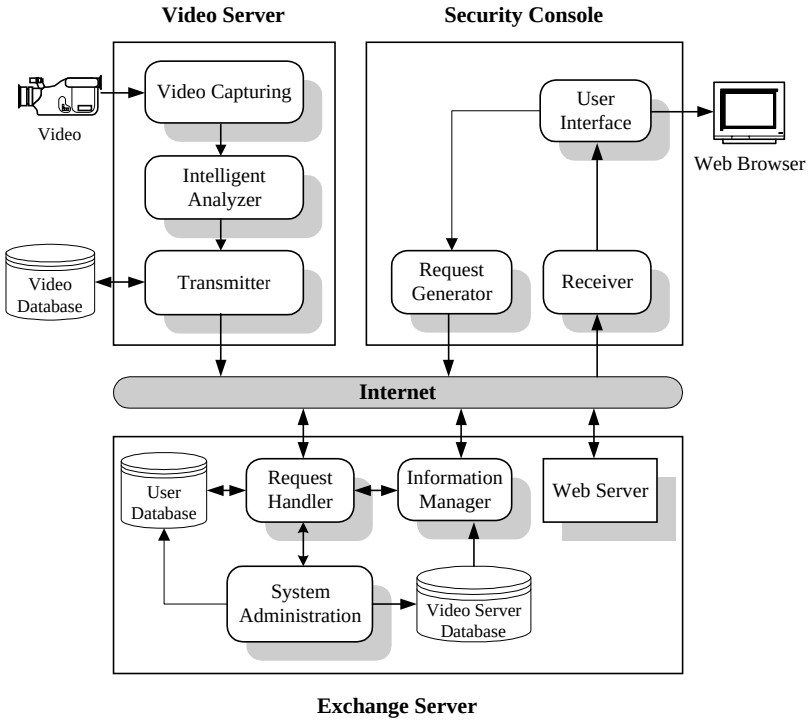


Figure 13. System implementation.

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Intelligent Analyzer carries out motion detection or intelligent analysis for any suspicious event. According to different application requirements, it can be configured to be at different security levels. For some applications, for example, the oversight of children at nursery schools, it can be set to a low level security without analysis and detection. For applications such as monitoring a closed shop at night, it can be set to be a moderate level security as motion detection, which simply detects the occurrence of any activity in the monitored site. For applications that require a high level security such as intelligent elevator monitoring, it is configured to perform intelligent analysis. In this case, video sequences from the video capturing component is analyzed using motion analysis techniques such as segmentation and difference pictures [14, 15] to classify the activities in the monitored location. After the analysis, the video sequence and the result of motion detection or intelligent analysis will be passed to the Transmitter.

Transmitter is responsible for video compression and buffering, parity packets generation, and the transmission of updated images, alerts and video sequences. It also stores the compressed video sequence into the Video Database. The adaptive transmission and recovery mechanism has been incorporated to minimize the impact of packet loss for video transmission. Figure 14 shows the architecture of the Transmitter.

When the Intelligent Analyzer detects any suspicious event or status change, it will send a signal to notify the Transmitter. An alert or a status change signal will be generated and transmitted over a TCP connection to inform the Exchange Server. At the same time, the Scene Updating component will be informed to transmit the updated image of the current scene to the Exchange Server. The updated scene will then be broadcast to all the connected Security Consoles.

When the Request Parser receives requests from the Security Console for live or stored video data transmission, the Compression component compresses the incoming video data on a first-come-first-serve basis. A two-level JPEG compression scheme has been adopted

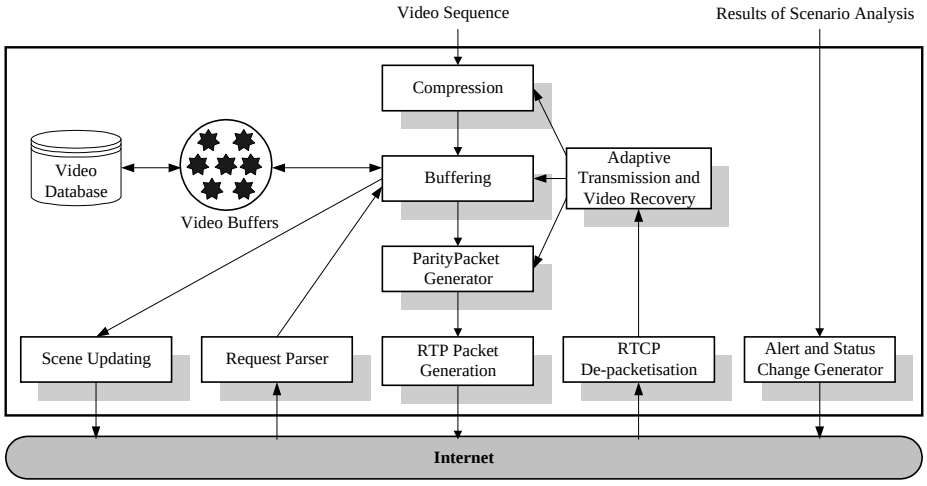


Figure 14. Architecrure of the Transmitter.

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for video coding. The frame encoded with lower quality is added to the low-quality video buffer, and the one with higher quality is added to the high-quality video buffer. For Adaptive Transmission and Video Recovery, each receiver receives packet loss information from the RTCP De-packetisation component and the new packet loss rate is analyzed and used to estimate its current network condition. The appropriate transmission rate is then determined and adjusted to maximize the use of network resources. The use of the low-quality video or the high-quality video stream for transmission is also determined based on the network condition. If redundancy transmission is needed for packet loss recovery, the Parity Packet Generator is used to determine the block size and generate parity packets for redundancy transmission using the exclusive-or (XOR) operation.

Finally, the RTP Packet Generation component packetises the compressed video data in RTP format for transmission. In the RTP header, a sequence number is generated for each RTP packet that can be used to order the incoming RTP packets at the receiver. Besides the RTP header, several other fields are also defined for storing additional information of the parity packet data, the block size and the length of video data packets in the block.

5.2. Exchange Server

Exchange Server consists of *Information Manager*, *Request Handler*, *System Administration* and *Web Server*. System Administration is responsible for the management and configuration of Video Servers, and the management of authorized users. It is also responsible for maintaining the two databases, namely, Video Server Database and User Database. Request Handler handles requests from Security Consoles for user verification and video server information. The Information Manager maintains information such as the IP address, the latest status and the image of current scene for each Video Server in its buffer. When a Security Console requests for a connection, the Information Manager will transmit the list of the available Video Servers and its related information to the Security Console. During the monitoring session, whenever the scene of a Video Server is updated, the Information Manager will broadcast the updated scene to the connected Security Consoles. The Web Server provides an URL address for users to connect to the iSecure system to activate the Security Console.

5.3. Security Console

Security Console is embedded in a web browser, and connects to the Exchange Server through its Web Server. The Security Console comprises three components: *Receiver*, *User Interface* and *Request Generator*. Receiver is responsible for receiving alerts and images of updated scenes of the monitored locations broadcast by the Exchange Server. In addition, live or stored video sequences from the Video Servers for online monitoring purposes are also received. The received images or video sequences are then passed to the User Interface for display. Since the web browser can display JPEG images directly, a separate component for the decompression of video data is not necessary. Figure 15 shows the architecture of the Receiver.

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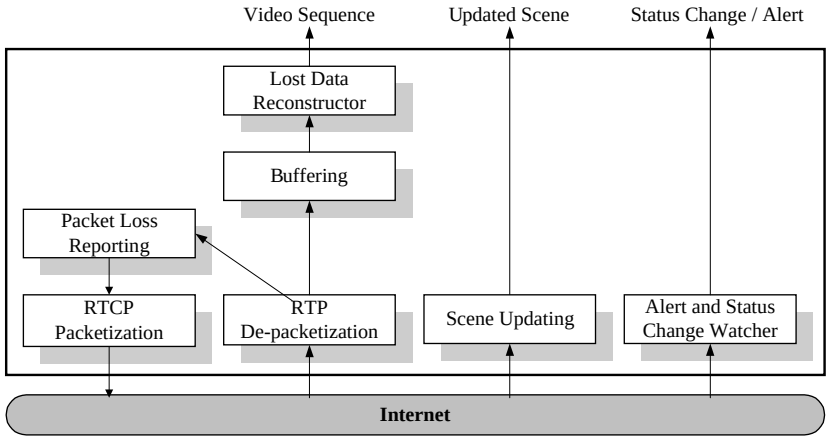


Figure 15. Architecture of the Receiver.

The Scene Updating component receives the updated images from the Exchange Server. The Alert and Status Change Watcher component listens for any alert signals or status change signals from the Exchange Server. Upon reception of an alert signal, it will determine its origin and bring the user to its attention through an alarm sound and an alert message. The security operator on duty can then request for viewing the video sequence of the suspicious event stored in the video database of the targeted Video Server or monitoring the location in real-time. For status change signals, the updated image of the monitored location will be received for display.

For live or stored video monitoring, the RTP De-packetisation component depacketizes the incoming packets to retrieve the RTP header, the primary video data, and the parity packet data if redundant transmission exists. The Security Console will dynamically allocate a ring buffer for each video transmission. The IP address of the video server is obtained from the packet. It will be used to decide which buffer is used for storing the packet data. Then, the packet data is placed into the correct slot of the buffer in the right order by checking its sequence number. The slot position of any particular buffer for both video data packets and parity packets is computed using the following formula: Slot_Position = Sequence_Number *MOD* Buffer_Size. The size of the buffer is pre-defined based on the amount of delay jitters experienced by the packets and the average processing time for each incoming packet. The lost data reconstruction process occurs when the ring buffer is half full. This margin of safety cushions the variations of packet delay, duplication and out-of-order during video transmission over the Internet. Figure 16 illustrates the buffering mechanism.

The Lost Data Reconstructor component is used to reconstruct the lost video data when redundancy transmission is needed for any particular video transmission. Its process is similar to the generation of parity packets. For a given block, if no video data packet was lost during the transmission, the first K packets are the video data packets of the block (assuming the block size is K), in which case the parity packet will be ignored. If video data

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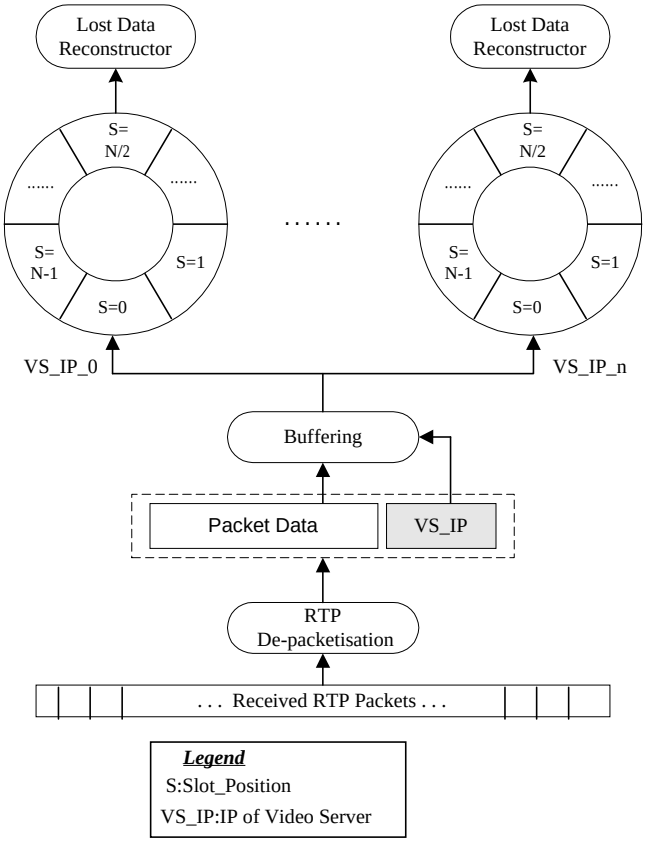


Figure 16. Buffering mechanism.

packets are lost within the block, the location of the missing packets can be identified from the empty locations in the buffer. If only one of the block's video data packets is lost, the lost packet can be recovered by applying the other $K - 1$ video data packets with the parity packet. However, if more than one video data packets are lost, the Lost Data Reconstructor can do nothing, but omit the lost packets from displaying. After reconstruction, the video data packets will be passed to the User Interface for display.

The RTP header extracted from the RTP De-packetisation process will be passed to the Packet Loss Reporting component for computing the packet loss information. The results are passed to the RTCP Packetisation component and transmitted to the Video Server at regular intervals. The packet loss information will be used in the Video Server for adaptive transmission and recovery of lost packets.

Through the User Interface, the user will be able to monitor, control and view the most recent scenes of all the locations being monitored. The interface displays information such as the status and current scene of the monitored locations. It also provides a means to alert the user of any suspicious event and displays live or stored video sequences from

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Figure 17. Monitoring window.

the targeted location. Figure 17 shows an example of the monitoring interface. The central area displays the current scenes of the monitored locations, and is constantly updated at pre-defined time intervals. When an alert for a suspicious event is received, the color of the corresponding circular button in the "Alarm" area will turn from "green" to "red", and an alarm will be sounded to draw the attention of the user. By clicking a button from the "Live Video" area, the user can request for live video sequence from the indicated location. The "View Recording" button allows the user to replay the recordings stored in each Video Server. The "Location Map" button will show the user a map of the monitored locations.

6. Applications

The iSecure system supports two remote monitoring applications for remote elevator monitoring and face-based door access control. The two applications have been developed to demonstrate the feasibility of the system architecture for supporting various monitoring features. Figure 18 shows the Intelligent Analyzer component of the Video Server for the two intelligent monitoring applications. With the captured video sequence from the Video

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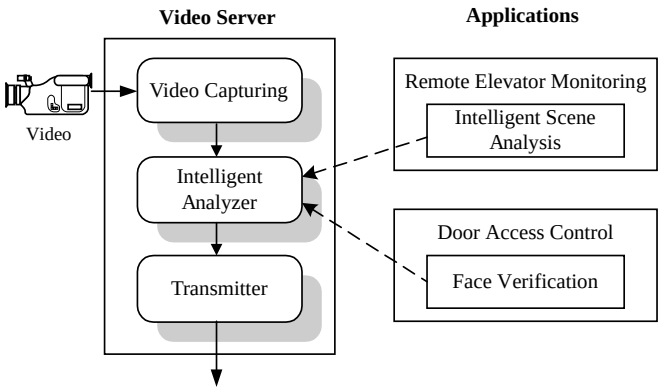


Figure 18. Intelligent Analyzer in Video Server.

Capturing component, it performs intelligent analysis for any suspicious events. The result of the analysis will then be passed to the Transmitter component. Two techniques, namely, intelligent elevator analysis for crime detection and automatic face verification, have been implemented into the Intelligent Analyzer.

6.1. Intelligent elevator analysis

The intelligent elevator analysis technique [34] has been incorporated into the remote elevator monitoring application for monitoring the scene in an elevator and understand the activities that occurred. Motions inside an elevator can be classified as normal or abnormal according to an analysis of human body motions inside the elevator. Normally, the occupants inside an elevator should stay still with little movement until the elevator stops and people get in and out. It is more complicated in the abnormal situations where various movements may occur. The activities can be classified according to different scenario types (or scripts). A scenario is a sequence of expected events. For example, one would expect a murderous scenario to have the scenes of more than one person entering into the elevator, struggling and finally the phenomena of red bloodstain and/or victim falling down. Four types of scenarios, namely, “normal”, “suspicious”, “overstaying” and “stain”, have been implemented.

6.2. Automatic face verification

Biometrics [20] is an emerging technology that allows an access control system to identify a person’s identity using the person’s unchangeable physiological or behavioral characteristics. Face recognition [17, 22] is one of the most suitable biometrics methods for supporting door access control. A face recognition technique known as Line Edge Map (LEM) technique [10] has been incorporated into the face-based door access control application. LEM is developed based on the structural and spatial information of a face. A face database of

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30 persons with 2 frontal images per person from the University of Bern was used to test the performance of the LEM technique. The recognition rate was found to be 100% for frontal faces. The results show that LEM provides a relatively robust representation for human face recognition under varying lighting conditions and facial expressions. It is also very fast with average processing time being less than 0.5 second.

7. System evaluation

The iSecure system has been successfully developed and implemented. In this section, the iSecure system is evaluated and compared with some of the popular remote monitoring systems including DigiEye [28], Vision-Based Traffic Surveillance System [21] and Webcam32 [27]. Table 1 gives the comparison results.

DigiEye is a multifunctional digital CCTV system produced by SyAC of Italy. It provides a number of remote monitoring functions such as motion detection, live video transmission, digital video recording and recorded video retrieval. Event recording is supported by the system since activities can be detected using the motion detection component. However, it can only detect whether there are any activities occurred at the monitored locations. No intelligent scenario analysis is supported for detecting specific activities. In addition, it cannot support remote video monitoring over the web.

Vision-based Traffic Surveillance System has been developed for road traffic monitoring over the Internet. The system consists of the FPA (Field Processing Agent) and TSM (Traffic Surveillance Manager). The FPA, which is located at the monitored location, provides real-time video data and traffic parameters including vehicle velocity and vehicle density for the TSM. It consists of a communication module and an image-processing module. The image-processing module performs traffic parameter estimation using video data from the camera. The TSM can be accessed using a web browser. It receives real-time traffic data from the FPA. The system does not support video recording and retrieval.

Table 1. Comparison of iSecure with other remote monitoring systems.

System features	DigiEye	Vision-Based Traffic Surveillance System	Webcam32	iSecure
Live video transmission	Yes	Yes	Yes	Yes
Video transmission control mechanism	No	No	No	Yes
Intelligent analysis	Motion detection	Traffic parameter estimation	No	Intelligent elevator analysis and face verification
Scene updating	No	No	No	Yes
Video recording	Event recording	No	Operator-controllable recording	Operator-controllable, event recording,
Recorded video retrieval	Yes	No	Yes	Yes
Web-based monitoring	No	Yes	Yes	Yes

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Webcam32 is a Web video product from Surveyor Corporation. It is an application that allows live video images to be displayed within a web page. It captures images from a video capture device. These images are then converted into a JPEG encoded form and sent to the requester over the Internet. Webcam32 can act as a web server capable of sending video images. Webcam32 can also be configured to upload JPEG images to a web server via FTP (File Transfer Protocol). These images can then be accessed through HTML web pages. Since Webcam32 can deliver live video over the web for multiple viewers, it can be used to support the monitoring of remote locations. However, it does not provide most of the typical monitoring functions.

Apart from supporting live video transmission as other systems, the iSecure system can also support adaptive transmission and recovery control for video transmission and intelligent monitoring. The adaptive transmission and recovery mechanism is able to control the bandwidth dynamically and minimize packet loss, and thus enhancing the quality of live video transmission over the Internet. The intelligent monitoring supports automatic detection of human motion or abnormal scenes at monitored locations to assist security operators and improve security. The result of the intelligent monitoring can also be used for automatic recording and supporting regular scene updating to reduce the need of continuous video transmission.

8. Conclusion

In this paper, the architecture of the iSecure system is described. It comprises three components, namely, Video Server, Exchange Server and Security Console. Video Server is responsible for video capturing, intelligent analysis, video compression and video transmission. Exchange Server acts as a gateway between video servers and security consoles. Security Console provides a user-friendly interface for users to perform monitoring tasks. The adaptive transmission and recovery mechanism has been incorporated into the iSecure system to enhance the quality of real-time video transmission. Finally, based on the generic system architecture of iSecure, two intelligent applications, namely, remote elevator monitoring and face-based door access control are developed. Furthermore, the iSecure system can be extended to support other intelligent remote monitoring applications.

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Appendix CC

Video Process Monitoring

By Steve Rubin, President & CEO Longwatch, Inc. | February 03, 2003 | News



Video Process Monitoring

By Steve Rubin, President & CEO
Longwatch, Inc.

There are three primary ways to enjoy a baseball game: view it in person, watch it on TV or listen to it on the radio. We've probably all used each of these methods at one time or another; some fans even combine a couple of methods such as bringing a radio to the game to hear the announcers describe what they are seeing. Maybe they don't trust their own interpretation of what they see, and need to have it explained. That's like watching readouts on an HMI screen—what's really happening out there? Why not cut to the chase and see what's going on?

Today, there are two primary ways to monitor a process: in person, by walking

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around the plant, or from a control room via an HMI screen. But there is a third way: Watching the process via camera monitors that put images directly on the HMI screen (Figure 1) or onto a cell phone or PDA. That way, you don't have to wonder what's happening at the process unit. You can see it.

Camera monitoring of process control is relatively rare. Granted, there are limited applications, such as a flare stack camera or a camera in the shipping area. Why hasn't video been applied more widely in process monitoring applications and what additional value could be delivered?

A camera image on an HMI screen can be used to verify that certain operations are actually being performed—such as an operator adding ingredients to a batch reactor. The video "snapshot" can be stored on disk, along with batch production data, as a visual record . Like a baseball game, it's an instant replay. Unlike a baseball game, you can watch it as many times as you want.

In water and wastewater treatment plants, where tanks, lagoons, pumping stations and other equipment is spread over a wide area, camera images can make sure that valves open and close, lagoons are at the right level , and a child hasn't fallen into the lagoon. The same stream of video has multiple purposes, much like a multi-variable sensor. Video not only provides process information, it can mitigate liability and provide security. With video, you know whether to take a shotgun or a wrench to the field to fix a stuck valve.

A camera image can be used to help diagnose problems in the field. Wouldn't it be nice to be able to actually see what the process is doing without having to walk out to a distillation column in a Texas summer? I've been to plenty of plants where the sensors have exhibited problems which confounded the operators. Open circuits on thermocouples, valves that stick, pressure transmitters that fail, and so on. In some instances, the engineers solve this problem by putting extra code in the control system, or install extra sensors, so that problems can be

diagnosed remotely. Imagine how easy it would be to simply look at a camera image of the valve while it was operating, to see if it was sticking.

For example, I've seen a situation where instrumentation told the operator that pumps were off-loading oil from a barge, only to find out later that the coupling was off and the oil didn't make it into the plant…it made it into the river! Another situation involved a cryogenic pump that froze up on a humid day and didn't work properly. These are situations that an operator could see and understand what was happening, if he or she had video.

Watching Instead of Visualizing

Whenever I'm visiting a plant, I'm usually given a tour of the facility, shown the process equipment and the instrumentation, and then brought to the control room. There, the operators show me the HMI displays that are designed to mimic the layout, behavior and status of the equipment. It's up to the operator to imagine, in his or her mind's eye, what's actually happening in the plant, given the indications from the instrumentation.

This is easier with today's HMIs than with the traditional dial, chart recorder and annunciators of 10-20 years ago, but this method relies on the accuracy and timeliness of the instrumentation readings, as well as the fidelity of the HMI's mimic display.

Some process measurements are easier to see than they are to instrument (the flare camera comes to mind…a quick look tells you that it's lit and if it is smoking). And a camera image can tell you if a process vessel is overflowing, a line is leaking, or if steam is escaping, Figure 2. After all, "a picture's worth a thousand words."

"Attention by exception" is really how most process plants operate. We periodically observe indications, but only take action when an alarm condition

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occurs. The alarm may be an “alert” about an event, or it may be an actual transition requiring remedial action.

If a video image of the process unit appeared on the screen when an exception occurred, the operator would be able to immediately see what was happening. This method of operation is much better than the standard “surveillance” approach of watching closed-circuit TV monitors, waiting to pick up visual cues to changes. Studies have shown that humans will lose interest and be unable to detect changes shown on screens if they are forced to stare for more than 20 minutes.

How many times have you needed to “babysit” an intermittent problem in the field or the plant? Video is a tool that can significantly boost efficiency. A video system can be configured to watch equipment and take video snapshots when certain conditions occur—such as that intermittent problem.

With proper configuration, a “before” and “after” clip can be generated to help troubleshoot the cause of the problem. In other words, the camera watches the process continuously, and stores video images internally; when an alarm condition occurs, it can transmit a video snapshot of the unit for, say, five minutes before the alarm occurred, and then continue transmitting real-time images for as long as necessary. All the images can be stored for playback and analyzed as many times as necessary.

Transmitting Data to the Control System

If video can help us discern more about the real conditions, help us see into remote areas, and bring us more information faster…then why has video been so slow to be adopted in process applications? Until recently, all camera technology was analog, and thus it required its own network for operation. Many traditional video systems were originally designed for casinos, parking garages, and shopping malls. It was extremely difficult to connect these “closed circuit

TVs" to an HIM screen.

But many plants have a much more suitable network, one that's almost hack-proof, paid for, and reliable: the instrumentation network for the SCADA/HMI system, Figure 3. This network was designed to handle digital communications between controllers and computers, and it can easily accommodate video images, too.

Some users are reluctant to use the SCADA (or "level one") network for anything other than process control communications. In some respects, that makes sense: when there's a plant upset, you want to make sure that control messages (for example: turn off a motor) are delivered on-time and reliably. But there are ways to embed chunks of video clips into "envelopes" that simply pass through the SCADA network. These messages travel at a lower priority than the control messages, so that it might take longer for the entire video clip to show up at the HMI. But it's better than seeing nothing, and better than driving to a remote process unit.

New camera systems use the bandwidth available in most industrial networks to report video information to the host system, handle real-time diagnostics and the like. It's easy to "drop" cameras on these networks, especially if two networks are being used in the plant: one for instrumentation/control and the other for operations data/information .

While digital cameras will quickly saturate most networks, proper software provides a means of controlling the network traffic, in an orderly fashion, so that video and control messages can co-exist.

Adding a video camera to most industrial networks simply requires a local "Ethernet port" or a drop-in communications module, similar to adding another smart sensor. The camera plugs in and can be configured as just another sensor.

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However, configuration and the integration with a SCADA/HMI system can be tricky if you don't have good application software.

Dealing With Data

Digital cameras can become the electronic equivalent of purple loosestrife (prevalent in the Charles River basin around Boston): Nice to look at, but overloads the environment quickly. In fact, just four cameras transmitting images could use 55MB of bandwidth every minute! Storing video from twelve megapixel cameras for 10 days would take 2.4 terabytes of storage.

How can we deal with the issues of:

- Mitigating impact and traffic on the network,
- Deterministic response of the network,
- Reasonable storage requirements and fast access to video-of-interest, and
- Integrating easily with the operator's standard console

in a way that's consistent with good engineering and operating practices for industries?

The solution lies with software specifically designed for video applications in factory automation. Essentially, the software asks for video images to be transmitted over the factory network only when it needs the data—such as when an alarm occurs or a step occurs in a batch procedure.

The software converts a computer into a comprehensive digital video recorder (DVR) that:

- Continuously collects and archives high-resolution video from a multitude of cameras

- Automatically edits the video stream into before-and-after “clips” when an “event” occurs
- Sends that video clip, along with an alarm message, to the HMI or SCADA system for further handling by the user
- Automatically latches the alarm so that the user is always notified (and must acknowledge) and no alarms are lost
- Automatically stores and forwards messages if the network is temporarily unavailable
- Communicates efficiently over almost any network provided, from gigabit fiber networks, to mid-speed wireless and wired systems, all the way down to 9600 baud wireless and telephone lines.

Newer industrial video monitoring systems have all these features. Installation is simple, requiring only plug-in connections to the existing network. The software to process video data can be embedded in most commercial HMI/SCADA software systems, or interfaced via OPC. And the commands to take video snapshots can be defined by ISA-88 recipes, or sent by any major distributed control system, at various stages in a batch or continuous process, or in response to an alarm.

A key need is to edit the videos down to the clips that are important, and store those compressed clips in a way that makes them easy to retrieve. A relational database serves this need well, especially in manufacturing and process control applications.

How do you interface to the HMI? Fortunately, the industry has developed standards such as OPC, HTTP and even Modbus. These enable application programs to share data structures and pass commands between applications. In the case of Longwatch, we use OPC so that the operator can, from an HMI (like InTouch or iFIX) send a command to acknowledge a video alarm, create an event clip “on the fly,” or even go into “live streaming”

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mode to take an immediate look into the field.

Video has the opportunity to be applied to process control applications in ways that were just not possible a few years ago. Better yet, there is technology that enables video to be transmitted over very long distances, on existing networks, so that “blind spots” in the operation are eliminated at very low cost.

Video images can also be transmitted to cell phones or PDAs, so that engineers can diagnose problems from home in the middle of the night. Or an engineer can stand next to the process unit, watch the recorded video snapshot of a problem, and try to figure out what really happened . Because the video data is available as an historical record, images and process data can be sent to an outside expert for an analysis.

Having video available on HMI screens helps operators see what’s going on at a process unit, verifies and provides a record that events occurred, and helps operators and engineers diagnose problems from afar.

FIGURE CAPTIONS



Figure 1: Video images on the HMI screen at the Littleton water department

in Littleton, MA, allow operators to see what's happening in the well house and surrounding area.



Figure 2: An operator at the water plant in Madison, MA, can quickly glance at video images from important areas of the process.

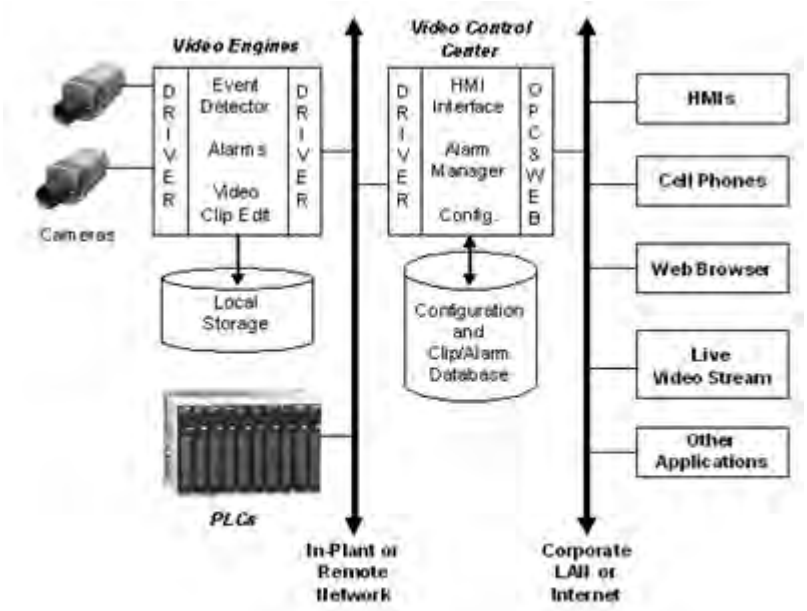


Figure 3: Diagram shows how cameras transmit data over standard industrial networks to a video processor. The video processor stores the data in a relational database and makes images available to an HMI/SCADA system, DCS, PLC, process historians, web browsers, cellphones and PDAs.

Longwatch, Inc. was founded by industrial automation and software veterans with the goal of simplifying video delivery over existing SCADA, HMI and distributed control networks. The result is the Longwatch Surveillance System™, a portfolio of products that enables SCADA system users to view events and easily verify alarms at local and remote sites using both legacy and new networking infrastructures. The system integrates video and system alarms on the same display for fast, reliable operation and decision-making. Visit the website



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Appendix DD

US006578070B1

(12) **United States Patent**
Weaver et al.

(10) **Patent No.: US 6,578,070 B1**
(45) **Date of Patent: *Jun. 10, 2003**

(54) **METHOD AND APPARATUS FOR IMPLEMENTING SEAMLESS PLAYBACK OF CONTINUOUS MEDIA FEEDS**

(75) Inventors: **Daniel Weaver**, Redwood City; **David J. Pawson**, Palo Alto, both of CA (US)

(73) Assignees: **nCube Corporation**, Beaverton, OR (US); **Thirdspace Living, Limited** (GB)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **09/352,630**

(22) Filed: **Jul. 13, 1999**

Related U.S. Application Data

(63) Continuation of application No. 08/956,262, filed on Oct. 22, 1997, now Pat. No. 6,138,147.

(51) **Int. Cl.**[7] **G06F 15/16**

(52) **U.S. Cl.** **709/206**; 709/236; 709/203; 707/104

(58) **Field of Search** 709/206, 236, 709/203; 707/104

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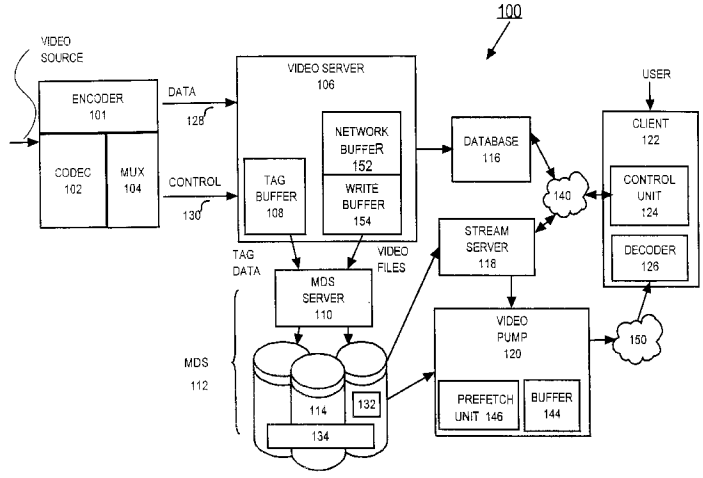
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Primary Examiner—Krisna Lim

(57) **ABSTRACT**

A method and system for storing a continuous feed of video is provided. According to one aspect of the invention, the continuous feed is encoded in a digital video format to produce a digital data stream. A series of content files is created by repeatedly performing the steps of (1) storing the digital data stream in a current file, and (2) establishing a new file as the current file when the current file satisfies a predetermined condition. If the series of content files satisfy a particular deletion criteria, then a particular content file that satisfies a particular deletion criteria is deleted. A determination is made as to whether any reader is currently playing information from the particular content file. If it is determined that a reader is playing information from the particular content file then the step of deleting the particular content file is delayed. In certain aspects, tag information that indicates information about frames contained in the digital data stream is generated. The tag information includes timestamps that indicate timing of frames relative to a beginning of the digital data stream. An initial time value that indicates an absolute time that corresponds to the beginning of the digital data stream. When a request from a client for playback beginning at a specified absolute time is received, the initial time value is subtracted from the specified absolute time to determine a relative time. The tag information is used to identify a location in the digital data stream that corresponds to the relative time. The digital data stream is then transmitted to the client beginning at the location in the digital data stream that corresponds to the relative time.

20 Claims, 8 Drawing Sheets



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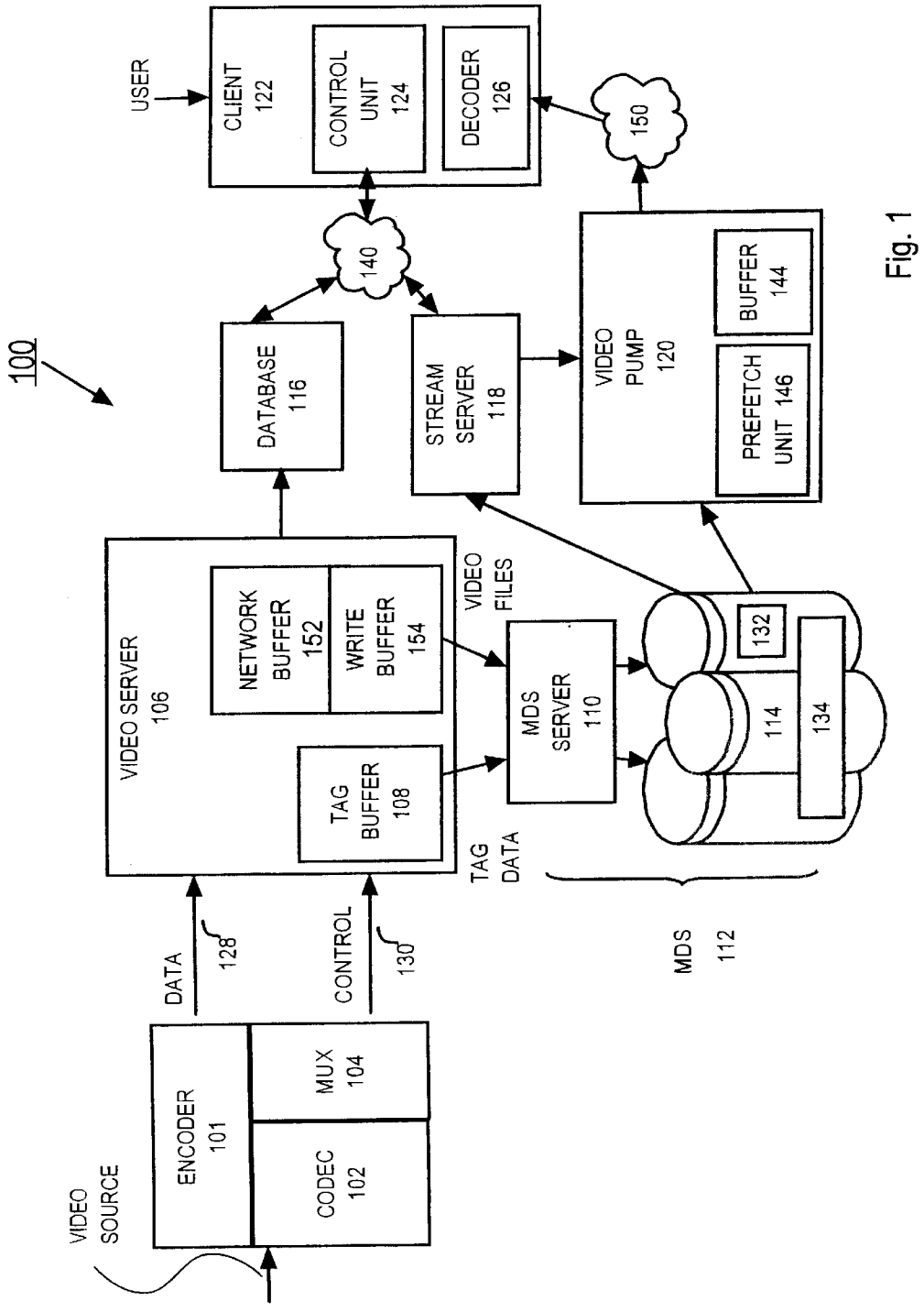

100
USER
CLIENT 122
CONTROL UNIT 124
DECODER 126
150
140
DATABASE 116
STREAM SERVER 118
VIDEO PUMP 120
BUFFER 144
PREFETCH UNIT 146
VIDEO SERVER 106
NETWORK BUFFER 152
WRITE BUFFER 154
TAG BUFFER 108
VIDEO FILES
MDS SERVER 110
132
114
134
TAG DATA
MDS 112
DATA 128
CONTROL 130
VIDEO SOURCE
ENCODER 101
CODEC 102
MUX 104

Fig. 1

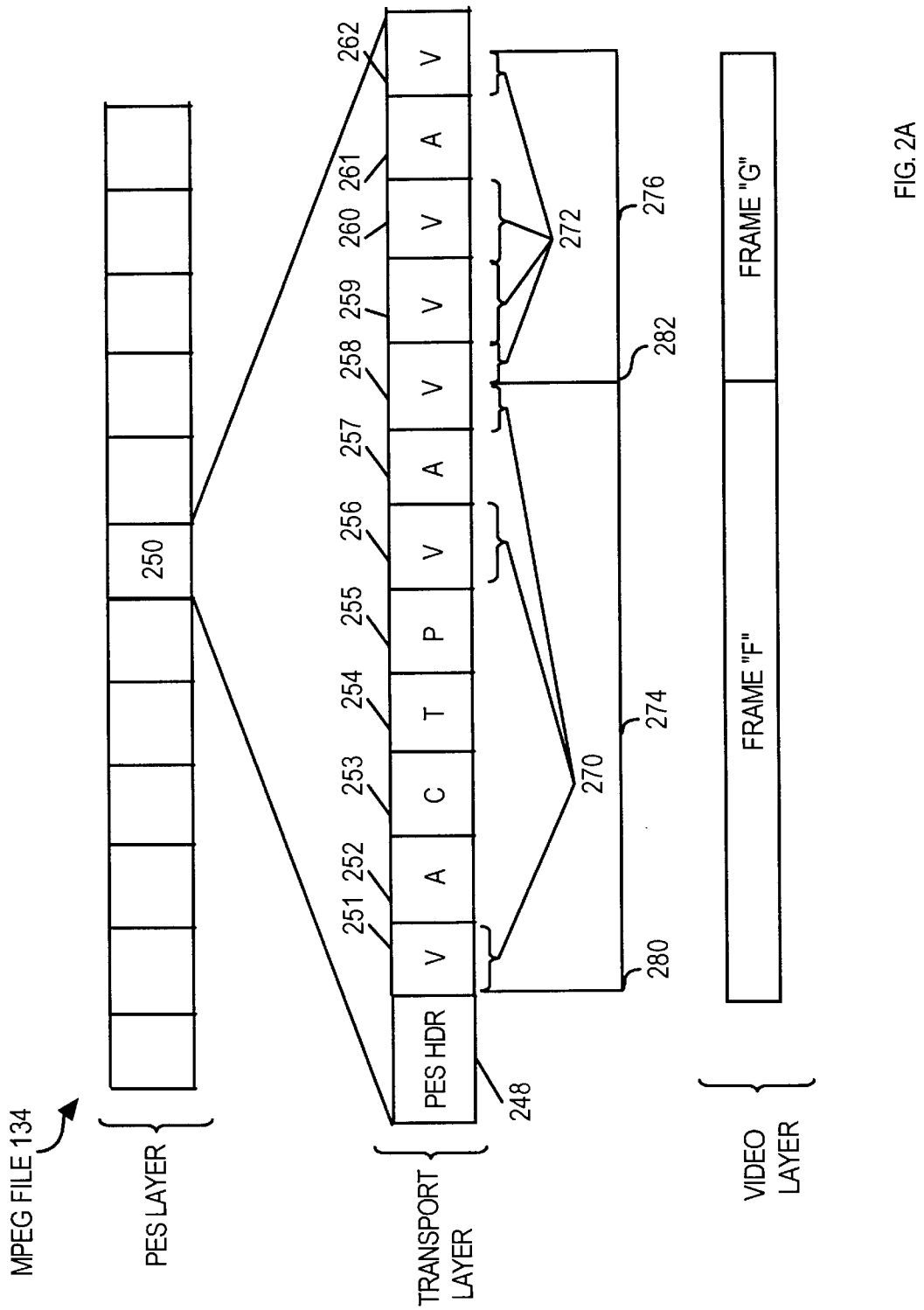

MPEG FILE 134
PES LAYER
TRANSPORT LAYER
VIDEO LAYER
250
PES HDR
248
V
A
C
T
P
V
A
V
V
V
A
V
251
252
253
254
255
256
257
258
259
260
261
262
270
272
274
276
280
282
FRAME "F"
FRAME "G"

FIG. 2A

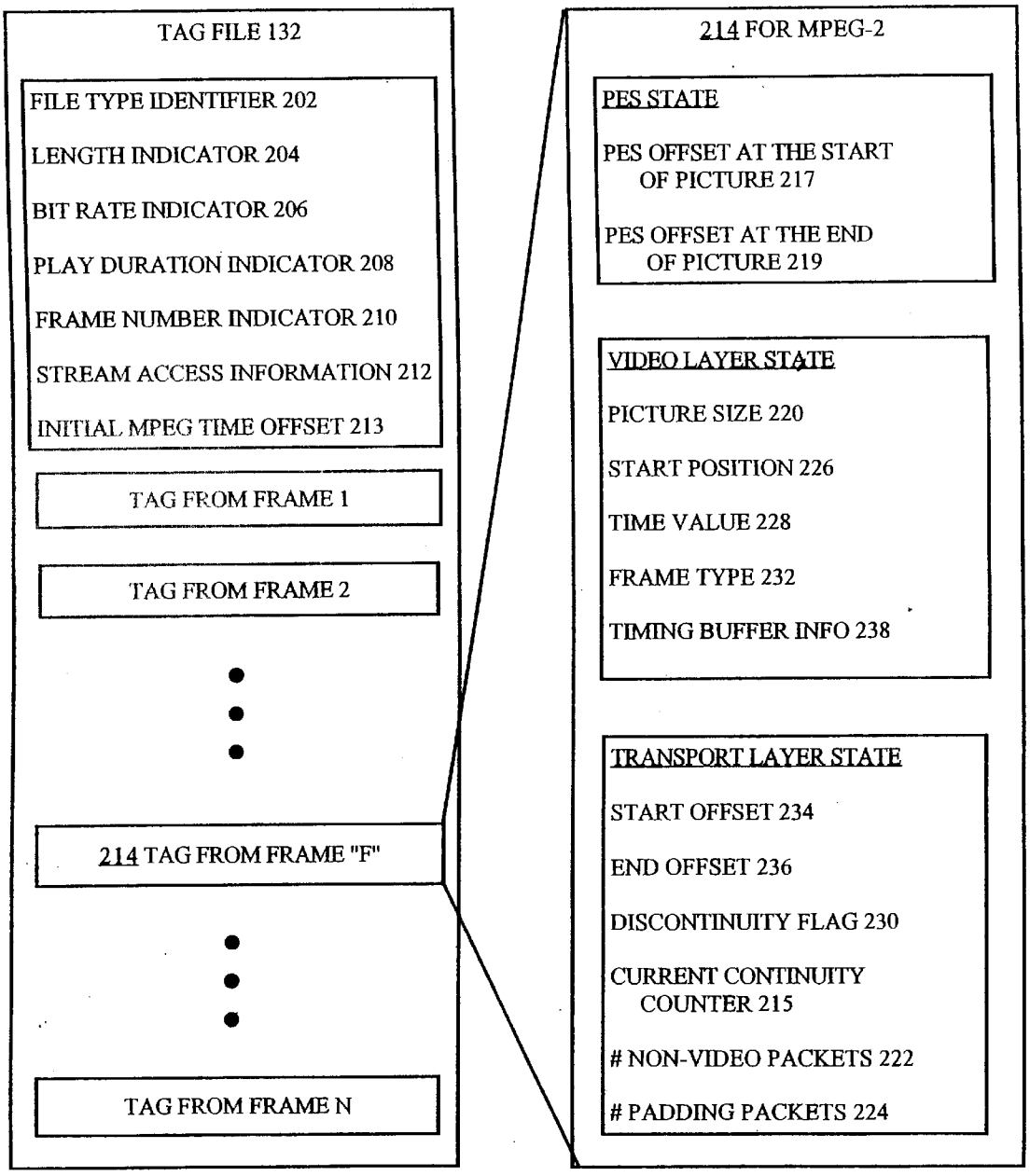

TAG FILE 132
FILE TYPE IDENTIFIER 202
LENGTH INDICATOR 204
BIT RATE INDICATOR 206
PLAY DURATION INDICATOR 208
FRAME NUMBER INDICATOR 210
STREAM ACCESS INFORMATION 212
INITIAL MPEG TIME OFFSET 213
TAG FROM FRAME 1
TAG FROM FRAME 2
214 TAG FROM FRAME "F"
TAG FROM FRAME N
214 FOR MPEG-2
PES STATE
PES OFFSET AT THE START OF PICTURE 217
PES OFFSET AT THE END OF PICTURE 219
VIDEO LAYER STATE
PICTURE SIZE 220
START POSITION 226
TIME VALUE 228
FRAME TYPE 232
TIMING BUFFER INFO 238
TRANSPORT LAYER STATE
START OFFSET 234
END OFFSET 236
DISCONTINUITY FLAG 230
CURRENT CONTINUITY COUNTER 215
NON-VIDEO PACKETS 222
PADDING PACKETS 224

FIG 2B

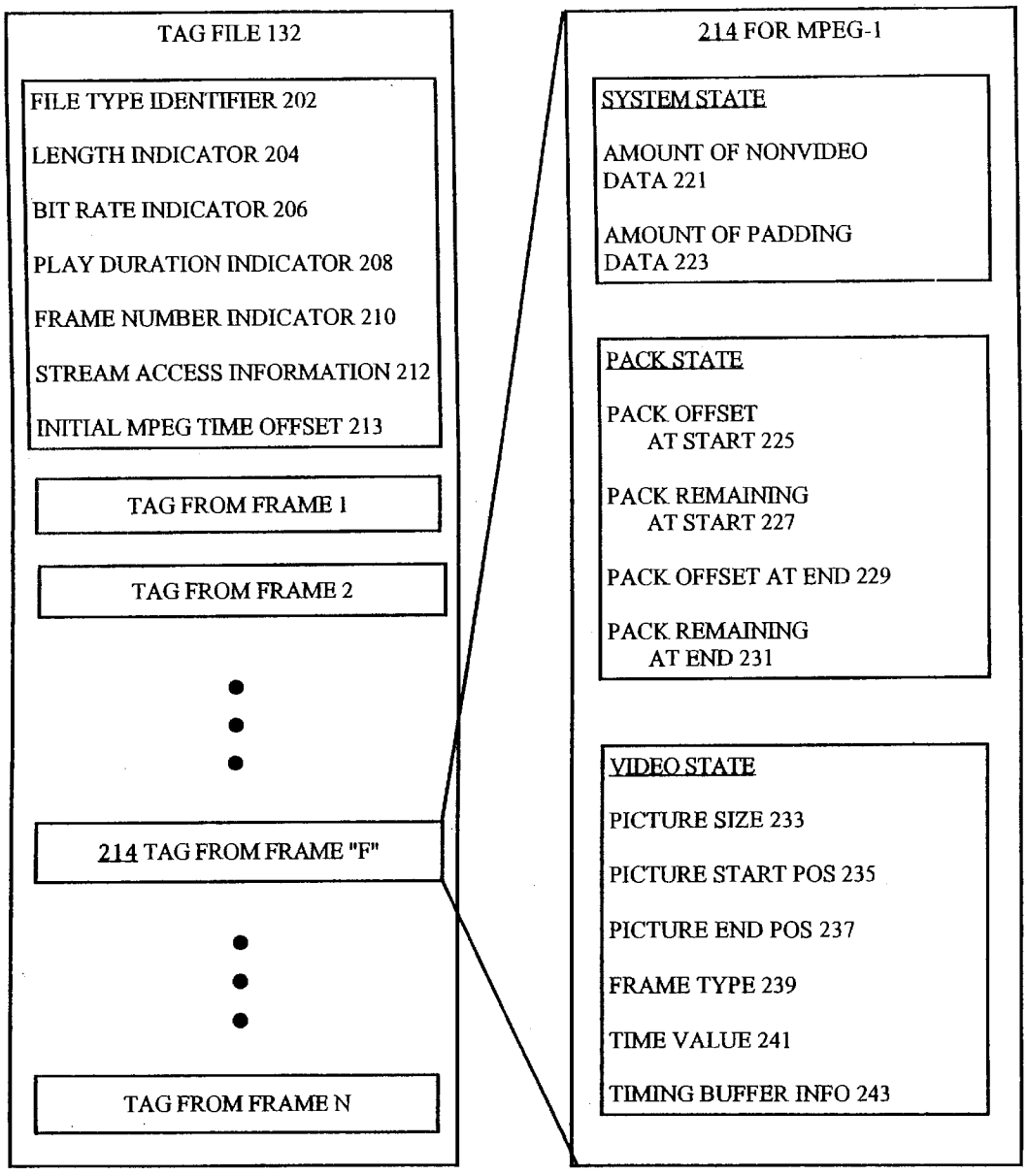

TAG FILE 132
FILE TYPE IDENTIFIER 202
LENGTH INDICATOR 204
BIT RATE INDICATOR 206
PLAY DURATION INDICATOR 208
FRAME NUMBER INDICATOR 210
STREAM ACCESS INFORMATION 212
INITIAL MPEG TIME OFFSET 213
TAG FROM FRAME 1
TAG FROM FRAME 2
214 TAG FROM FRAME "F"
TAG FROM FRAME N
214 FOR MPEG-1
SYSTEM STATE
AMOUNT OF NONVIDEO DATA 221
AMOUNT OF PADDING DATA 223
PACK STATE
PACK OFFSET AT START 225
PACK REMAINING AT START 227
PACK OFFSET AT END 229
PACK REMAINING AT END 231
VIDEO STATE
PICTURE SIZE 233
PICTURE START POS 235
PICTURE END POS 237
FRAME TYPE 239
TIME VALUE 241
TIMING BUFFER INFO 243

FIG 2C

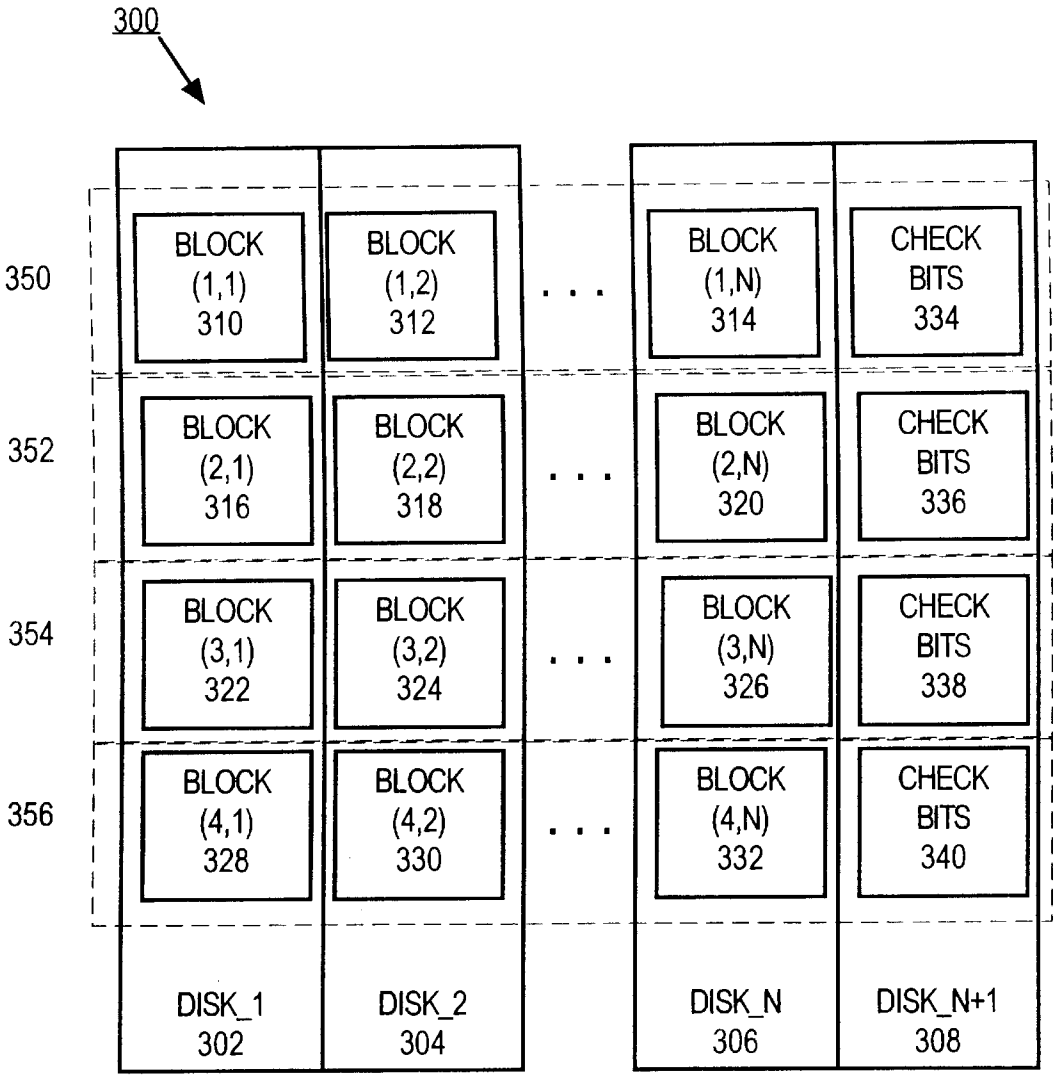

300
350
352
354
356
BLOCK (1,1) 310
BLOCK (1,2) 312
BLOCK (1,N) 314
CHECK BITS 334
BLOCK (2,1) 316
BLOCK (2,2) 318
BLOCK (2,N) 320
CHECK BITS 336
BLOCK (3,1) 322
BLOCK (3,2) 324
BLOCK (3,N) 326
CHECK BITS 338
BLOCK (4,1) 328
BLOCK (4,2) 330
BLOCK (4,N) 332
CHECK BITS 340
DISK_1 302
DISK_2 304
DISK_N 306
DISK_N+1 308

FIG. 3A

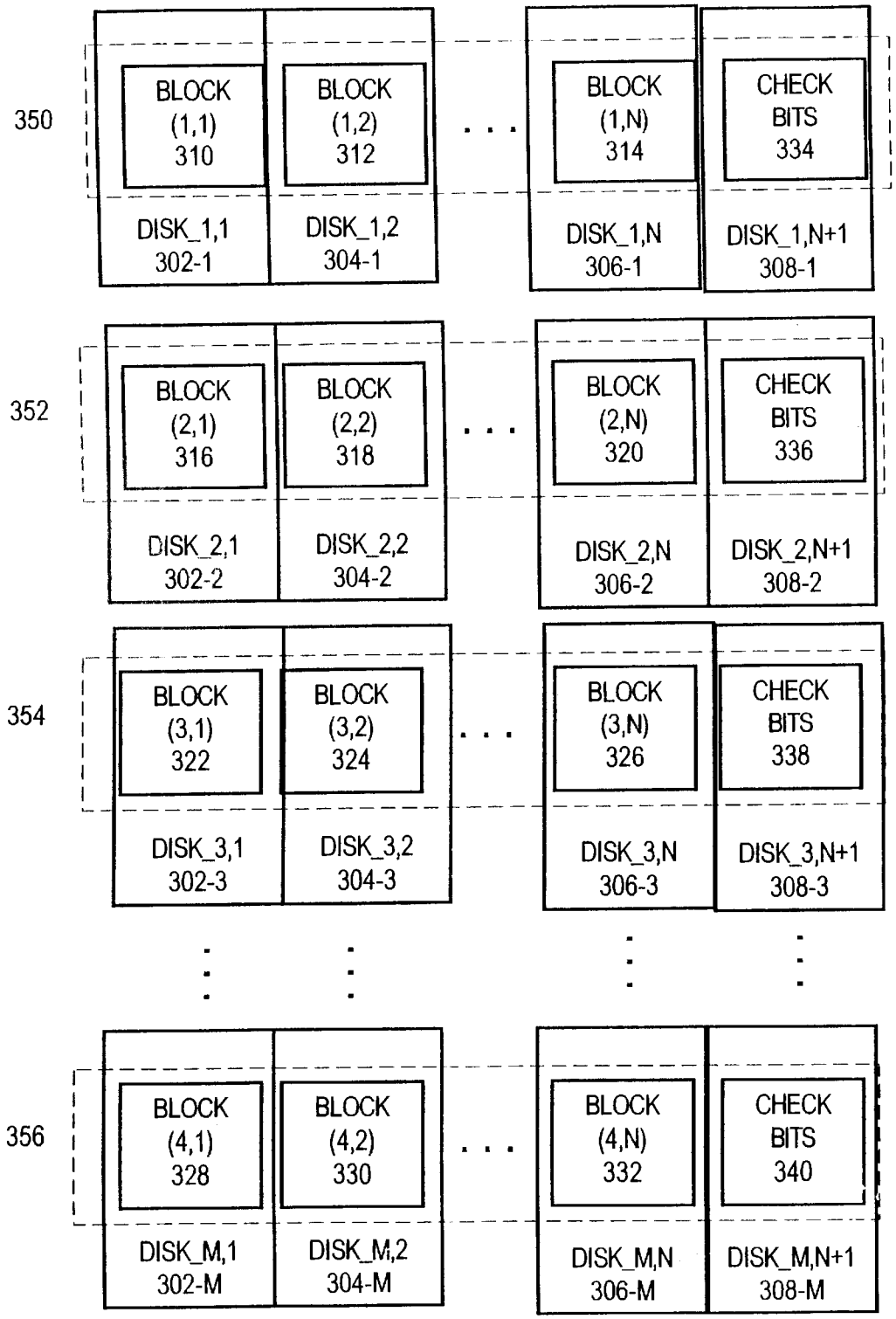

350
BLOCK (1,1) 310
BLOCK (1,2) 312
BLOCK (1,N) 314
CHECK BITS 334
DISK_1,1 302-1
DISK_1,2 304-1
DISK_1,N 306-1
DISK_1,N+1 308-1
352
BLOCK (2,1) 316
BLOCK (2,2) 318
BLOCK (2,N) 320
CHECK BITS 336
DISK_2,1 302-2
DISK_2,2 304-2
DISK_2,N 306-2
DISK_2,N+1 308-2
354
BLOCK (3,1) 322
BLOCK (3,2) 324
BLOCK (3,N) 326
CHECK BITS 338
DISK_3,1 302-3
DISK_3,2 304-3
DISK_3,N 306-3
DISK_3,N+1 308-3
356
BLOCK (4,1) 328
BLOCK (4,2) 330
BLOCK (4,N) 332
CHECK BITS 340
DISK_M,1 302-M
DISK_M,2 304-M
DISK_M,N 306-M
DISK_M,N+1 308-M

FIG. 3B

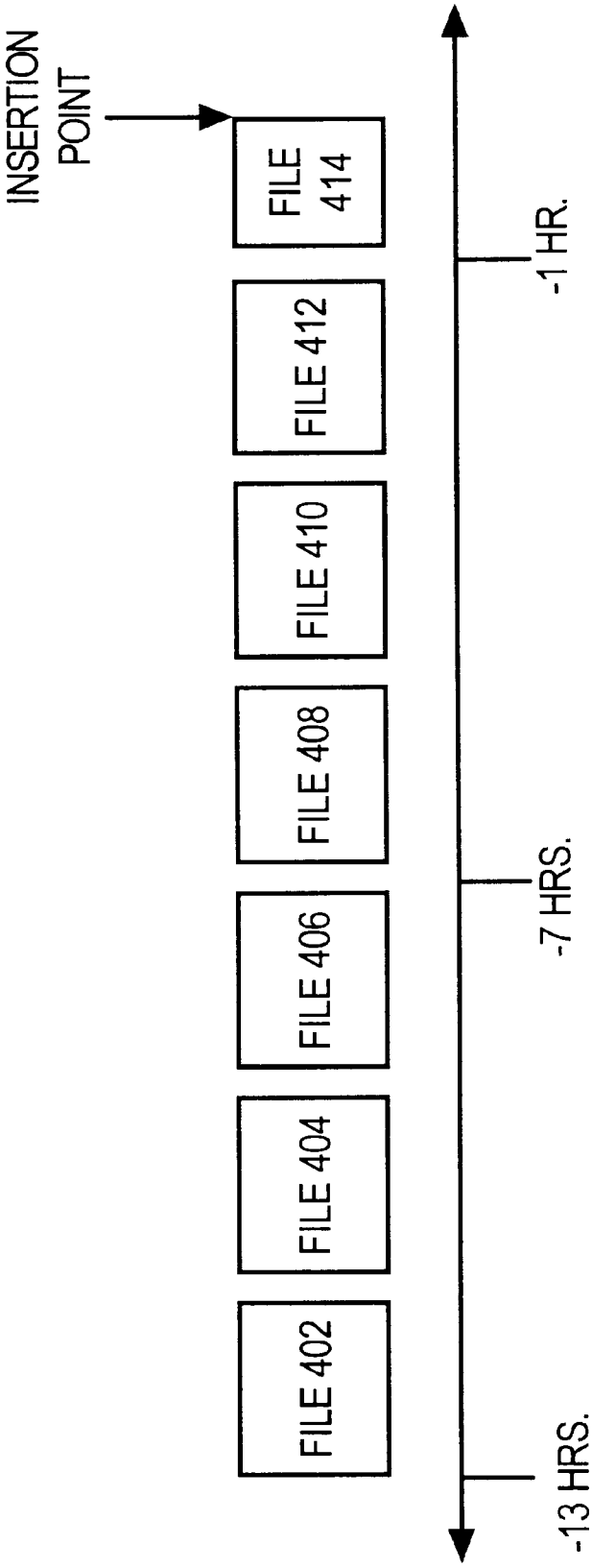
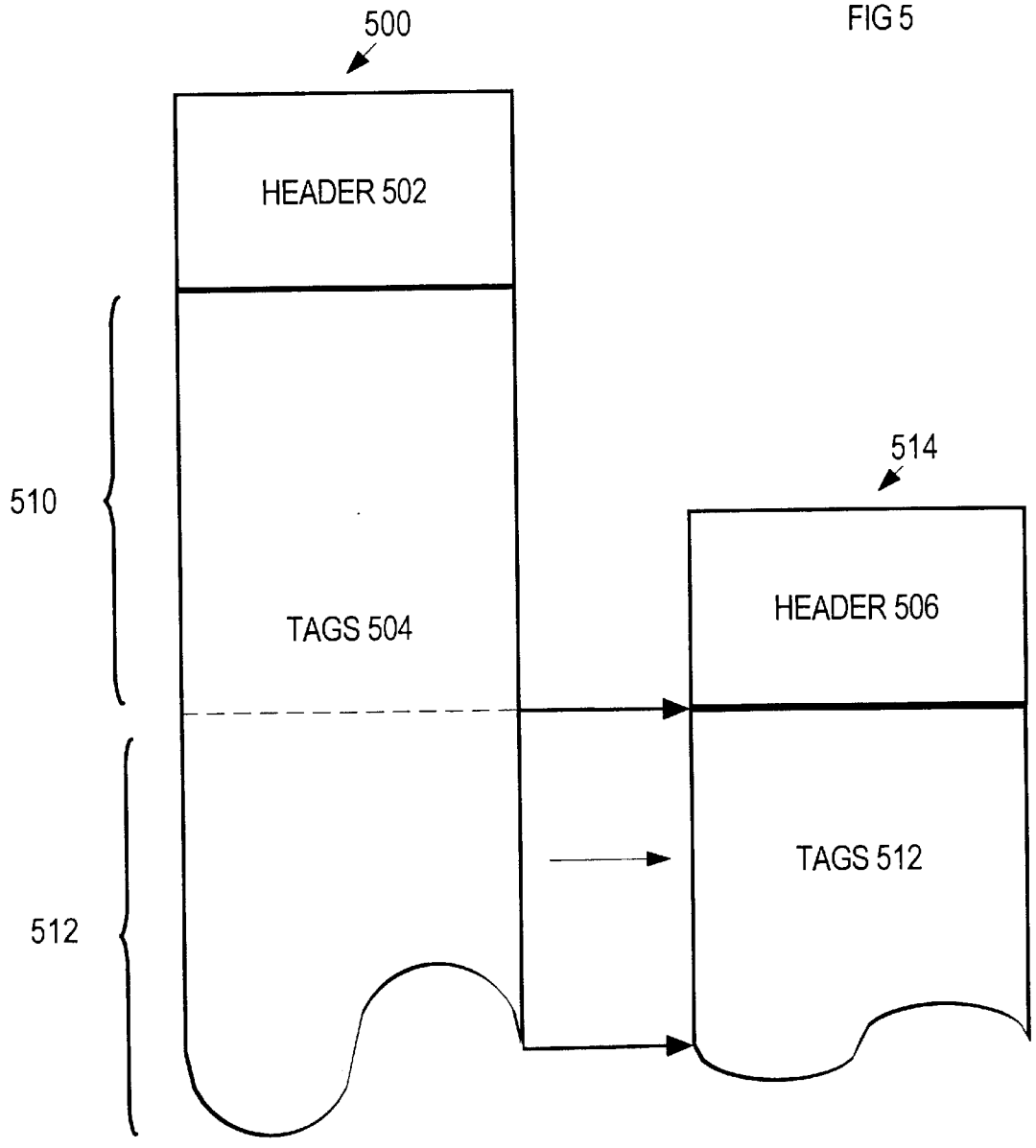

INSERTION POINT
FILE 414
FILE 412
FILE 410
FILE 408
FILE 406
FILE 404
FILE 402
-1 HR.
-7 HRS.
-13 HRS.

FIG. 4

FIG 5



METHOD AND APPARATUS FOR IMPLEMENTING SEAMLESS PLAYBACK OF CONTINUOUS MEDIA FEEDS

This application is a continuation of application Ser. No. 08/956,262 filed Oct. 22, 1997, now U.S. Pat. No. 6,138,147 issued on Oct. 24, 2000.

This application is a continuation of and claims priority from patent application Ser. No. 08/956,262, filed by Daniel Weaver and David J. Pawson, on Oct. 22, 1997, and issued as U.S. Pat. No. 6,138,147 on Oct. 24, 2000, which is hereby incorporated by reference in its entirety, and which is a continuation-in-part of U.S. patent application Ser. No. 08/859,860, which was filed on May 21, 1997 and issued as U.S. Pat. No. 5,864,682 on Jan. 26, 1999, and which is a continuation of U.S. patent application Ser. No. 08/502,480, which was filed Jul.14, 1995, and issued as U.S. Pat. No. 5,659,539, on Aug. 19, 1997.

RELATED APPLICATIONS

The present application is related to: U.S. patent application Ser. No. 08/956,261, filed by Daniel Weaver, Mark A. Porter and David J. Pawson on the equal day herewith, and issued as U.S. Pat. No. 6,112,226 on August 29, 2000, the contents of which are incorporated herein by reference in its entirety.

The present application is related to: U.S. patent application Ser. No. 08/956,263, filed by Daniel Weaver, Mark A. Porter and David J. Pawson on the equal day herewith, and issued as U.S. Pat. No. 6,119,154 on Sep. 12, 2000, the contents of which are incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

The present invention relates to a method and apparatus for processing audio-visual information, and more specifically, to a method and apparatus for providing non-sequential access to audio-visual information represented in a live content stream.

BACKGROUND OF THE INVENTION

In recent years, the media industry has expanded its horizons beyond traditional analog technologies. Audio, photographs, and even feature films are now being recorded or converted into digital formats. To encourage compatibility between products, standard formats have been developed in many of the media categories.

As would be expected, the viewers of digital video desire the same functionality from the providers of digital video as they now enjoy while watching analog video tapes on video cassette recorders. For example, viewers want to be able to make the video jump ahead, jump back, fast forward, fast rewind, slow forward, slow rewind and freeze frame.

Various approaches have been developed to provide non-sequential playback of digital video data. With respect to digital video data, non-sequential playback refers to any playback operation that does not play all of the encoded frames in the exact order in the sequence in which they were encoded. For example, jump ahead and fast forward operations are non-sequential in that some frames are skipped. Rewind operations at any speed are non-sequential in that during a rewind operation, frames are not played in the sequence in which they are encoded.

One approach to providing non-sequential playback of digital video data, referred to herein as the tag-based approach, is described in U.S. Pat. No. 5,659,539, entitled "Method and Apparatus for Frame Accurate Access of Digital Audio-visual Information" issued to Porter et al on Aug. 19, 1997, the contents of which are incorporated herein by this reference. According to the tag-based approach, a stored digital video file is parsed to generate "tag information" about individual frames within the file.

Specifically, the tag file contains information about the state of one or more state machines that are used to decode the digital representation. The state information varies depending on the specific technique used to encode the audio-visual work. For MPEG-2 files, for example, the tag file includes information about the state of the program elementary stream state machine, the video state machine, and the transport layer state machine.

During the performance of the audio-visual work, data from the digital representation is sent from a video pump to a decoder. The information in the tag file is used to perform seek, fast forward, fast rewind, slow forward and slow rewind operations during the performance of the audio-visual work. Seek operations are performed by causing the video pump to stop transmitting data from the current position in the digital representation, and to start transmitting data from a new position in the digital representation. The information in the tag file is inspected to determine the new position from which to start transmitting data. To ensure that the data stream transmitted by the video pump maintains compliance with the applicable video format, prefix data that includes appropriate header information is transmitted by the video pump prior to transmitting data from the new position.

Fast forward, fast rewind, slow forward and slow rewind operations are performed by selecting video frames based on the information contained in the tag file and the desired presentation rate, and generating a data stream containing data that represents the selected video frames. The selection process takes into account a variety of factors, including the data transfer rate of the channel on which the data is to be sent, the frame type of the frames, a minimum padding rate, and the possibility of a buffer overflow on the decoder. Prefix and suffix data are inserted into the transmitted data stream before and after the data for each frame in order to maintain compliance with the data stream format expected by the decoder.

The tag-based approach works well when there is enough time between the creation of the original digital video stream and the viewing of the digital video stream to allow the original digital video stream to be parsed to generate tag information. However, when the digital video stream is being viewed as it is being generated, parsing the digital video stream becomes impractical. The amount of computational power required to parse the digital video stream as it arrives would be prohibitively expensive. On the other hand, it is not considered acceptable to increase the latency between the occurrence of many types of video feeds (e.g. sporting events) and the time at which such feeds are available for audience viewing.

When a video stream is made available for viewing before generation of the stream has been completed, the video stream is said to be a "live feed". At a professional level, non-linear digital editors can be used to rapidly review footage of a live feed for a single user. However, these systems are not intended for and cannot be easily adapted to serve many users. For example, if a hundred users were watching the same live feed but wanted to rewind, pause, and fast forward the feed at different times, each would require a separate non-linear digital editor.

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Another problem associated with providing non-linear access to live digital video streams is that users may attempt to fast forward into portions of the video stream that do not yet exist. For example, a viewer may attempt to fast forward a live feed to see the final score of game which, in reality, has not yet ended. It is desirable to provide techniques for handling these types of situations in a way that ensures that the decoder will not freeze nor the video stream become corrupted.

Based on the foregoing, it is clearly desirable to provide a method and apparatus for sequentially displaying non-sequential frames of a live digital video. It is further desirable to provide such non-sequential access to live digital video in a way that does not require each viewer to operate prohibitively expensive hardware. It is also desirable to provide safeguards against attempts to access portions of a live digital video stream that do not yet exist.

SUMMARY OF THE INVENTION

A method and system for storing a continuous feed of video is provided. According to one aspect of the invention, the continuous feed is encoded in a digital video format to produce a digital data stream. A series of content files is created by repeatedly performing the steps of (1) storing the digital data stream in a current file, and (2) establishing a new file as the current file when the current file satisfies a predetermined condition. If the series of content files satisfy a particular deletion criteria, then a particular content file that satisfies a particular deletion criteria is deleted. A determination is made as to whether any reader is currently playing information from the particular content file. If it is determined that a reader is playing information from the particular content file then the step of deleting the particular content file is delayed.

According to another aspect of the invention, the deletion may be delayed until the particular content file is no longer being accessed, or until a certain amount of time has passed since the time at which it would have been deleted but for the fact that it was being accessed.

According to another feature of the invention, a series of content files is created by repeatedly performing the steps of (1) storing the digital data stream in a current file; (2) generating and storing tag information separate from the digital video stream that indicates information about frames contained in the digital data stream; and (3) establishing a new file as the current file when the current file satisfies a predetermined condition. If the series of content files satisfy a particular deletion condition, then a particular content file that satisfies a particular deletion criteria is deleted.

According to one aspect, the step of storing tag information includes the steps of generating a first header for a first tag file and storing tag information sequentially in the first tag file. When a set of tags within the first tag file becomes invalid, a second header for a second tag file is generated. All tags in the first tag file, except the set of tags, are copied from the first tag file to the second tag file. New tag information is stored sequentially within the second tag file and the first tag file is deleted.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings and in which like reference numerals refer to similar elements and in which:

FIG. **1** is a block diagram that illustrated a video delivery system according to an embodiment of the invention;

FIG. **2**A is a block diagram that illustrates the format of an MPEG file;

FIG. **2**B is a block diagram of an exemplary tag file according to an embodiment of the invention;

FIG. **2**C is a block diagram illustrating the tag information generated for each frame in an MPEG-1 file according to an embodiment of the invention;

FIG. **3**A is a block diagram illustrating a storage system that uses RAID error correction techniques according to an embodiment of the invention;

FIG. **3**B is a block diagram illustrating a storage system that combines RAID error correction and disk striping according to an embodiment of the invention;

FIG. **4** is a block diagram illustrating a series of content files used to store the content of a continuous feed according to an embodiment of the invention; and

FIG. **5** is a block diagram illustrating the migration of tag information from an old tag file to a new tag file in response to the expiration of tag data within the old tag file.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A method and apparatus for providing non-sequential access to a live digital video stream is described. In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be apparent, however, to one skilled in the art that the present invention may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form in order to avoid unnecessarily obscuring the present invention.

FUNCTIONAL OVERVIEW

According to one aspect of the invention, the difficulty associated with applying the tag-based approach to live digital video feeds is addressed by eliminating the need to parse an incoming digital video stream in real time. Instead of generating tag data by parsing the digital video stream, the unit responsible for encoding the live feed retains information about how the data was encoded and transmits that information to the video server along with the encoded data. The tag information arrives at the video server along with the corresponding content, so the content itself does not have to be parsed.

According to another aspect of the invention, the video server is configured to ensure that the client cannot seek or scan past the end of the received content. Due to the fact that there will be some amount of skew between the arrival time of the content and the corresponding tags, the server is configured to make sure that tags are not used prematurely, i.e. such that they would cause the server to go past the end of the available content.

EXEMPLARY SYSTEM

FIG. **1** is a block diagram illustrating an exemplary audio-visual information delivery system **100** for delivering and providing non-sequential access to live digital video feeds. Audio-visual information delivery system **100** generally includes an encoder **101**, a video server **106**, a Media Data Store (MDS) **112**, a database **116**, a stream server **118**, a video pump **120**, and a client **122**.

THE ENCODER

Encoder **101** receives audio visual input and generates a digital stream of data that encodes the audio visual input

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according to a particular format. Numerous video encoding formats have been developed and are well known in the industry. For example, the MPEG formats are described in detail in the following international standards: ISO/IEC 13818-1, 2, 3 (MPEG-2) and ISO/IEC 11172-1, 2, 3 (MPEG-1). Documents that describe these standards (hereafter referred to as the "MPEG specifications") are available from ISO/IEC Copyright Office Case Postale 56, CH 1211, Genève 20, Switzerland. While specific formats may be referenced herein for the purposes of explanation, the present invention is not restricted to any particular digital stream format.

Encoder **101** includes a Coder/Decoder (CODEC) **102** and a multiplexer (MUX) **104**. CODEC **102** converts visual or audio-visual information from an input source to compressed digital data. CODEC **102** may be, for example, a fractal compressor or an MPEG compressor. For the purposes of illustration, it shall be assumed that the video source being captured by CODEC **102** is a live source and, consequently, CODEC **102** is encoding video at 1X relative to real time. However, the video source may alternatively be a stored video source which CODEC **102** encodes at any rate relative to real time.

MUX **104** multiplexes the compressed audio and visual information generated by CODEC **102** to generate a compressed video stream. In the compressed video stream, the data representing video frames and audio are merged and formatted according to the particular digital format supported by encoder **101**. The specific operations performed during the merging process will vary based on the type of encoding employed. For example, the merging process may involve determining the order and placement of portions of digitized audio and video in the stream and inserting metadata at various points within the stream. The metadata may take the form, for example, of header information that identifies the starting point and content of "packets" within the stream. The stream of compressed audio-visual information constructed by MUX **104** is transmitted from the encoder **101** to the video server **106** over a communication channel **128**.

CONTROL INFORMATION

According to one aspect of the invention, the encoder **101** sends control information to the video server **106** over a communication channel **130** in parallel with the video stream. The control information sent over channel **130** includes specific information about how the encoder **101** constructed the video stream. This control information includes tag data that will be used by the stream server **118** to provide non-sequential access to the video stream. Specifically, the control information may include information about the type, length, and boundaries of the various frames encoded in the video stream as well as header information that specifies the compression ratio, the bit rate, and other types of information the video server **106** requires to determine how to process the video stream.

Significantly, the generation of the control information involves minimal additional computational power because MUX **104** generates most of the information already during the construction of the content stream. Specifically, MUX **104** arranges and encapsulates the digital video and audio data from CODEC **102**. Since MUX **104** is packaging the content, MUX **104** knows the contents of and boundaries between the packages.

COMMUNICATION BETWEEN THE ENCODER AND THE VIDEO SERVER

While CODEC **102** will typically be implemented in hard-wired circuitry, MUX **104** is preferably implemented by program-controlled circuitry, such as a processor programmed to execute a particular sequence of instructions that are stored in a memory. Consequently, MUX **104** may include a processor executing a conventional multiplexing program that has been linked with and makes calls to a software library that controls the communication with the video server **106**.

All data transmitted between the encoder **101** and the video server **106** is preferably sent using a reliable communication mechanism. According to one embodiment, the video content on communication channel **128** is handled as a simple bytestream and is transmitted via a lightweight, reliable protocol. For example, TCP is sufficient on lightly loaded networks. The control information and metadata on communication channel **130** contain more complicated data types and are sent via an object oriented protocol, such as the Common Object Resource Broker Architecture Interface Definition Language ("CORBA IDL").

Communication between the encoder **101** and the video server **106** occurs in sessions. According to one embodiment, a session is performed in three phases: OPEN, SEND and CLOSE. The operations performed during each of the phases is as follows:

OPEN—any provisioning that the video server **106** needs to perform for network or disk bandwidth or disk space occurs. A pipe for the video stream data (the "content") is created.

SEND TAGS and SEND DATA—these calls are made multiple times as content is encoded. The video server **106** stores all content immediately to disk and updates an end-of-file position. Tags are held in memory until the accompanying content data has been stored. Tags are held for an additional period of time to guarantee that a seek to that tag will succeed, i.e. that video pump **120** will not starve for data.

CLOSE—content pipe is torn down. Server resources are released and content services and clients are notified that the feed has become a normal static piece of content.

Encoder **101** generates content data and control data in parallel. However, the control data associated with a particular portion of content is not necessarily generated by encoder **101** at the same time as the particular portion of content. For example, encoder **101** may actually determine how it is going to line up content frames before the encoder **101** actually lines up the frames. Under these circumstances, the control data that indicates how the frames are lined up may be transmitted by encoder **101** before the content data that contains the frames.

THE VIDEO SERVER

Video server **106** receives the video stream and control data from encoder **101** and causes the data to be stored in MDS **112**. In the illustrated system, the video server **106** sends an MPEG video stream to MDS server **110**, and MDS server **110** stores the MPEG video stream in an MPEG file **134**. In parallel, the video server **106** sends to the MDS server **110** tag information extracted from the control data received on line **130**. The tag data is stored in a tag file **132** on disks **114**. The video server **106** may also send information about the content, including tag data, to be stored in database **116**.

Once tag data is transmitted by video server **106**, any other entity in the system, including video pump **120**, may use the tag data to attempt to access the content associated with the tag data. Consequently, the immediate transmission of tag data to MDS server **110** may result in errors when, for

example, the tag data arrives at video server **106** before the corresponding content data. Therefore, prior to sending the tag data to MDS server **110**, video server **106** buffers each tag data item in a tag buffer **108** until it is safe for entities, such as video pump **120**, to access the content associated with the tag data item. The use of tag buffer **108** to avoid premature reads of content data is described in greater detail hereafter.

EXEMPLARY MPEG FILE

Digital audio-visual storage formats, whether compressed or not, use state machines and packets of various structures. The techniques described herein apply to all such storage formats. While the present invention is not limited to any particular digital audio-visual format, the MPEG-2 transport file structure shall be described for the purposes of illustration.

Referring to FIG. **2***a*, it illustrates the structure of an MPEG-2 transport file **134** in greater detail. The data within MPEG file **134** is packaged into three layers: a program elementary stream ("PES") layer, a transport layer, and a video layer. These layers are described in detail in the MPEG-2 specifications. At the PES layer, MPEG file **134** consists of a sequence of PES packets. At the transport layer, the MPEG file **134** consists of a sequence of transport packets. At the video layer, MPEG file **134** consists of a sequence of picture packets. Each picture packet contains the data for one frame of video.

Each PES packet has a header that identifies the length and contents of the PES packet. In the illustrated example, a PES packet **250** contains a header **248** followed by a sequence of transport packets **251–262**. PES packet boundaries coincide with valid transport packet boundaries. Each transport packet contains exclusively one type of data. In the illustrated example, transport packets **251**, **256**, **258**, **259**, **260** and **262** contain video data. Transport packets **252**, **257** and **261** contain audio data. Transport packet **253** contains control data. Transport packet **254** contains timing data. Transport packet **255** is a padding packet.

Each transport packet has a header. The header includes a program ID ("PID") for the packet. Packets assigned PID **0** are control packets. For example, packet **253** may be assigned PID **0**. Other packets, including other control packets, are referenced in the PID **0** packets. Specifically, PID **0** control packets include tables that indicate the packet types of the packets that immediately follow the PID **0** control packets. For all packets which are not PID **0** control packets, the headers contain PIDs which serve as a pointers into the table contained in the PID **0** control packet that most immediately preceded the packets. For example, the type of data contained in a packet with a PID **100** would be determined by inspecting the entry associated with PID **100** in the table of the PID **0** control packet that most recently preceded the packet.

In the video layer, the MPEG file **134** is divided according to the boundaries of frame data. As mentioned above, there in no correlation between the boundaries of the data that represent video frames and the transport packet boundaries. In the illustrated example, the frame data for one video frame "F" is located as indicated by brackets **270**. Specifically, the frame data for frame "F" is located from a point **280** within video packet **251** to the end of video packet **251**, in video packet **256**, and from the beginning of video packet **258** to a point **282** within video packet **258**. Therefore, points **280** and **282** represent the boundaries for the picture packet for frame "F". The frame data for a second video frame "G" is located as indicated by brackets **272**. The boundaries for the picture packet for frame "G" are indicated by bracket **276**.

Structures analogous to those described above for MPEG-2 transport streams also exist in other digital audio-visual storage formats, including MPEG-1, Quicktime, AVI, Proshare and H.261 formats. In the preferred embodiment, indicators of video access points, time stamps, file locations, etc. are stored such that multiple digital audio-visual storage formats can be accessed by the same server to simultaneously serve different clients from a wide variety of storage formats. Preferably, all of the format specific information and techniques are incorporated in the tag generator and the stream server. All of the other elements of the server are format independent.

EXEMPLARY TAG FILE

The contents of an exemplary tag file **132** shall now be described with reference to FIG. **2***b*. In FIG. **2***b*, the tag file **132** includes a file type identifier **202**, a length indicator **204**, a bit rate indicator **206**, a play duration indicator **208**, a frame number indicator **210**, stream access information **212** and an initial MPEG time offset **213**. File type identifier **202** indicates the physical wrapping on the MPEG file **134**. For example, file type identifier **202** would indicate whether MPEG file **134** is a MPEG-2 or an MPEG-1 file.

Length indicator **204** indicates the length of the MPEG file **134**. Bit rate indicator **206** indicates the bit rate at which the contents of the MPEG file **134** should be sent to a client during playback. The play duration indicator **208** specifies, in milliseconds, the amount of time required to play back the entire contents of MPEG file **134** during a normal playback operation. Frame number indicator **210** indicates the total number of frames represented in MPEG file **134**.

Stream access information **212** is information required to access the video and audio streams stored within MPEG file **134**. Stream access information **212** includes a video elementary stream ID and an audio elementary stream ID. For MPEG-2 files, stream access information **212** also includes a video PID and an audio PID. The tag file header may also contain other information that may be used to implement other features.

In addition to the general information described above, the tag file **132** contains an entry for each frame within the MPEG file **134**. The entry for a video frame includes information about the state of the various MPEG layers relative to the position of the data that represents the frame. For an MPEG-2 file, each entry includes the state of the MPEG-2 transport state machine, the state of the program elementary stream state machine and the state of the video state machine. For an MPEG-1 file, each entry includes the current state of the Pack system MPEG stream and the state of the video state machine.

Tag file entry **214** illustrates in greater detail the tag information that is stored for an individual MPEG-2 video frame "F". With respect to the state of the program elementary stream state machine, the tag entry **214** includes the information indicated in Table 1.

TABLE 1

DATA	MEANING
PES OFFSET AT THE START OF PICTURE 217	The offset, within the PES packet that contains the frame data for frame "F" of

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TABLE 1-continued

DATA	MEANING
	the first byte of the frame data for frame "F".
PES OFFSET AT THE END OF PICTURE 219	The offset between the last byte in the frame data for frame "F" and the end of the PES packet in which the frame data for frame "F" resides.

With respect to the state of the video state machine, tag entry **214** includes the information indicated in Table 2.

TABLE 2

DATA	MEANING
PICTURE SIZE 220	The size of the picture packet for frame "F".
START POSITION 226	The location within the MPEG file of the first byte of the data that corresponds to frame "F"
TIME VALUE 228	The time, relative to the beginning of the movie, when frame "F" would be displayed during a normal playback of MPEG file 134.
FRAME TYPE 232	The technique used to encode the frame (e.g. I-frame, P-frame or B-frame).
TIMING BUFFER INFORMATION 238	Indicates how full the buffer of the decoder is (sent to the decoder to determine when information should be moved out of the buffer in order to receive newly arriving information).

With respect to the state of the transport layer state machine, tag entry **214** includes the information indicated in Table 3.

TABLE 3

DATA	MEANING
START OFFSET 234	The distance between the of the first byte in the frame data and the start of the transport packet in which the first byte resides.
# OF NON-VIDEO PACKETS 222	The number of non-video packets (i.e. audio packets, padding packets, control packets and timing packets) that are located within the picture packet for frame "F".
# OF PADDING PACKETS 224	The number of padding packets that are located within the picture packet for frame "F".
END OFFSET 236	The distance between the last byte in the frame data and the end of the packet in which the last byte resides.
CURRENT CONTINUITY COUNTER 215	The Continuity value associated with frame "F".
DISCONTINUITY FLAG 230	Indicates whether there is a discontinuity in time between frame "F" and the frame represented in the previous tag entry.

Assume, for example, that entry **214** is for the frame "F" of FIG. **2***b*. The size **220** associated with frame "F" would be the bits encompassed by bracket **274**. The number **222** of non-video packets would be five (packets **252**, **253**, **254**, **255** and **257**). The number **224** of padding packets would be one (packet **255**). The start position **226** would be the distance between the beginning of MPEG file **134** and point **280**. The start offset **234** would be the distance between the start of packet **251** and point **280**. The end offset **236** would be the distance between point **282** and the end of packet **258**.

The tag information generated for each frame in an MPEG-1 file is illustrated in FIG. **2***c*. Referring to FIG. **2***c*, entry **214** includes data indicating the state of three state machines: a system state machine, a pack state machine, and a video state machine. Specifically, tag entry **214** includes the information shown in Table 4.

TABLE 4

DATA	MEANING
AMOUNT OF NON-VIDEO DATA 221	The amount of non-video data (in bytes) contained within the start and end boundaries of the frame data for frame "F".
AMOUNT OF PADDING DATA 223	The amount of padding data (in bytes) contained within the start and end boundaries of the frame data for frame "F".
PACK OFFSET AT START 225	The offset between the start boundary of the frame data for frame "F" in the beginning of the pack packet that contains the start boundary for frame "F".
PACK REMAINING AT START 227	The distance between the start boundary for frame "F" and the end of the pack packet that contains the start boundary of frame "F".
PACK OFFSET AT END 229	The offset between the end boundary for frame "F" in the beginning of the packet that contains the end boundary for frame "F".
PACK REMAINING AT END 231	The distance between the end boundary for frame "F" and the end of the pack packet that contains the end boundary of frame "F".
PICTURE SIZE 233	The distance (in bytes) between the start boundary for frame "F" and the end boundary for frame "F".
PICTURE START POS 235	The distance between the start of the MPEG-1 file and the start boundary for frame "F".
PICTURE END POS 237	The position, relative to the beginning of the MPEG-1 file, of the end boundary for frame "F".
FRAME TYPE 239	The technique used to encode the data that represents frame "F".
TIME VALUE 241	The time, relative to the beginning of the movie, when frame "F" would be displayed during a normal playback of MPEG file 134.
TIMING BUFFER INFO 243	Indicates how full the decoder is (sent to the decoder to determine when information should be moved out of the buffer in order to receive newly arriving information).

The tag information includes data indicating the state of the relevant state machines at the beginning of video frames. However, the state machines employed by other digital audio-visual formats differ from those described above just as the state machines employed in the MPEG-1 format differ from those employed in MPEG-2. Consequently, the specific tag information stored for each frame of video will vary based on the digital audio-video format of the file to which it corresponds.

THE MDS

MDS **112** includes MDS server **110** and one or more non-volatile storage devices, such as disks **114**. In the illustrated embodiment, MPEG file **134** is stored across numerous disks **114** to increase the fault tolerance of the system. Consider, for example, the multi-disk system **300** illustrated in FIG. **3**A. System **300** includes N+1 disk drives. An MPEG file is stored on N of the N+1 disks. The MPEG file is divided into sections **350**, **352**, **354** and **356**. Each

section is divided into N blocks, where N is the number of disks that will be used to store the MPEG file. Each disk stores one block from a given section.

In the illustrated example, the first section **350** of the MPEG file includes blocks **310**, **312** and **314** stored on disks **302**, **304** and **306**, respectively. The second section **352** includes blocks **316**, **318** and **320** stored on disks **302**, **304** and **306**, respectively. The third section **354** includes blocks **322**, **324** and **326** stored on disks **302**, **304** and **306**, respectively. The fourth section **356** includes blocks **328**, **330** and **332** stored on disks **302**, **304** and **306**, respectively.

The disk **308** which is not used to store the MPEG file is used to store check bits. Each set of check bits corresponds to a section of the MPEG file and is constructed based on the various blocks that belong to the corresponding section. For example, check bits **334** corresponds to section **350** and is generated by performing an exclusive OR operation on all of the blocks in the first section **350**. Similarly, check bits **336**, **338** and **340** are the products of an exclusive OR performed on all of the blocks in the section **352**, **354** and **356**, respectively.

System **300** has a higher fault tolerance than a single disk system in that if any disk in the system ceases to operate correctly, the contents of the bad disk can be reconstructed based on the contents of the remaining disks. For example, if disk **304** ceases to function, the contents of block **312** can be reconstructed based on the remaining blocks in section **350** and the check bits **334** associated with section **350**. Similarly, block **318** can be constructed based on the remaining blocks in section **352** and the check bits **336** associated with section **352**. This error detection and correction technique is generally known as "Redundant Array of Inexpensive Disks" or RAID.

During real-time playback using RAID, video pump **120** reads and processes the MPEG file on a section by section basis so that all of the information is available to reconstruct any faulty data read from disk. Techniques for performing RAID in real time are described in U.S. Pat. No. 5,623,595, entitled "METHOD AND APPARATUS FOR TRANSPARENT, REAL TIME RECONSTRUCTION OF CORRUPTED DATA IN A REDUNDANT ARRAY DATA STORAGE SYSTEM", the contents of which is incorporated herein by this reference.

During normal playback operations, there is sufficient time to perform the disk accesses required to read an entire section while the data from the previous section is being transmitted in the MPEG data stream. However, during fast forward and fast rewind operations, less than all of the data in any section will be sent in the MPEG data stream. Because less data is sent, the transmission of the data will take less time. Consequently, less time will be available to read and process the subsequent section.

For example, assume that only one frame X from section **350** was selected for display during a fast forward operation. During the time it takes to transmit the segment for frame X, the data for the next selected frame Y is read and processed. Assume that the next frame Y is located in section **352**. If the MPEG file is read and processed on a section by section basis (required for RAID), then all of the blocks in section **352** are read and processed during the transmission of the single frame X. Even if it were possible to read and process all of the blocks in section **352** in the allotted time, it may still be undesirable to do so because of the resources that would be consumed in performing the requisite disk accesses.

In light of the foregoing, video pump **120** does not use RAID during fast forward and fast rewind operations. Rather, video pump **120** reads, processes and transmits only the data indicated in the commands it receives from the stream server **118**. Thus, in the example given above, only the frame data for frame Y would be read and processed during the transmission of the segment for frame X. By bypassing RAID during fast forward and fast rewind operations, disk bandwidth remains at the same level or below that used during normal playback operations.

Since RAID is not used during real-time fast forward and fast rewind operations, faulty data cannot be reconstructed during these operations. Consequently, when the video pump **120** detects that the data for a selected frame is corrupted or unavailable, the video pump **120** discards the entire segment associated with the problem frame. Thus, if the data associated with a frame cannot be sent, then the prefix and suffix data for the frame is not sent either. However, any padding packets that were to be sent along with the prefix or suffix data will still be sent.

By sending data in entire "segments", conformance with the digital audio-visual format is maintained. In one embodiment, the video pump **120** will send down padding packets to fill the line to maintain the correct presentation rate. In the preferred embodiment, this behavior is selectable by the client.

DATA STRIPING

The RAID techniques described above improve both throughput (because all data from all disks in an array are read in parallel) and reliability (due to error correction). To further increase throughput, RAID may be used in conjunction with data striping. Using data striping, segments of logically sequential data are written to multiple physical devices (or sets of physical devices) in a round-robin fashion. The amount of data stored at each storage element in the round-robin sequence is referred to as a "stripe". When each storage element in the round-robin sequence is an array of RAID disks, each segment of data is referred to as a RAID stripe.

FIG. **3**B illustrates a system in which data striping is used in conjunction with RAID. The system of FIG. **3**B is similar to that of FIG. **3**A with the exception that each of the disks in FIG. **3**A has been replaced by a series of M disks. Thus, disk **302** has been replaced by disks **302-1** through **302**-M. The segment portions stored on disk **302** have been stored on disks **302-1** to **302**-M in a sequential, round robin fashion. For example, assume that the MPEG file has been divided into **50** segments and that disk **302** has been replaced with **25** disks. Under those circumstances, disk **302-1** would store the first portion of segments **1** and **26**. Disk **302-2** would store the first portion of segments **2** and **27**, etc.

Data striping increases throughput because different processes can be reading from different disk arrays in parallel. For example, one data pump may be reading the first segment of an MPEG file from the RAID array that includes Disk_**1**,**1** through Disk_**1**,N+1, while another data pump is concurrently reading the second segment of the same MPEG file from the RAID array that includes Disk_**2**,**1** through Disk_**2**,N+1.

For throughput performance reasons, reads and writes occur in discrete chunks, typically disk RAID stripes. In a typical digital video delivery system, each access unit is 256 kB or 2 megabits, and the content is 2 Mb/sec MPEG. Consequently, each RAID stripe corresponds to approximately one second of video, though this could easily range from about 0.2 to 10 seconds per stripe depending on content bit rate and server configuration.

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THE CLIENT

Audio-visual information delivery system **100** contains one or more clients, such as client **122**. Client **122** generally represents devices configured to decode audio-visual information contained in a stream of digital audio-visual data. For example, client **122** may be a set top converter boxes coupled to an output display, such as television. Client **122** includes a decoder **126** for decoding a digital data stream, and a control unit **124** for communicating information to the stream server **118**.

Stream server **118** is able to receive information from client **122** over a control network **140**. Control network **140** may be any network that allows communication between two or more devices. For example, control network **140** may be a high bandwidth network, an X.25 circuit or an electronic industry association (EIA) 232 (RS-232) serial line.

The client **122** communicates with the stream server **118** and database **116** via the control network **140**. For example, client **122** may send a query to database **116** requesting information about what is currently available for viewing. The database **116** responds by sending the requested information back to the client **122**. The user of client **122** may then select to view a particular audio-visual work beginning at a particular location and at a particular speed. Client **122** transmits requests to initiate the transmission of audio-visual data streams and control information to affect the playback of ongoing digital audio-visual transmissions through network **140** to stream server **118**.

THE VIDEO PUMP AND STREAM SERVER

The video pump **120** is coupled to the stream server **118** and receives commands from the stream server **118**. The video pump **120** is coupled to the disks **114** such that the video pump **120** stores and retrieves data from the disks **114**.

In addition to communicating with the stream server **118**, the client **122** receives information from the video pump **120** through a high bandwidth network **150**. The high bandwidth network **150** may be any of type of circuit-style network link capable of transferring large amounts of data. A circuit-style network link is configured such that the destination of the data is guaranteed by the underlying network, not by the transmission protocol. For example, the high bandwidth network **150** may be an asynchronous transfer mode (ATM) circuit or a physical type of line, such as a T1 or E1 line. In addition, the high bandwidth network **150** may utilize a fiber optic cable, twisted pair conductors, coaxial cable, or a wireless communication system, such as a microwave communication system.

Network **150** may alternatively be a relatively low bandwidth network, or a combination of high bandwidth and low bandwidth communication mediums. For example, a portion of network **150** may comprise a relatively high bandwidth ATM circuit, while a relatively low bandwidth device such as a 28.8 K modem is used downstream to deliver the video information from the network to the client **122**.

The audio-visual information delivery system **100** permits a server, such as the video pump **120**, to transfer large amounts of data from the disks **114** over the high bandwidth network **150** to the client **122** with minimal overhead. In addition, the audio-visual information delivery system **100** permits the client **122** to transmit requests to the stream server **118** using a standard network protocol via the control network **140**. In a preferred embodiment, the underlying protocol for the high bandwidth network **150** and the control network **140** is the same. The stream server **118** may consist of a single computer system, or may consist of a plurality of computing devices configured as servers. Similarly, the video pump **120** may consist of a single server device, or may include a plurality of such servers.

To receive a digital audio-visual data stream from a particular digital audio-visual file, client **122** transmits a request to the stream server **118**. In response to the request, the stream server **118** transmits commands to the video pump **120** to cause video pump **120** to transmit the requested digital audio-visual data stream to the client that requested the digital audio-visual data stream. For live feeds, the video server **106** will be storing the video stream into the video file **134** at the same time the video pump **120** is sending a video stream from the file **134** to the client **122**.

The commands sent to the video pump **120** from the stream server **118** include control information specific to the client request. For example, the control information identifies the desired digital audio-visual file, the beginning offset of the desired data within the digital audio-visual file, and the address of the client. In order to create a valid digital audio-visual stream at the specified offset, the stream server **118** also sends "prefix data" to the video pump **120** and requests the video pump **120** to send the prefix data to the client. As shall be described in greater detail hereafter, prefix data is data that prepares the client to receive digital audio-visual data from the specified location in the digital audio-visual file.

The video pump **120**, after receiving the commands and control information from the stream server **118**, begins to retrieve digital audio-visual data from the specified location in the specified digital audio-visual file on the disks **114**. For the purpose of explanation, it shall be assumed that audio-visual information delivery system **100** delivers audio-visual information in accordance with one or more of the MPEG formats. Consequently, video pump **120** will retrieve the audio-visual data from an MPEG file **134** on the disks **114**.

The video pump **120** transmits the prefix data to the client, and then seamlessly transmits MPEG data retrieved from the disks **114** beginning at the specified location to the client. The prefix data includes a packet header which, when followed by the MPEG data located at the specified position, creates an MPEG compliant transition packet. The data that follows the first packet is retrieved sequentially from the MPEG file **134**, and will therefore constitute a series of MPEG compliant packets. The video pump **120** transmits these packets to the requesting client via the high bandwidth network **150**.

The requesting client receives the MPEG data stream, beginning with the prefix data. The client decodes the MPEG data stream to reproduce the audio-visual sequence represented in the MPEG data stream.

PREMATURE READ AVOIDANCE

When client **122** is playing an MPEG stream at the same time the MPEG stream is being generated by encoder **101**, safeguards should be taken to ensure that client **122** does not stall (because it has reached the end of valid content data) or play bad data (because it has read beyond the end of the currently available content data). If the video pump **120** prematurely reads a stripe of disks **114**, video pump **120** will send invalid data to the client **122**, resulting in the display of unintended content or garbage (dirty content). Such a premature read will occur if, for example, a user requests display of a portion of the video stream that has not yet been stored on disks **114**. To prevent this, end-of-file information for MPEG file **134** is maintained to indicate the current

end-of-file **134**. As more content data is added to file **134**, the end-of-file information is updated so that the new data may be accessed.

One approach to avoid premature reads is to repeatedly update a table of contents on disks **114** with a new end-of-file value, and have the video pump **120** check this value before reading stripes from disks **114**. The MDS server **110** updates the end-of-file to indicate that the content file **134** includes new content only after it has been verified that the new content has been successfully stored to disks **114**. Unfortunately, unless this end-of-file information is guaranteed to be held in dynamic memory, this technique leads to a jitter in the latency period of updates that is difficult to predict.

Another approach to avoid premature reads is for the MDS server **110** to actively transmit the new end-of-file information to all processes that are reading the content. Thus, MDS server **110** stores content data into file **134** on disks **114**, waits for verification that the content has been stored, and then transmits messages indicating the existence of the newly stored content to all processes reading the content data (e.g. video pump **120**). The MDS server **110** may make such end-of-file notification messages periodically (e.g. after every 5 seconds) or after a predetermined amount of new content data has been successfully stored (e.g. after every 1 Megabyte). Unfortunately, notification times will also jitter due to variations in the content arrival times, which is a function of the encoder **101** and the network between the encoder **101** and the video server **106**.

According to one embodiment, the tag information is used to indicate the current end-of-file. Specifically, video server **106** effectively updates the end-of-file of file **134** by sending tag information from tag buffer **108** for storage by MDS **112**. As soon as the tag information that corresponds to a particular portion of content has been transmitted by video server **106**, the video pump **120** is free to perform a seek to that particular portion of video. Until the tag information that corresponds to a particular portion of video is released, video pump **120** may not perform a seek to the corresponding portion of video. Because the newest tag information indicates the current end-of-file, newly connected users may simply seek to the content associated with the newest tag information, and begin playing the feed at the real-time rate.

MINIMUM TAG DELAY PERIOD

To prevent client **122** from stalling or playing bad data, the transmission of tag data from tag buffer **108** to MDS **112** is delayed. Preferably, the duration of the delay is long enough to ensure that the associated content data will not be prematurely accessed. On the other hand, delaying the tag data longer than necessary increases the latency between when content is encoded and when users can seek or scan to the content. Consequently, it is desirable to determine a minimum tag delay period, and to buffer tag data in tag buffer **108** for the minimum tag delay period. The minimum tag delay period for a tag data item is determined by the maximum latency associated with delivering the corresponding content data from encoder **101** to video pump **120**.

Video server **106** includes a network buffer **152** and a write buffer **154**. Typically, the video server **106** will be reading content data from channel **128** into network buffer **152** at the same time that video server **106** is writing content data from write buffer **154** to disks **114**. In embodiments that use RAID storage techniques, content data is received and buffered within video server **106** in units that correspond to one RAID stripe.

Video pump **120** includes a prefetch unit **146** and a buffer **144**. Video pump **120** reads content data from disks **114** asynchronously. To read content data, prefetch unit **146** requests the transmission of a particular portion of content data, and disks **114** respond by either sending the requested content data or by indicating that the requested data cannot be sent. Some latency occurs between the time the prefetch unit **146** requests data, and the time the data is received by video pump **120**.

When content data from file **134** arrives at video pump **120**, video pump **120** stores the content data from file **134** into the buffer **144**. As bandwidth becomes available on network **150**, video pump **120** transmits content data from the buffer **144** over network **150** to client **122**. As with the video server **106**, content data is pre-fetched and buffered within video pump **120** in units that correspond to one RAID stripe when RAID storage techniques are used.

As explained above, the video pump **120** is typically copying data from one RAID stripe into network buffers and prefetching the following stripe. Likewise, the video server **106** is typically writing one RAID stripe of content to the data store and receiving data from the network into a second memory buffer. Consequently, there are typically four RAID stripes "in transit", so the latency between when any content data is generated and when it is available to be played is approximately the time it takes to deliver four RAID stripes worth of data.

RAID stripes are usually 128 K bits or 256 K bits per disk. The combined total of all disks in a RAID stripe is therefore 1 to 2 Megabits. For typical MPEG files, each raid stripe will correspond to approximately one second of video. Consequently, having four RAID stripes in transit results in a minimum latency of approximately 4 seconds.

The implication for tag data is that a given tag may only be released by the video server **106** for use by other entities when the corresponding content is available to be played (i.e. has been successfully stored on disk for two seconds). Therefore, in a video delivery system where the content delivery has a four second latency, the tag data retained in tag buffer **108** is transmitted no earlier than four seconds after the generation of the corresponding content.

According to one embodiment, jitter and stalling are both avoided by transmitting a batch of tag data from tag buffer **108** to MDS **112** every twelve seconds. The tag data batch transmitted at every twelve second interval includes all tag information in tag buffer **108** that is at least twelve seconds old. Tag data that is less than twelve seconds old is retained in tag buffer **108** and transmitted to MDS **112** in a batch at the end of the next twelve second interval. MDS server **110** sends the tag data to the various entities (e.g. video pump **120**) that are reading video file **134**, and then stores the tag information on disks **114**.

DIGITAL CHANNELS

Video files generated for specific audio-visual works, such as sporting events, will be of finite length. Consequently, their corresponding content files will also consume a finite amount of storage making it practical to perpetually store the entire content file for later viewing. However, a traditional television "channel" is composed of a never-ending sequence of audio-visual works. Perpetually retaining all of the content of a digital channel would continuously consume storage at an unacceptably high rate. On the other hand, it is desirable to allow users to view programs that they may not have been able to view at the time the programs were originally broadcast. For example,

it would be desirable for a viewer to have access to the last 24 hours of programming that was broadcast over a digital channel. According to an embodiment of the invention, historical viewing for an infinite feed is provided through the use of a continuous finite buffer, where older data "expires" and is overwritten with new data.

CONTENT EXPIRATION

In order to have continuous buffer of data, for instance the last 24 hours of Lifetime, Television for Women, older content needs to be deleted along with the corresponding tags. Various approaches may be used to implement such a continuous buffer.

With respect to the content data, the simplest approach to implement a continuous buffer is to create a single file large enough to hold 24 hours of footage. The file is then treated as a circular buffer. Specifically, after the creation of the initial 24 hour file, the MDS server **110** would establish the beginning of the file as the current "insertion point". The MDS server **110** would then store new content data over the old data at the insertion point, and move the insertion point to the end of the new data. When the insertion point hits the end of the file, it wraps around again to the beginning of the file.

Unfortunately, this single-file circular buffer approach makes it difficult to grow or shrink the time of the file. For example, assume that the insertion point is in the middle of the file, and a decision is made to expand the file to cover 48 hours. Under these circumstances, the MDS server **110** could not begin to extend the time covered for another **12** hours, when the insertion point would have reached the end of the file. Using the single circular buffer approach, it is also difficult to detect if a client has paused and had the "horizon" move over their position, such that when they resume the content they were watching has been overwritten.

FIG. **4** illustrates an alternative, more flexible approach to buffering a predetermined amount of an infinite video feed. Referring to FIG. **4**, the content data is stored in a group of smaller files **402–414**. Each of the smaller files stores a subset of the buffered content data. In the illustrated embodiment, each of files **402–412** store two hours worth of content. File **414** currently stores one hour of content. The current insertion point is at the end of file **414**. When file **414** reaches two hours of content, file **414** will be closed and a new content file will be created. As content files age, the older content files are deleted to free up disk space for new files. During playback, files are joined together seamlessly by the video pump as the content data is sent to the client.

When the buffering technique illustrated in FIG. **4** is used, a lenient expiration policy can be set. Specifically, a policy may be established that a file is not deleted until all clients have finished with the (file and any files that precede the file). For example, assume that users are allowed to access the last 12 hours of a feed. When file **414** is completed, files **404–414** will contain the most recent 12 hours, so file **402** is no longer required. However, a client may currently be viewing the contents of file **402**. Consequently, file **402** is not immediately deleted. Rather, new clients are prevented from accessing file **402**, but the client currently accessing file **402** is allowed to finish playing file **402**. When the last client has finished playing file **402**, the file **402** is deleted.

To put a cap on the number of existing files, a time limit may be established for clients to finish playing old files. For example, when file **414** is completed, not only are new clients prevented from accessing file **402**, but the clients currently accessing file **402** are given two hours to finish playing file **402**. At the end of two hours, file **402** is then deleted to free up disk space without regard to whether any clients were still reading file **402**.

TAG EXPIRATION

When a content file (e.g. file **402**) is deleted, the tags that correspond to the deleted content file are considered "expired", and therefore can also be deleted. Ideally, tags are stored in a format, such as a database table, that allows easy deletion of old tags as well as the addition of new ones. Unfortunately, the overhead associated with storing and retrieving tags from a database table may be too expensive to be practical under live feed conditions. For ease and speed of access, therefore, tags are typically stored in a flat file.

Referring to FIG. **5**, it illustrates a flat tag file **500**. The flat tag file **500** includes a header **502** followed by a set of tags **504**. The header **502** indicates information about the contents of tag file **500**, including the set of content files to which the tags within tag file **500** correspond.

As new tags arrive, the tags are appended to tag file **500**. Because tag file **500** is associated with a continuous feed, tag file **500** will grow indefinitely unless a mechanism is provided for deleting expired tags. However, tag file **500** itself should remain valid even after the expiration of some tags (e.g. tags **510**) within the tag file **500**, since clients may continue to access and use the tags **512** within tag file **500** that have not yet expired. Therefore, the expiration mechanism cannot simply delete the expired tags **510** from the tag file **500**.

Rather than directly delete the expired tags from within tag file **500**, a temporary tag file **514** is created by constructing a new header **506** and appending to the new header **506** a copy of the unexpired tags **512** from the old tag file **500**. The new header **506** includes the same information as the old header **502**, except that data within header **502** indicates that tag file **500** includes tags for the deleted content file, while data within header **506** does not.

While new tag file **514** is being created, new tag data is appended to both the new tag file **514** and the old tag file **500**. After the new tag file **514** is created, new tag data is appended to the new tag file **514** rather than the old tag file **500**. To ensure that the new tag data is appended after tag data **512**, storage for the to-be-copied tags **512** is preallocated in the new tag file **514**, and the new tags are appended after the preallocated storage while the existing tags **512** are copied into the preallocated storage.

When all of the unexpired tags **512** have been copied to the new tag file **514**, the old tag file **500** is closed and the new tag file **514** is renamed over the top of the old tag file **500**. After the new tag file **514** has been renamed, the tag file readers (e.g. stream server **118**) that were using the old tag file **500** are reset based on the information contained in the header of the new tag file **514**. According to one embodiment (the "push model"), messages are sent to the tag file readers to expressly inform them that the tag file has been modified, and that they should update themselves based on header information in the new tag file **514**.

According to an alternative "pull model" embodiment, the tag file readers are not expressly informed. Rather, they are configured to read and update themselves based on the header information of the new tag file if they ever fail in an attempt to read a tag. The pull model approach has the benefit that it avoids the transmission of messages which, under many circumstances, are not necessary.

When tags associated with a particular content segment are deleted, clients may continue to view the content seg-

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ment. However, the clients will not be able to perform non-sequential access operations that require the deleted tag information, such as fast forward and rewind.

TIMESTAMPING

Tag information includes timestamp information for each of the frames in the corresponding content data. For the purposes of decoding, the timestamp information typically represents time relative to the beginning of a feed (i.e. the "presentation time"), and is mapped to the byte offset in the content file of the frame that corresponds to that presentation time. However, for continuous feeds, such relative time values are not meaningful. For example, a user would want to request playback beginning at Jan. 21, 1997 16:30:23, rather than beginning at 5,345,789.76 seconds from the time a station began broadcasting.

According to one embodiment of the invention, absolute time values are supported by storing an absolute time value that corresponds to the "zero" relative time value. Therefore, when a client specifies playback from an absolute time, the absolute time value associated with "zero" is subtracted from the specified absolute time value to yield a relative time value. The relative time value is then used by stream server **118** to identify the appropriate tag information, and the tag information is used by stream server **118** to cause video pump **120** to begin sending content from the appropriate location in the content file **134**.

Typically, the transport formats of digital video provide a fixed number of bits (e.g. 33 bits) to represent timestamps. For continuous feed environments, the relative timestamp values will inevitably reach numbers that cannot be represented by the number of bits available in the transport format. When this occurs, the timestamp values "wrap" and begin again at zero.

To address the wrapping problem, a higher-precision wrap value (e.g. 64 bits) is maintained. When performing a seek or other non-sequential access, the stream server **118** uses the higher-precision timestamp values. When transmitting content to a client, the video pump **120** sends the lower-precision timestamps.

The video encoding and delivery techniques described herein empower users with control of functions that were previously in the exclusive domain of program providers. For example, program providers currently determine which plays of a SuperBowl will be replayed to viewers, the speed at which they will be replayed, and how many times they will be replayed.

However, viewers may have strongly differing opinions as to which plays merit multiple viewings. For example, two viewers may dispute the accuracy of a particular call. However, the program provider may not consider the play that gave rise to the call to be significant enough to replay the play. Using the techniques provided herein, viewers may determine for themselves which plays should be immediately replayed, at what speed they are replayed, and how many times they are replayed.

In the foregoing specification, the invention has been described with reference to specific embodiments thereof. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader spirit and scope of the invention. The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense.

What is claimed is:

1. A method for storing a continuous feed of video, the method comprising the steps of:

receiving a digital data stream produced by encoding said continuous feed in a digital video format;

creating a series of content files by repeatedly performing the steps of:

storing said digital data stream in a current file; and

establishing a new file as said current file when said current file satisfies a predetermined condition;

if said series of content files satisfy a particular deletion condition, then deleting a particular content file that satisfies a particular deletion criteria;

determining whether any reader is currently playing information from said particular content file, and

delaying the step of deleting if a reader is currently playing information from said particular content file.

2. The method of claim **1** wherein the step of delaying is performed by delaying the step of deleting until either:

a predetermined period of time has elapsed; or

no readers are currently playing information from said particular content file.

3. The method of claim **1** wherein the step of establishing a new file as said current file when said current file satisfies a predetermined condition includes the step of establishing a new file as said current file when said current file contains a predetermined amount of said continuous feed.

4. A method for storing a continuous feed of video, the method comprising the steps of:

receiving a digital data stream produced by encoding said continuous feed in a digital video format;

creating a series of content files by repeatedly performing the steps of:

storing said digital data stream in a current file; and

establishing a new file as said current file when said current file satisfies a predetermined condition;

if said series of content files satisfy a particular deletion condition, then deleting a particular content file that satisfies a particular deletion criteria; and

preventing new readers from beginning to access data from said particular content file in said series of content files.

5. The method of claim **4** wherein the step of establishing a new file as said current file when said current file satisfies a predetermined condition includes the step of establishing a new file as said current file when said current file contains a predetermined amount of said continuous feed.

6. A method for storing a continuous feed of video, the method comprising the steps of:

receiving a digital data stream produced by encoding said continuous feed in a digital video format;

creating a series of content files by repeatedly performing the steps of:

storing said digital data stream in a current file;

generating and storing tag information separate from said digital video stream that indicates information about frames contained in said digital data stream; and

establishing a new file as said current file when said current file satisfies a predetermined condition;

if said series of content files satisfy a particular deletion condition, then deleting a particular content file that satisfies a particular deletion criteria.

7. The method of claim **6** wherein the step of storing tag information includes the steps of:

generating a first header for a first tag file;

storing tag information sequentially in said first tag file;

when a set of tags within said first tag file becomes invalid, performing the steps of generating a second header for a second tag file;

copying all tags in said first tag file, except said set of tags, from said first tag file to said second tag file;

storing new tag information sequentially within said second tag file; and deleting said first tag file.

8. The method of claim **7** wherein the step of deleting said first tag file comprises the step of renaming said second tag file over said first tag file.

9. A computer-readable medium having stored thereon sequences of instructions for storing a continuous feed of video, the sequences of instructions comprising instructions for performing the steps of:

receiving a digital data stream produced by encoding said continuous feed in a digital video format;

creating a series of content files by repeatedly performing the steps of:

storing said digital data stream in a current file; and

establishing a new file as said current file when said current file satisfies a predetermined condition;

if said series of content files satisfy a particular deletion condition, then deleting a particular content file that satisfies a particular deletion criteria;

determining whether any reader is currently playing information from said particular content file, and

delaying the step of deleting if a reader is currently playing information from said particular content file.

10. The computer-readable medium of claim **9** wherein the step of delaying is performed by delaying the step of deleting until either:

a predetermined period of time has elapsed; or

no readers are currently playing information from said particular content file.

11. The computer-readable medium of claim **9** wherein the step of establishing a new file as said current file when said current file satisfies a predetermined condition includes the step of establishing a new file as said current file when said current file contains a predetermined amount of said continuous feed.

12. A computer-readable medium having stored thereon sequences of instructions for storing a continuous feed of video, the sequences of instructions comprising instructions for performing the steps of:

receiving a digital data stream produced by encoding said continuous feed in a digital video format;

creating a series of content files by repeatedly performing the steps of:

storing said digital data stream in a current file; and

establishing a new file as said current file when said current file satisfies a predetermined condition;

if said series of content files satisfy a particular deletion condition, then deleting a particular content file that satisfies a particular deletion criteria; and

preventing new readers from beginning to access data from said particular content file in said series of content files.

13. The computer-readable medium of claim **12** wherein the step of establishing a new file as said current file when said current file satisfies a predetermined condition includes the step of establishing a new file as said current file when said current file contains a predetermined amount of said continuous feed.

14. A computer-readable medium having stored thereon sequences of instructions for storing a continuous feed of video, the sequences of instructions comprising instructions for performing the steps of:

receiving a digital data stream produced by encoding said continuous feed in a digital video format;

creating a series of content files by repeatedly performing the steps of:

storing said digital data stream in a current file;

generating and storing tag information separate from said digital video stream that indicates information about frames contained in said digital data stream; and

establishing a new file as said current file when said current file satisfies a predetermined condition;

if said series of content files satisfy a particular deletion condition, then deleting a particular content file that satisfies a particular deletion criteria.

15. The computer-readable medium of claim **14** wherein the step of storing tag information includes the steps of:

generating a first header for a first tag file;

storing tag information sequentially in said first tag file;

when a set of tags within said first tag file becomes invalid, performing the steps of generating a second header for a second tag file;

copying all tags in said first tag file, except said set of tags, from said first tag file to said second tag file;

storing new tag information sequentially within said second tag file; and

deleting said first tag file.

16. The computer-readable medium of claim **15** wherein the step of deleting said first tag file comprises the step of renaming said second tag file over said first tag file.

17. A computer-readable medium having stored thereon sequences of instructions for providing non-sequential access to video from a continuous feed, the sequences of instructions comprising instructions for performing the steps of:

encoding said continuous feed in a digital video format to produce a digital data stream;

generating tag information that indicates information about frames contained in said digital data stream, said tag information including timestamps that indicate timing of frames relative to a beginning of said digital data stream;

storing an initial time value that indicates an absolute time that corresponds to said beginning of said digital data stream;

receiving a request from a client for playback beginning at a specified absolute time;

subtracting said initial time value from said specified absolute time to determine a relative time;

using said tag information to identify a location in said digital data stream that corresponds to said relative time; and

transmitting said digital data stream to said client beginning at said location in said digital data stream that corresponds to said relative time.

18. The computer-readable medium of claim **17** wherein:

said digital data stream includes timestamp values having a first precision; and

said step of generating tag information includes generating timestamp values that have a second precision,

wherein said second precision is higher than said first precision.

19. The method of claim **6** wherein the step of establishing a new file as said current file when said current file satisfies a predetermined condition includes the step of establishing a new file as said current file when said current file contains a predetermined amount of said continuous feed.

20. The computer-readable medium of claim **16** wherein the step of establishing a new file as said current file when said current file satisfies a predetermined condition includes the step of establishing a new file as said current file when said current file contains a predetermined amount of said continuous feed.

* * * * *

Appendix EE

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(12) **United States Patent**
Freeman et al.

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(54) **VIDEO RECORDING DEVICE RESPONSIVE TO TRIGGERING EVENT**

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(58) **Field of Classification Search** 348/143, 348/148, 152–155; 386/109, 111–112, 117, 386/125–126; 360/5–6
See application file for complete search history.

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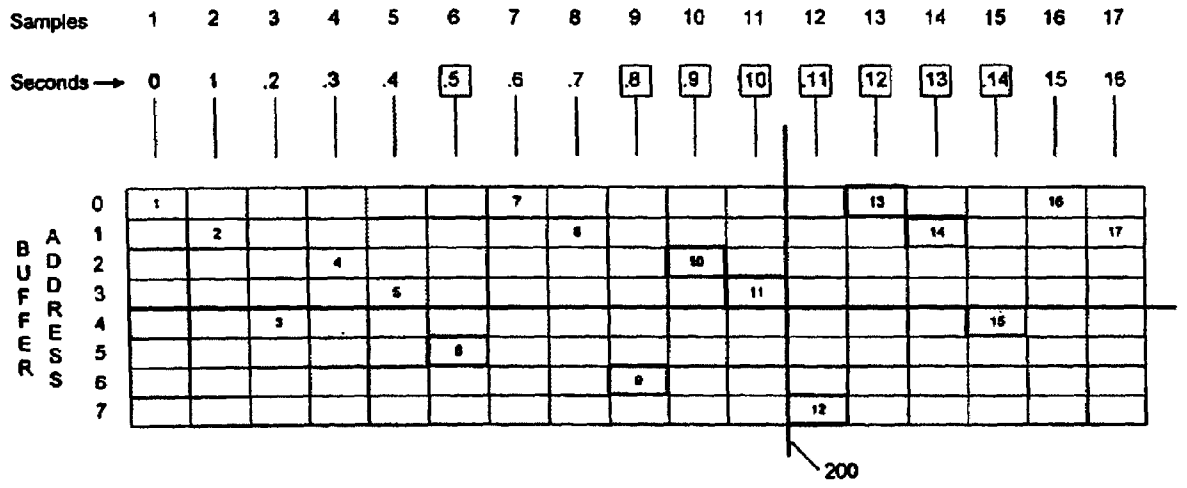
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(57) **ABSTRACT**

A compact video image recording device for recording video images before and after a triggering event and which utilizes no moving parts is disclosed. The recording device includes at least one camera wherein each camera comprises a lens and a video image sensor. Each video image sensor generates an electronic signal representative of a video image impinging the respective sensor. The output of each image sensor is processed, compressed and generally employed to produce frame data which are successively stored in a successive frame locations of a semiconductor memory organized as a circular buffer memory. Upon the occurrence of a triggering event, a additional frames are stored in the buffer memory and further storage of frames then terminates. A video record is thus created of video images received both before and after the triggering event via a device which contains no moving parts and which can withstand substantial shock and vibration.

24 Claims, 7 Drawing Sheets



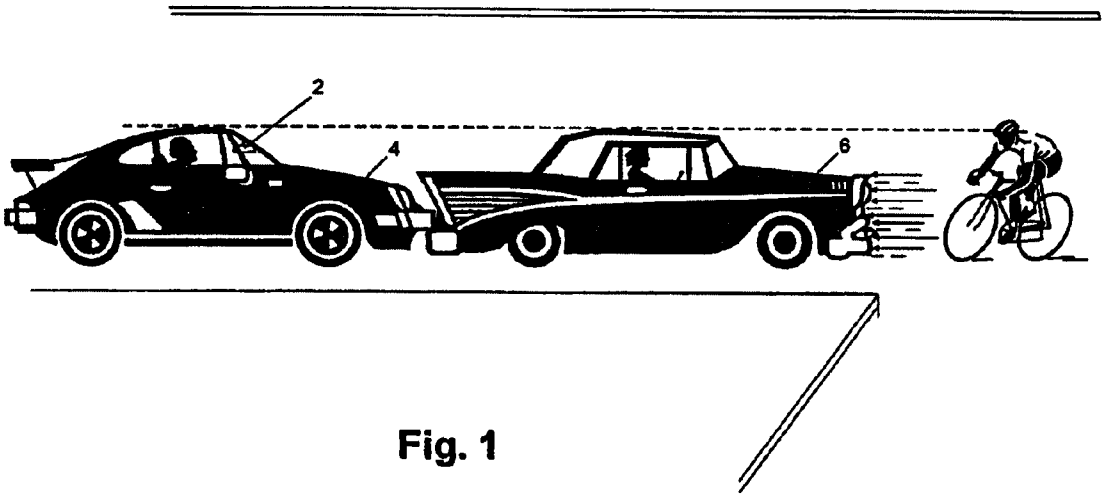


Fig. 1

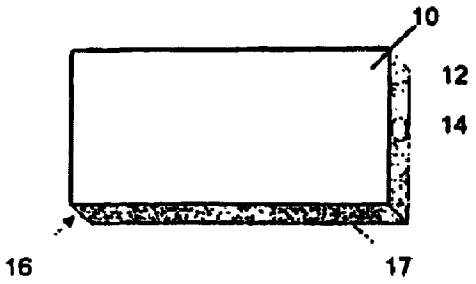


Fig. 2a

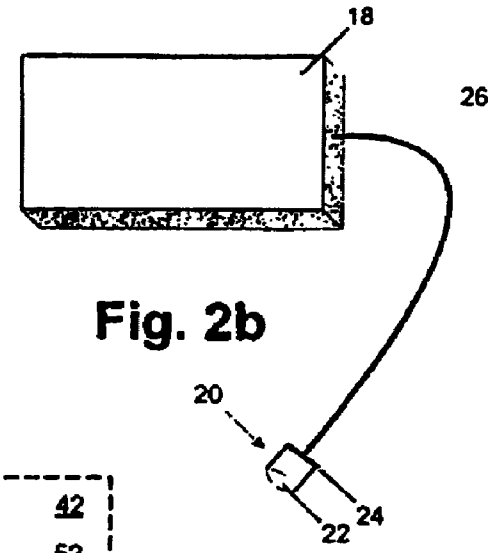
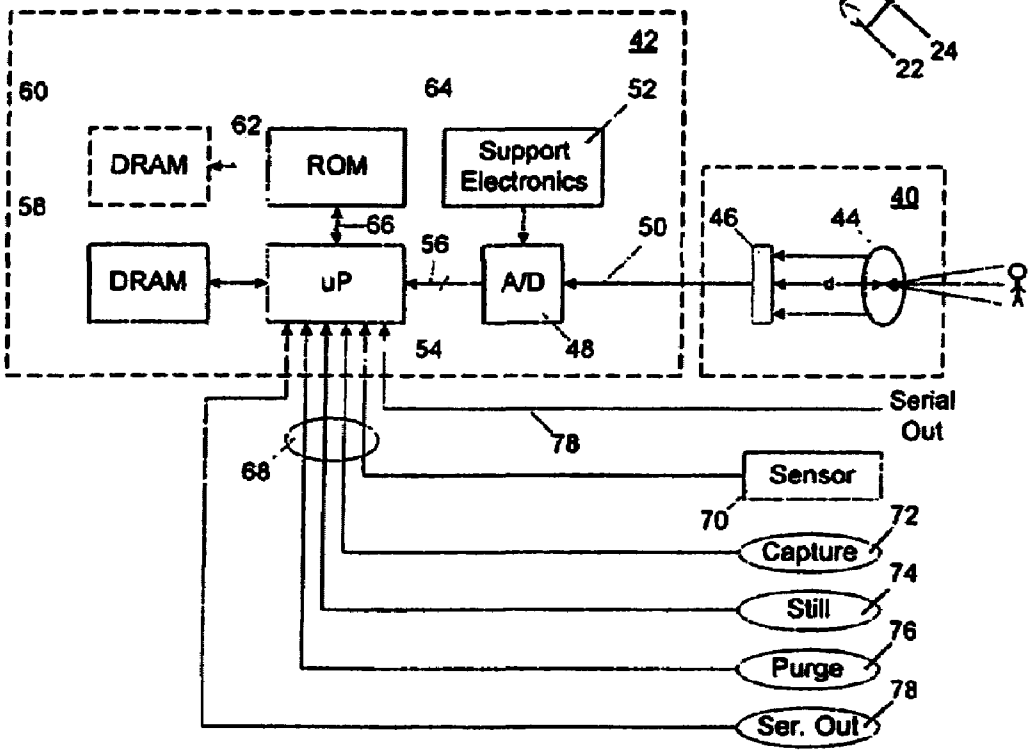


Fig. 2b



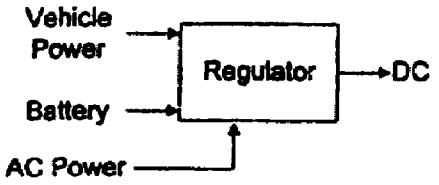


Fig. 3

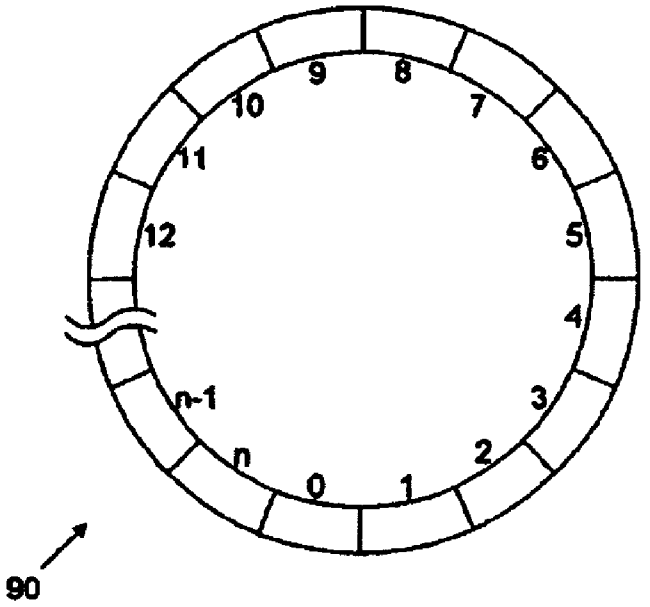

9
8
7
6
5
4
3
2
1
0
n
n-1
12
11
10
90

Fig. 4a

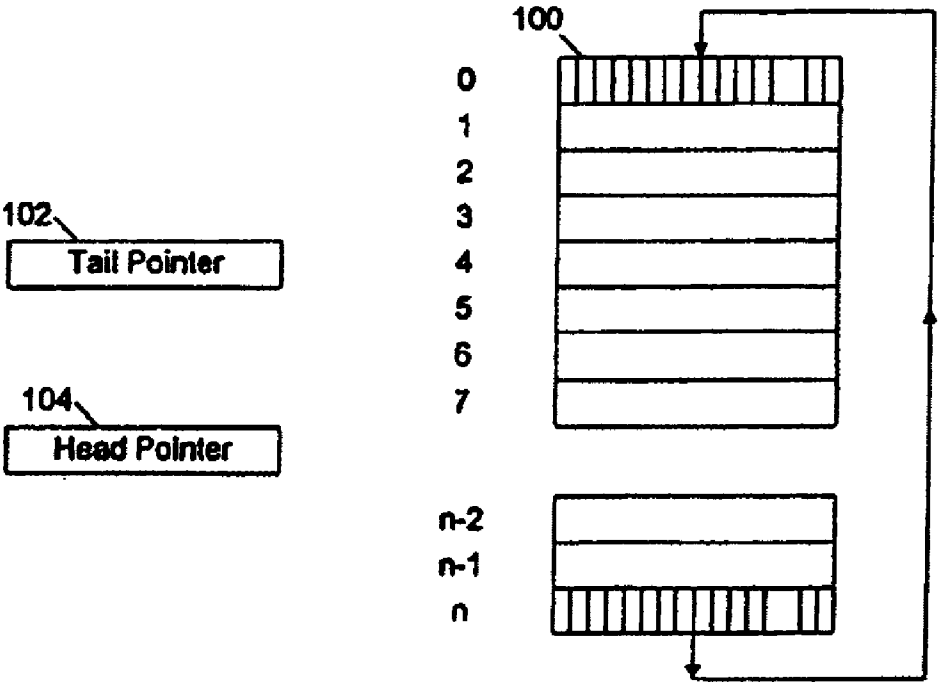

100
0
1
2
3
4
5
6
7
n-2
n-1
n
102
Tail Pointer
104
Head Pointer

Fig. 4b

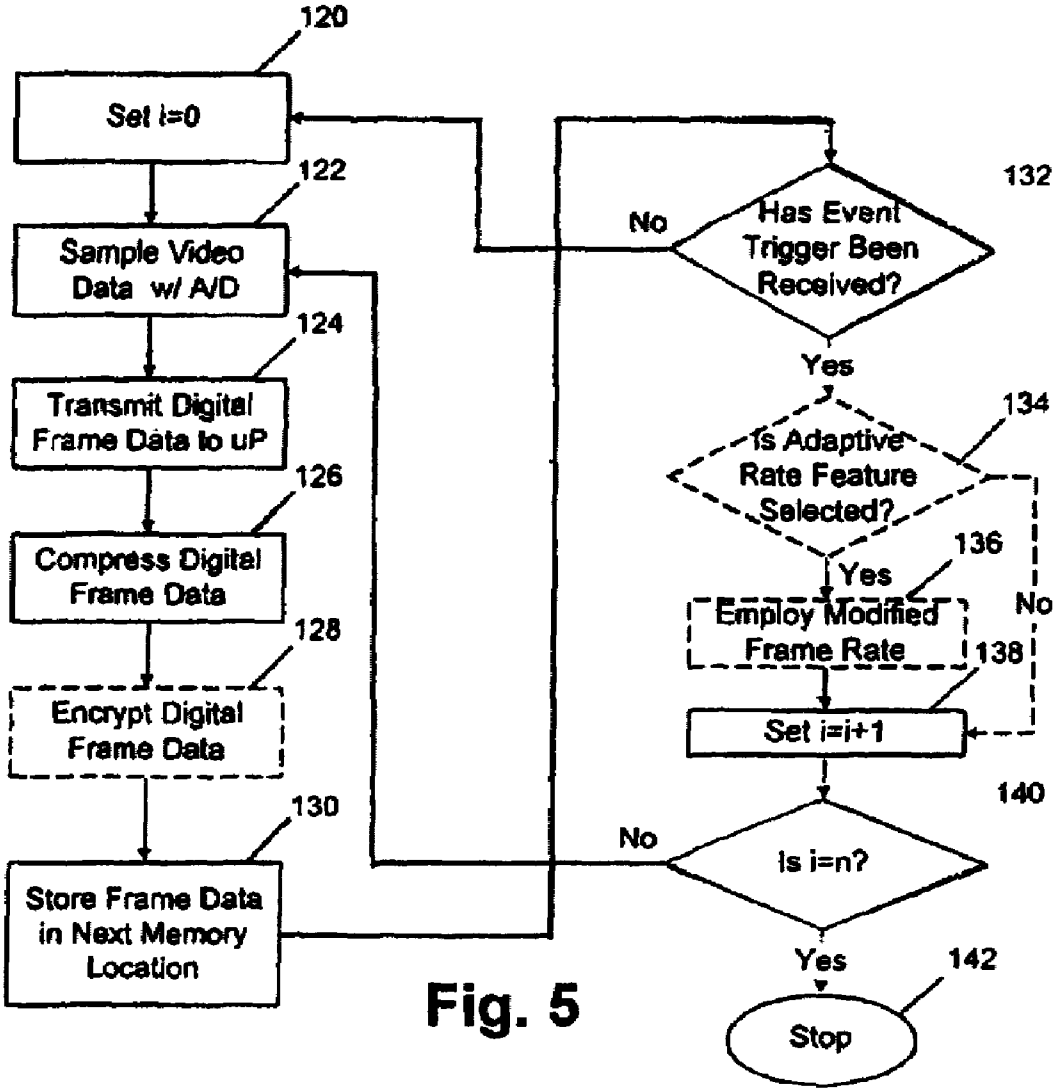

120
Set i=0
122
Sample Video Data w/ A/D
124
Transmit Digital Frame Data to uP
126
Compress Digital Frame Data
128
Encrypt Digital Frame Data
130
Store Frame Data in Next Memory Location
132
Has Event Trigger Been Received?
No
Yes
134
Is Adaptive Rate Feature Selected?
Yes
136
Employ Modified Frame Rate
No
138
Set i=i+1
140
Is i=n?
No
Yes
142
Stop

Fig. 5

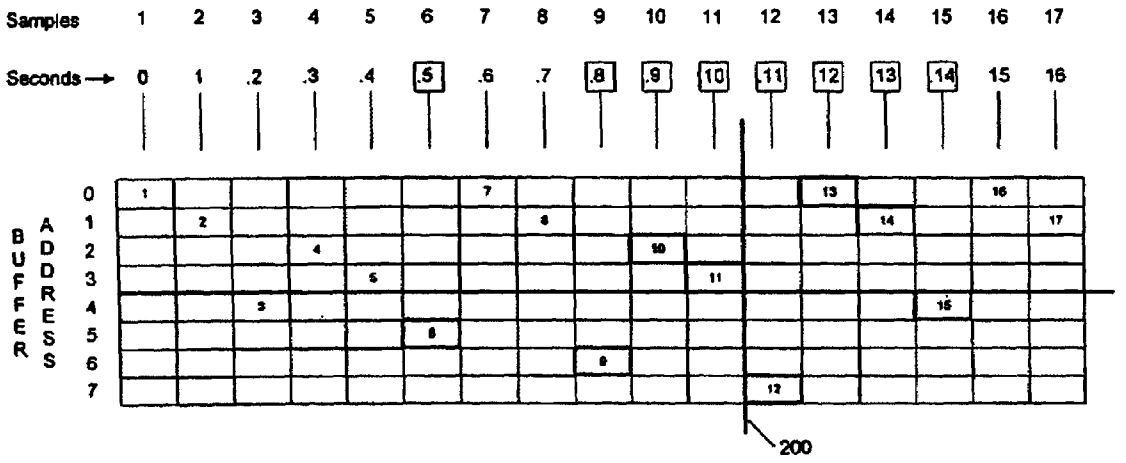

Samples 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Seconds → 0 1 .2 .3 .4 .5 .6 .7 .8 .9 10 .11 12 13 14 15 16
BUFFER ADDRESS
0
1
2
3
4
5
6
7
200

Fig. 6

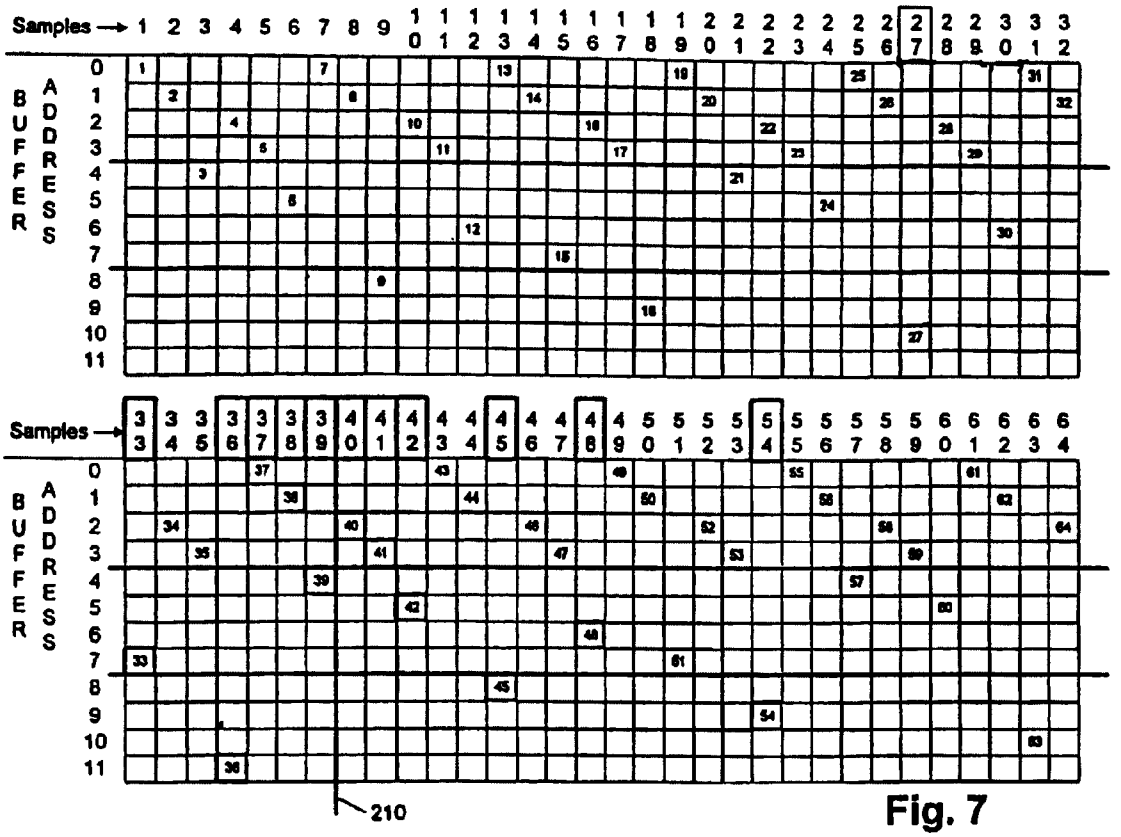

Samples → 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
BUFFER ADDRESS 0 1 2 3 4 5 6 7 8 9 10 11
Samples → 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64
BUFFER ADDRESS 0 1 2 3 4 5 6 7 8 9 10 11
210

Fig. 7

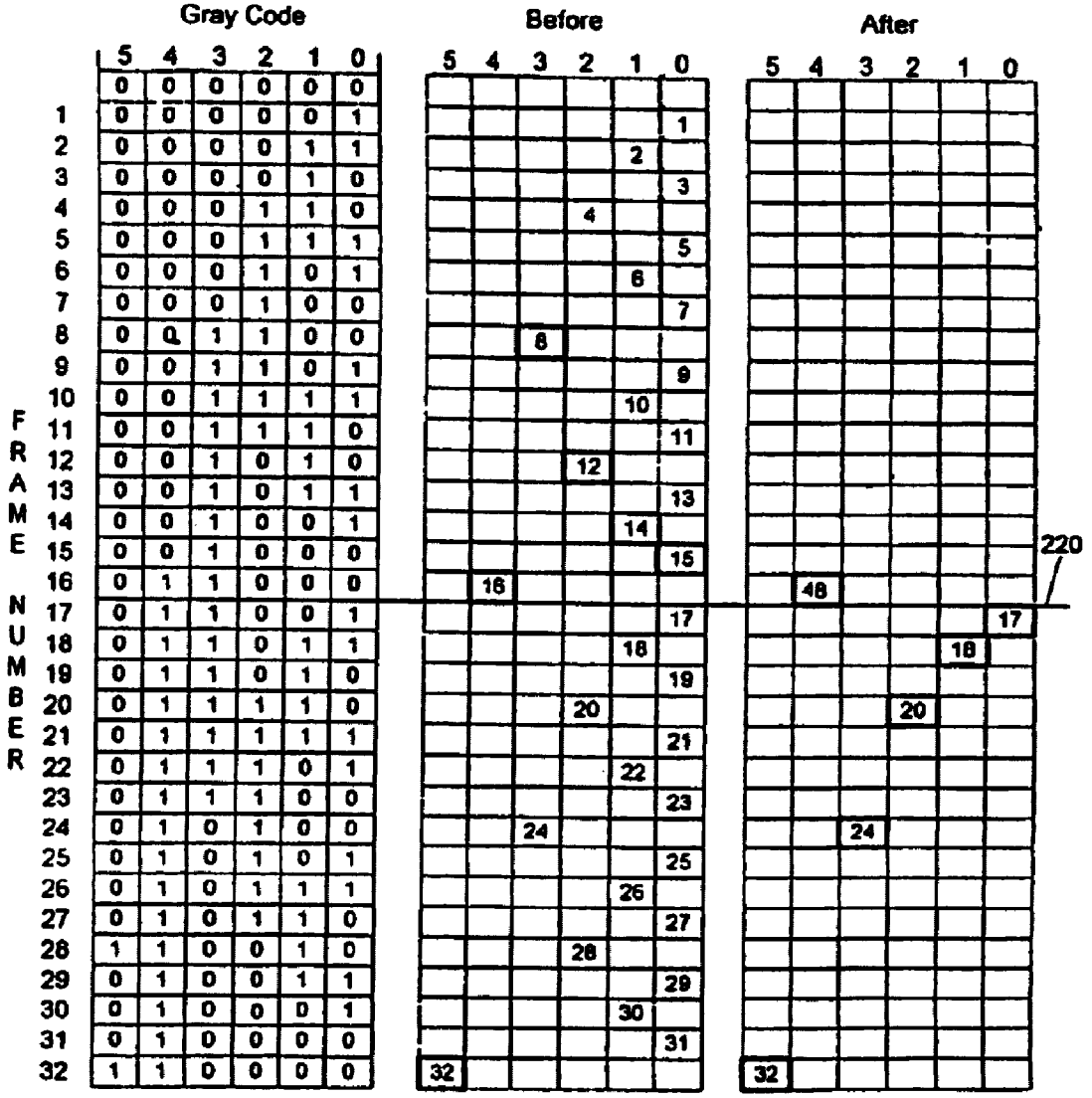

Gray Code
Before
After
5 4 3 2 1 0
FRAME NUMBER
1 0 0 0 0 0 1
2 0 0 0 0 1 1
3 0 0 0 0 1 0
4 0 0 0 1 1 0
5 0 0 0 1 1 1
6 0 0 0 1 0 1
7 0 0 0 1 0 0
8 0 0 1 1 0 0
9 0 0 1 1 0 1
10 0 0 1 1 1 1
11 0 0 1 1 1 0
12 0 0 1 0 1 0
13 0 0 1 0 1 1
14 0 0 1 0 0 1
15 0 0 1 0 0 0
16 0 1 1 0 0 0
17 0 1 1 0 0 1
18 0 1 1 0 1 1
19 0 1 1 0 1 0
20 0 1 1 1 1 0
21 0 1 1 1 1 1
22 0 1 1 1 0 1
23 0 1 1 1 0 0
24 0 1 0 1 0 0
25 0 1 0 1 0 1
26 0 1 0 1 1 1
27 0 1 0 1 1 0
28 1 1 0 0 1 0
29 0 1 0 0 1 1
30 0 1 0 0 0 1
31 0 1 0 0 0 0
32 1 1 0 0 0 0
220

Fig. 8

VIDEO RECORDING DEVICE RESPONSIVE TO TRIGGERING EVENT

GOVERNMENTAL RIGHTS

Not Applicable

RELATED APPLICATIONS

Not Applicable

BACKGROUND OF THE INVENTION

The present invention relates to video recording devices and more particularly to a video camera which stores successive frames in at least one circular buffer memory and which may continue to store frames for a period following the occurrence of a triggering event.

Numerous applications exist in which it is desirable to retain a video record for evidentiary or historical purposes. For example, in an automobile, or on a bicycle or motorcycle, it would be desirable to record a video image of the circumstances existing immediately prior to an accident and after an accident. Additionally, in security applications, it would be highly desirable to be able to record a video image of the circumstances existing immediately prior to an event triggering an alert condition and following the triggering of such a condition. Additionally, in numerous other applications it would be desirable to be able to create a video record of circumstances existing both before and after a triggering event.

A number of image recording devices are well known in the art. In time lapse photography a series of still pictures are taken over a period of time. Such pictures are typically taken with a periodically actuated still or a motion picture camera and employ photographic film. The cameras are loaded with a limited supply of film and the camera must be reloaded when the supply of film is exhausted. Accordingly, such devices are not well suited for applications in which it is desired to record images over a long period of time when only a very short period of time is of interest and the particular period of interest cannot be predicted.

In security applications, a video camera is often employed to record a video image on magnetic tape on a continuous basis. When the tape is exhausted it must be replaced.

Both photographic cameras employing photographic film and video cameras utilizing magnetic tape as the recording media employ mechanical transport mechanisms which are susceptible to failure when subjected to shock and vibration. Accordingly, such devices are ill suited for use in applications and environments in which shock and vibration are the norm.

For the above reasons, a video recording device would be desirable which could record video frames on a continuing basis and capture a video record of circumstances surrounding a triggering event occurring at an unpredictable time. It would further be desirable for such a device to be compact, lightweight, cost effective and avoid the aforementioned deficiencies of prior art video recording devices employing mechanical transports.

SUMMARY OF THE INVENTION

In accordance with the present invention, a video recording device is disclosed which is contained within a compactly sized housing. One or more video image sensors are mounted to the housing. Alternatively, one or more video image sensors are provided which are electrically coupled to the housing via wires so as to permit the image viewing area to be selected freely via suitable mounting of the sensors by a user. The video recording device records video frames successively in at least one circular buffer memory organized as a continuous loop overwriting the oldest frame within the respective buffer memory with a more recently received frame. Upon receipt of a triggering event, a predetermined number of additional frames are recorded within the circular buffer memory at which point recording ceases. A plurality of circular memory buffer groups may be provided to extend the overall recording time for the device by selectively storing video data samples to the respective buffer groups. The foregoing video recording device can be fabricated as a compact transportable unit which employs no moving parts and which has relatively low power consumption facilitating battery operation in certain embodiments.

More specifically, a video camera is provided which comprises a lens and a video image sensor. The lens is employed to focus a video image on a video image sensor such as a charge coupled device sensor or an artificial retina as hereinafter discussed. The output of the video image sensor comprises an analog signal which is coupled to one or more A/D converters. The A/D converter(s) is sampled to generate a digital representation of the video image sensor analog output signal. A predetermined number of digital samples comprise one video frame. The digitized output signal(s) from the A/D converter(s) is coupled to a central controller in the form of a microprocessor or any other suitable controller. The microprocessor compresses the digitized frame data and stores the compressed frame data in the next sequential location of the circular buffer. In one embodiment, the digitized frame data is encrypted prior to storing the same in the buffer so as to prevent unauthorized access to such data. The circular frame buffer comprises a semiconductor memory such as DRAM or any other suitable high speed semiconductor memory.

Upon detection of a trigger event, the video recording device records a predetermined number of additional frames and then ceases to record further frame data. In this manner, a video event record is obtained which commences prior to the triggering event and extends in time after the triggering event. Triggering events may include an accelerometer output signal crossing a predetermined threshold, a signal employed to initiate air bag deployment in an automobile, a signal representing a recognized change in a video image or acoustic signal, a signal indicative of a security or fire alarm condition, a button actuated by a user, or any other suitable activation signal known in the art. Further, an activation button is provided which permits a user to take a single frame "snap shot" which is retained within the buffer memory until purged upon user activation of a purge button.

A serial output channel is provided to permit recorded frame data to be downloaded to a computer for viewing.

The above described apparatus thus provides a video recording device which has high reliability, is compact, cost effective and suitable both for consumer and commercial applications.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be more fully understood by reference to the following Detailed Description of the Invention in conjunction with the drawings of which:

FIG. **1** is a pictorial view illustrating an application for use of the video recording device of the present invention;

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FIG. **2***a* is a pictorial view of a housing for a video recording device in accordance with the present invention in which a camera comprising a lens and image sensor is mounted within the housing;

FIG. **2***b* is a pictorial view of an alternative embodiment of a housing for the video recording device of FIG. **1** in which the camera is disposed external to the housing and in electrical communication with video processing circuity (not shown) disposed within the housing;

FIG. **3** is an electrical block diagram of a video recording device in accordance with the present invention;

FIG. **4***a* is a simplified schematic representation of a circular memory buffer employed within the video recording device of FIG. **3**;

FIG. **4***b* is a representation of a semiconductor memory buffer employed in the video recording device of FIG. **3** to implement a circular memory buffer and associated head and tail pointers;

FIG. **5** is a flowchart illustrating the recording method in accordance with the present invention;

FIG. **6** is a table illustrating one storage technique for storage of video data in the semiconductor memory buffer;

FIG. **7** is a table illustrating an alternative storage technique for storage of video data in the semiconductor memory buffer; and

FIG. **8** is a table illustrating a further alternative storage technique for storage of video data in the semiconductor memory buffer.

DETAILED DESCRIPTION OF THE INVENTION

An application of a video recording device **2** in accordance with the present invention is illustrated in FIG. **1**. The recording device **2** is mounted within a first vehicle **4** which has come to a stop behind a second vehicle **6** at an intersection. Vehicle **6** has also come to a stop at the intersection, however, has backed up so as to impact vehicle **2** causing damage to vehicle **4**. It would be highly desirable for the driver of vehicle **4** to have an evidentiary record which establishes that the accident was caused by vehicle **6** since it would normally be presumed in such a circumstance that the driver of vehicle **4** was the cause of the accident. The video recording device **2** in accordance with the present invention generates such a record by continually recording video frames in a circular buffer at a predetermined frame rate. In response to a trigger event, such as an air bag activation signal or a button activated by the driver, the video recording device records a predetermined number of additional frames before ceasing to record further frames. In the foregoing manner, the driver of vehicle **4** can establish the true cause of the accident. The foregoing example is provided solely as an illustration of the operation of the video recording device **2** of the present invention.

A housing **10** for a video recording device **2** in accordance with the present invention is depicted in FIG. **2***a*. The housing **10** includes a camera comprising a lens **12** and a video image sensor (not shown) which may comprise a charge coupled device (CCD), an artificial retina, or any other suitable optical sensor operative to provide output signals when a video image impinges the sensor. By way of illustration, the sensor may comprise a model TC241 CCD array manufactured by Texas Instruments or an artificial retina such as identified and described volume 372, number 197 NATURE, 1994 which is incorporated herein by reference. The lens **12** is specified to have appropriate optical characteristics and is oriented so as to focus a video image of the desired field of view on the video image sensor. While the housing of FIG. **2***a* illustrates the use of a single camera, multiple cameras may be employed and selectively oriented to capture images at desired viewing angles. For example, one camera may be positioned at the forward edge **14** of the housing **10** and a second camera at the trailing edge **16** of the housing **10** to capture images at 180° viewing angles. Additionally, by way of example, cameras may be disposed on the leading edge **14** and a side edge **17** of the housing **10** so as to capture video images along orthogonal viewing angles. It is further understood that any desired number of cameras may be employed.

Another embodiment of a video recording device assembly in accordance with the present invention is depicted in FIG. **2***b*. The video recording device illustrated in FIG. **2***b* includes a housing **18** and a camera **20** which is disposed external to the housing **18**. The lens **22** focuses a video image on the sensor **24** which, in the preferred embodiment, produces an electrical output signal for communication to a video signal processor. The sensor **24** communicates the electrical output signal via wires **26** to the video signal processor disposed within the housing **18**. The wires **26** may be coupled to the circuitry (not shown) via a connector or alternatively may be hardwired to such circuitry. While a single video image sensor **20** is depicted in FIG. **2***b*, as with respect to FIG. **2***a*, the video recording device in accordance with the present invention may employ multiple cameras **20** which may be selectively mounted and positioned at desired viewing angles so as to permit a corresponding number of video images to be captured.

The housings illustrated in FIGS. **2***a* and **2***b* may be fabricated in a PCMCIA configuration with a PCMCIA connector disposed at one end so as to permit the housing to be inserted into a laptop computer or any other suitable computer having a PCMCIA interface to permit viewing of images captured within the video recording device.

A block diagram of the video recording device in accordance with the present invention is depicted in FIG. **3**. As illustrated in FIG. **3**, the recording device includes a camera **40** and video electronics **42**. The camera **40** is comprised of a lens **44** which is disposed a predetermined distance d from the surface of an image sensor **46**. The image sensor **46**, as described above, may comprise a charge couple device array, an artificial retina, or any other suitable image sensor operative to provide an output signal representative of a video image which impinges upon the sensor. In a preferred embodiment employing a CCD array as the sensor **46**, the CCD array produces an analog output signal which in electrically coupled to an analog to digital converter **48** via a signal path **50**. The analog to digital converter may comprise a model AD775 A to D converter manufactured by Analog Devices, Inc. or any other suitable analog to digital converter. Support electronics **52** are provided which include a clock generator which is coupled to the analog to digital converter **48** to permit the sensor output **50** to be sampled at predetermined intervals and other conventional timing circuitry. The analog to digital convertor **48** generates a digital representation of the sensor output signal **50**. A predetermined number of samples of the sensor output signal **50** comprise a single video frame. For example, in one exemplary embodiment, each frame contains 256 horizontal samples by 128 vertical samples yielding an uncompressed size of 32,768 bytes. Sixty four such frames can be stored in a two (2) megabyte memory.

Generally, color images require approximately thirty (30) percent more storage space. One could thus store approxi

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mately fifty (50) frames of uncompressed color image information in the two (2) megabyte memory.

For images of the above identified sizes a compression ratio of four to one (4:1) is readily achievable. Such would permit **256** black and white images or 200 color images to be stored in the two (2) megabyte memory. At a recording rate of ten (10) frames per second, the two (2) megabyte memory will accommodate thus accommodate 25 seconds of black and white images or 20 seconds of color images. A greater recording interval may be achieved by employing a lower sampling rate or by utilizing a larger memory.

The output of the analog to digital converter is electrically coupled to inputs of a central control processor **54** via signal path **56** which comprises a parallel signal bus. The central control processor **54** in a preferred embodiment, may comprise an M32RD microprocessor which is commercially available from Mitsubishi Electric, any other suitable microprocessor, an Application Specific Integrated Circuit (ASIC) or any other suitable implementation of a central control processor operative to perform the presently described functions.

The central control processor **54** is coupled to a semiconductor memory **58** which comprises a DRAM a in preferred embodiment. Within the M32RD device referenced above, two (2) megabytes of DRAM is incorporated in the commercially available device. Thus the microprocessor **54** and the DRAM **58** may be obtained as a single integrated circuit. Additional semiconductor memory **60** may be coupled to the microprocessor **54** via a bus **62** in the event that it is desired to increase the semiconductor memory capacity of the video recording device. It may be desired to increase the memory capacity of the recording device to permit a greater number of frames to be captured or to accommodate the storage of video images received from plural cameras.

The central control processor **54** executes a control program which is stored within a Read Only Memory (ROM). The ROM **64** is coupled to the central control processor via bus **66**. The central control processor **54** is provided with a number of inputs **68** which permit activation of the video recording device and control of the device by a user. Exemplary inputs comprise, an event sensor **70**, a "capture" button **72**, a "still" button **74** and a "purge" button **76**. Additionally, the central control processor **54** includes a serial output channel **78** which permits stored video images to be downloaded to an external video device for viewing. In one embodiment, the serial output channel is compatible with the well known Xmodem serial protocol. It is appreciated that any suitable serial channel protocol may be employed.

The central control processor **54** receives successive samples of frame data from the analog to digital converter **48** and compresses the received frame data in order to reduce the storage capacity for the captured video data. One image compression technique which may be employed is disclosed in U.S. Pat. No. 4,917,812 to Adelson and Simoncelli. While any suitable compression technique may be employed, in a preferred embodiment of the invention, an asymmetric compression technique (known in the art) is used which minimizes the computational load on the central control processor to compress the image data during compression of the image data at the expense of greater complexity in the decompression algorithm. The use of an asymmetric compression technique thus places greater processing demands on the processor which will ultimately perform the decompression which, is likely to comprise a personal computer (PC), a workstation, or some other computer which generally possesses the necessary processing speed to perform such decompression or which is not burdened by the constraint of real time processing. In this manner, the video electronics **42** are not burdened with additional cost associated with added processing power.

Following the compression of the frame data, the central control processor stores the compressed data within the semiconductor memory **58**. The semiconductor memory **58** is structured as a circular memory buffer as illustrated in FIG. **4***a*. Thus, following compression, each compressed video frame is stored in the next successive frame buffer location and any frame data contained in such location is overwritten. For example, referring to FIG. **4***a*, if the last frame were stored at location **3** of the circular buffer **90**, the subsequent video frame would be stored at location **4** of the circular frame buffer. The video recording device, absent receipt of some trigger event from the sensor **54** or activation of other input by the user, continues to store captured frame data in successive locations of the circular buffer, overwriting previously received frame data stored in respective buffer locations with the most recently received frame data.

The operation of the circular buffer is described with more particularity below and with respect to FIG. **4***b*. The semiconductor memory buffer is sized to as to permit the desired number of frames to be concurrently stored in the buffer. The buffer **100** utilizes a plurality of bytes to store each frame as illustrated in frame buffer locations **0** and n. The specific number of bytes required for a particular frame is dependent upon the resolution of the video image sensor **46**, the sampling rate of the analog to digital converter **48**, and the efficiency of the compression algorithm.

Associated with the semiconductor memory buffer **58** (and additional buffer memory **60** if such is employed) are a tail pointer **102** and a head pointer **104**. The head pointer points to the address of the frame buffer location for storage of the next frame data. Such address is offset in the respective frame to address the respective byte for the frame data being stored. For simplicity, the operation of the buffer is explained with respect to the frame addresses recognizing that plural locations are utilized within the buffer to store the data associated with any given frame.

The head pointer **104** points to the location for storage of the incoming frame data. Thus, if the next frame data is to be stored in location **4**, the head pointer is set to location **4**. Once all of the data corresponding to frame **4** has been stored in the buffer, in normal operation and in the absence of a trigger event, the head pointer is incremented to point to frame number **5**. As an example, assume a semiconductor memory buffer **58** is employed in which n=127; i.e. the frame buffer is capable of storing 128 frames of data. It is further assumed for purposes of the present example that it is desired to have half of the captured frames precede the trigger event and half of the frames follow the trigger event. The head pointer **104** is incremented following the storing of each respective frame. In normal operation, the tail pointer is incremented each time the head pointer is incremented, however, the tail pointer comprises an address which lags the head pointer by sixty four. In the circular buffer frame address **0** follows frame address n (i.e. 127 in the present example).

Upon detection of a trigger event, the tail pointer ceases to increment while frames continue to be stored in subsequent frame locations. A test is performed prior to storing frame data to determine whether the frame location for the data to be stored is one location preceding the tail pointer in which case the frame data pertaining to that frame is stored. No subsequent frames are stored in the frame buffer. Thus, following the trigger event, the buffer contains frame data

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commencing at a location z and ending at a location z−1; i.e. if the tail pointer stopped incrementing upon detection of a trigger event when pointing to address **6**, the last captured video image would be stored in location **5** and further image capture and storage would cease.

The sensor **54** may comprise any sensor which provides a trigger output signal in response to a condition which is desired to initiate the capture of the video image or images occurring prior to and following the occurrence of the trigger output signal, For example, the sensor may comprise an accelerometer, an air bag deployment sensor of the type normally used in automobiles to initiate the deployment of an air-bag, a security or fire alarm alert condition sensor used to detect movement, glass breakage, unauthorized entry such as found in a burglar alarm for example fire or smoke, an acoustic signal characteristic of a specific event such as gunshots, or any other signal indicative of a specified event. Moreover, while a single sensor **70** is illustrated for simplicity, it should be appreciated that plural sensors may be employed to activate the capture of video images by the present video recording device and that video image capture may be initiated by any one of such sensors or a combination of such sensors.

Upon detection of a trigger event from the sensor **70**, the central control processor **54** receives only a predetermined number of additional frames and stores such frames in the semiconductor memory **58** in the successive frame locations within the circular buffer **90**. Following the recording of the predetermined number of additional frames, the video recording devices ceases to record further frame data. Thus, if the central controller is programmed to record half the number of frames which are capable of being stored within the semiconductor memory **58** or **58** and **60**, as applicable, the video frame data stored within the circular buffer corresponds to an equal number of video frames captured prior to the trigger event and after the trigger event. It is appreciated that any desired percentage of frames may be captured prior to or after the trigger event by specifying how many frames are to be captured and stored after the trigger event.

In one preferred embodiment, it is envisioned that the semiconductor memory will support the storage of 5 frames of video data per second for approximately 30 seconds. Thus, the memory will support the storage of approximately 150 video frames. If it is desired to record the same number of frames before and after detection of a trigger event from sensor **70**, seventy five additional frames would be recorded and stored in the circular buffer **90** subsequent to the detection of the trigger event. It should be appreciated that the number of frames that are recorded before and after are a matter of design choice, the only limitation being that the total number of frames to be recorded not exceed the frame capacity of the semiconductor memory. Thus, in the above example in which the video electronics include DRAM supporting storage of 150 video frames, if it was desired to obtain a record which provided ten percent of the frame data prior to the trigger event and ninety percent of the frame data following the trigger event, an additional 135 frames would be recorded and stored subsequent to the trigger event.

Referring again to FIG. **3**, the video electronics **42** and sensor **46** are powered by a DC regulator which may derive input power from an AC source, when such is available, from a vehicle battery, or from batteries such as AA cells or any other suitable batteries. When powered by a vehicle battery, it is recognized that in the event of an accident or in some cases, when the vehicle is turned off, the vehicle battery power may cease to provide power. In such event, the battery cells provide an alternative source of power to permit the buffers **58** and **60** to be periodically refreshed (should DRAMs be employed), Since the refresh current is extremely low for DRAMs, the data captured within the buffer may be maintained for many weeks before the captured video data is lost. It is estimated that two or four AA cells will support full operation of the video recording device for between two and five hours of recording operation thus permitting fully portable operation of the unit on, for example, a bicycle or in any other application in a steady source of power is not readily available, at a minimal cost in added weight. It is also estimated that two (2) to (4) AA battery cells will maintain the contents within memory for between one (1) and (4) months.

The video recording device is provided with a capture button **72** which serves as a user activatable trigger event. Thus, a user of the device may initiate video capture by pushing the capture button **72**. Upon activation of the capture button, a trigger signal is provided to an detected by the central control processor **54**. The operation of the video electronics **42** upon user activation of the capture button **72** is otherwise as described with respect to the occurrence of a trigger event in response to a trigger signal provided by the sensor **70**.

The still button **74** is optionally provided and coupled to the central control processor **54**. Upon activation of the still button, the video electronics captures a video frame and stores the frame within the buffer memory **58** or the extended buffer memory **60**. In one embodiment, a frame which is stored as a result of the activation of the still button **74** is stored in a protected memory buffer area which is not employed as a part of the circular buffer **90**. In another embodiment of the video recording device, the captured frame is stored within a frame location within the circular buffer, however, the frame is protected from overwriting while video capture within the circular buffer continues. Such may be accomplished via tagging protected frame locations containing captured still frames and checking to determine whether a frame location is protected prior to writing to the frame location. Alternatively, a "still" frame may be stored at the upper, lower or some other designated portion end of the circular buffer and the head and tail pointers controlled so as not to result in the overwriting of the "still" frame.

The purge button **76** is optionally provided and is electronically coupled to the central control processor **54**. Upon activation of the purge button, the contents of the circular buffer and any still images that have been captured are erased. Thus, in the event that a user captures images which, for any reason, such user does not desire to retain, they may be erased.

In one embodiment of the invention, the captured digital data is encrypted with any suitable encryption algorithm prior to storing the captured frame data in the buffer memory. The encryption of the captured frame data assures that such data cannot be accessed without authority of the user.

The serial channel **78** is employed to download captured and stored video images to an external Personal Computer (PC), Workstation or other suitable device for viewing of the recorded images. Alternatively, the serial channel may be coupled to a radio transmitter to transmit RF signals to a base station for viewing. By way of example, upon detection of gunshots as a trigger event, and storage the specified number of frames within the circular frame buffer, the trigger event is used to cause the transmission of captured video data to a base station over an associated RF transmitter

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such as found in a police cruiser. The serial channel **78** may comprise a channel compliant with the well known Xmodem protocol, or any other suitable serial channel protocol, for example when the video recording device is employed in a home or another location in which AC power is employed, the serial channel may be appropriately coupled to the AC power line employing the well known X10 protocol for receipt and viewing by a device having an X10 protocol compliant receiver.

An electronic or tamper-evident mechanical seal may be optionally provided to assure that the information contained in the video recording device has not been tampered with prior to viewing to assure the evidentiary integrity of the captured images. The electronic seal may comprise encryption of the video data such that only an individual with authorization may view the recorded data. The mechanical tamper seal may be in the form of a paper or similar seal which is positioned on the case so to as to require rippage of the seal in the event the housing **10**, **18** has been opened or if cable connections have been exposed.

The frame rate of video capture may be optionally varied so as to provide a higher frame capture rate or a lower frame capture rate upon the occurrence of a trigger event. The inclusion of an adaptive frame capture rate permits higher or lower frequency rates to be employed in particular applications in which such might be desirable. Additionally, the resolution may be varied so as to provide a different resolution in response to a trigger event. For example, upon recognition of a trigger event, the recording device may record at a higher or lower resolution than that employed prior to the trigger event. Further, an exponential change in resolution may be employed. Finally, the change in resolution may be delayed for a predetermined number of frames following the trigger event.

For example, video data may be stored in the memory buffer using different storage techniques to achieve desired objectives. It may be desired to have higher frame storage rates around the trigger event with successively lower effective storage rates as one progresses further in time away from the trigger event (both before and after the event). It is appreciated that any number of storage methods may be employed via selective addressing of the semiconductor memory to extend the period of time captured within the semiconductor memory buffer, or to achieve almost any frame capture profile that may be desired. Several storage techniques illustrated in FIGS. **6** through **8** are discussed below.

An automatic gain control (AGC) (not shown) may optionally be electronically coupled between the video image sensor **46** and the A/D converter **50** to compensate for variations in light intensity and to prevent blooming of the captured video image.

The basic method of operation of the video recording device illustrated in the block diagram of FIG. **3** and described above is illustrated in the flow diagram depicted in FIG. **5**. As depicted in step **120** in FIG. **5**, upon initialization, a counter value i is initialized to 0. As illustrated in step **122**, the video data corresponding to a video frame is sampled by the A/D converter and converted to digital data. As shown in step **124**, the converted frame data is transmitted to the microprocessor. Upon receipt of the frame data, as illustrated in step **126**, the microprocessor compresses the frame data so as to permit a greater number of frames to be stored within the circular buffer memory than would otherwise be possible absent such compression. Additionally, as depicted in step **128**, the frame data may optionally be encrypted by the microprocessor to prevent unauthorized access to such data. As shown in step **130**, the frame data is stored in the next frame location within the circular memory buffer. In the event that any video data has previously been written to the specified memory location within the circular buffer, such data is overwritten. As illustrated in decision step **132**, a determination is made whether an event trigger has been received. If no event trigger is received, the counter i is reinitialized to 0 and sampling and storage of frame data continues. If the decision step **132** results in a determination that a trigger event has been received, as illustrated in decision step **134**, a determination is optionally made whether adaptive rate selection is employed. In the event that adaptive rate selection is employed, the sampling rate of the A/D converter is adjusted as depicted in step **136** and the modified frame rate is employed for subsequent frame storage. In the event that adaptive rate selection is not employed or enabled, following step **132** control passes to step **138** in which the counter i is incremented. As shown in decision step **140**, a determination is next made as to whether the counter is equal to the specified number of frames to be recorded subsequent to the occurrence of a trigger event. In the event that the determination reveals that the specified number of frames has not been recorded subsequent to the trigger event, control passes to step **122** and sampling continues. In the event the determination of step **140** reveals that the predetermined number of frames have been captured subsequent to the trigger event, control passes to step **142** and further frame capture ceases.

If frames are simply received and stored in successive locations of a circular buffer, it is apparent that the total record time will equal the number of frames allocated in the buffer for storage minus one times the frame sampling period. Thus, assuming a semiconductor memory which can hold 150 video frames and a ten (10) frame per second storage rate, the semiconductor memory will only be able to hold 14.9 seconds of video data. If the trigger is adjusted so as to provide for approximately one half of the frames to be recorded prior to the trigger event and one half of the frames subsequent to the trigger event, it is evident that only approximately 7.5 seconds of record time is achieved surrounding the event of interest.

FIGS. **6** through **8** illustrate several frame storage techniques which provide for storage of video information over a greater period of time than is achieved by simply storing each successive frame in a successive buffer location as discussed hereinabove wherein the entire buffer pool is treated as a single circular buffer.

The table depicted in FIG. **6** illustrates data samples received successively at 0.1 second intervals. For simplicity, eight data storage buffers having buffer addresses **0**–**7** are illustrated although typically many more data buffers would be employed. The data buffers are segregated into two groups of buffers with buffers having addresses **0**–**3** comprising a first buffer group and buffer having addresses **4**–**7** comprising a second buffer group. Each group is organized as a circular buffer in which a data sample is stored in the first storage location within the respective group following storage of data sample within the last storage location of the group.

A data sample is stored in the next location within the second group following storage of a predetermined number of data samples within the first group of storage buffers.

In normal operation and in the absence of the occurrence of a trigger event samples are stored as illustrated in FIG. **6**. More specifically, the first sample is stored in address **0** of the first group of buffers and the second sample is stored in address **1** of the first group of storage buffers. Following the

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storage of two data samples in the first group of storage buffers data sample **3** is stored in address **4** which comprises the first address in the second group of storage buffers. The next two data samples comprising samples **4** and **5** are stored in buffer addresses **2** and **3** comprising the next two successive buffer addresses within the first group of storage buffers. Sample **6** is stored in buffer address **5** which comprises the next successive buffer within the second group of storage buffers. This storage technique continues in the absence of a trigger event as illustrated for 17 data samples in FIG. **6**.

Once a trigger event has been received, data storage ceases following the storage of a predetermined number of data samples (P_n) within each group (n) of storage buffers where n=the number of the respective buffer groups. For example, with reference to FIG. **6**, a trigger event is indicated as having occurred following the receipt of data sample **11**. Data storage ceases following the storage of two additional data samples in the first group of storage buffers (samples **13** and **14**) and two additional samples within the second group of storage buffers (samples **12** and **15**). Thus, in the simplified illustration of FIG. **6**, the overall storage interval has been expanded from 0.7 seconds (8 successive samples at 0.1 second intervals) which would be obtained if all eight buffers were considered as a single buffer group to 0.9 seconds by organizing the eight buffers as two groups of buffers in which each comprises four buffers. Further, more frames are stored in the vicinity of the trigger event and fewer frames are stored for times farther away in time from the trigger event by employing the presently disclosed technique. It should further be appreciated that by employing greater numbers of groups of buffers, the time interval covered may be substantially increased while still obtaining the highest frame storage resolution immediately before and after the trigger event. Furthermore, it is possible to achieve storage of a greater number or a smaller number of frames before the trigger event or after the trigger event based upon the specification of the number of data samples that are to be stored within respective groups prior to termination of further data sample storage within the respective group.

A further example of the presently disclosed storage technique employing three groups of storage buffers, in which each group comprises four storage buffers, is illustrated in FIG. **7**. As illustrated in FIG. **7**, a data sample is stored in each successive group only following storage of a predetermined number of data samples within the preceding group. More specifically, the first group of storage buffers comprises buffer addresses **0** to **3**, the second group of buffers comprises addresses **4** to **7** and the third group of buffers comprises buffer addresses **8** to **11**. The first group of buffers comprise the highest resolution buffers since the greatest number of data samples are stored within this group. Successive groups each store fewer data samples than the preceding group. Any number of variations to the presently disclosed recording technique may be employed to obtain expansion of the time interval covered by the available number of storage buffers while maintaining high resolution recording around the trigger event. For example, while the technique illustrated in FIG. **7** provides for recording sample **9** to the first location of the third storage buffer group following storage of data samples **7** and **8** in address locations **0** and **1** respectively of the first buffer group, sample **7** could instead be stored in address **8** of the third buffer group and samples **8** and **9** could then be stored in address locations **0** and **1** of the first buffer group respectively with the storage pattern thereafter repeated in a circular manner for each of the respective buffer groups.

Referring again to the illustrated storage technique depicted in FIG. **7**, a trigger event **210** is illustrated as occurring between samples **39** and **40**. Subsequent to the trigger event **210**, recording continues within each buffer group until the predetermined number of data samples for that group has been received and stored. In the example depicted, storage of data samples within each group ceases following receipt and storage of two data samples within each of the respective groups. There is no requirement for the number of data samples to be stored subsequent to the trigger event to be the same for each of the groups and the number of data samples stored after the trigger event may be selected so as to favor storage of information either prior to or subsequent to the trigger event for each of the storage buffer groups.

Assuming a 0.1 second sampling interval, if a single circular buffer comprising twelve buffer locations were employed without segregating buffers into groups, the interval span would constitute 1.1 seconds. In the example depicted in FIG. **7** the time span covers 2.4 seconds with only three buffer groups although the specific time span varies with the positioning of the trigger event. By increasing the number of buffer groups high resolution may still be obtained around the trigger event with even greater overall time interval coverage.

Another alternative technique for storing video data in the video recording device is illustrated in FIG. **8**. A gray code generator, which in the exemplary embodiment comprises a six bit generator, is employed to generate a code in which only a single bit changes from each code to the next. The gray code generator may comprise a gray code counter implemented in hardware or alternatively, a conventional counter may be employed to address a look-up table which contains the respective gray codes and provides such codes as outputs. A buffer pool for storing video data is divided into two parts. One portion of the buffer pool (the Before column) is employed to stored video frames received prior to the trigger event **220** and a second portion of the buffer pool is employed to store video data received subsequent to the trigger event. In the example of FIG. **8**, six buffers are illustrated in each portion of the buffer pool for purposes of discussion although in practice any number of buffers may be employed within the respective portions and typically the total buffer pool would include many more than 12 buffers to obtain a substantially increased recording time.

Video data is periodically stored on an ongoing basis in the absence of a trigger event, in the buffer address corresponding to the gray code bit which changed when last incremented. Thus, as illustrated, when the gray code changes from 000000 to 000001 video data corresponding to frame **1** is stored in buffer location **0** (of the Before column) since the change in the gray code occurred in bit **0** of the gray code. Similarly, when the gray code changes from 000100 to 001100, video frame **8** is written to buffer location **3** since the change in the gray code occurred in gray code bit **3**. Due to the gray code addressing employed, the lowest address buffer is overwritten every other video frame. The higher the address of the buffer, the less frequent the overwriting of the respective buffer occurs. Following the storage of the video frame in the last buffer location within the first buffer portion, the sequence repeats with video frame data stored in respective buffers being rewritten with new video data.

After the gray code generator has cycled through the first buffer portion a number of times, it is assumed that a trigger event **220** occurs between frame numbers **16** and **17**. Once a trigger event has been received, storage of video frame

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data within the first portion of the buffer pool (the Before columns) ceases and video frames then stored in the second portion of the buffer pool (the After columns) using the same addressing technique described with respect to the first portion. Several rules, however are applied with respect to writing of video frame data within the second portion of the buffer pool after the detection of a video event. Once a video frame is written to a buffer within the second portion of the buffer pool all further writes to that buffer are suppressed. Additionally, writing of video frame data to the second portion of the buffer pool ceases when the last gray code is reached which preceded the trigger event. By way of illustration, since the trigger event was detected after gray code 011000 and before gray code 011001, attempt to write to the second buffer pool would cease following the writing (or suppression of writing, as applicable) to buffer **4**.

More specifically, following the trigger event **220** video frame **17** is written to buffer **0** of the second buffer pool (outlining highlighted) and video frame **18** is written to buffer **1** within the second buffer pool. Video frame **19**, however, is not written to buffer **0** of the second buffer pool after the trigger event, since a video frame (frame **17**) has already been written to buffer **0**. Video frame **20** is written to buffer **2** (highlighted by outlining) since no prior write has occurred to buffer **2** subsequent to the trigger event **220**. Writing or suppression of writing to the second buffer pool continues, as illustrated within the second buffer pool (the After columns) until the gray code is reached corresponding to the gray code immediately preceding the trigger event. In the foregoing manner the video data preceding and subsequent to the trigger event is stored for subsequent retrieval and display.

Thus, following the trigger event, and after termination of recording in the second buffer pool, frames **32**, **8**, **12**, **14**, **15** and **16** would be preserved within buffers **5**, **3**, **2**, **1**, **0** and **4** respectively of the first portion of the buffer pool and frames **17**, **18**, **20**, **24**, **32** and **16** would be preserved in buffers **0**, **1**, **2**, **3**, **5** and **4** respectively of the second portion of the buffer pool. The video frame preserved via the present storage technique in the first and second buffer pools in the present illustrative example are highlighted in bold for purposes of identification.

While the above described data storage techniques have been applied to the specific application of video data storage, it is appreciated that these described storage techniques are equally applicable to any application in which it is desired to store data received both before and after a trigger event wherein the timing of the trigger event is indeterminate.

The foregoing video recording device thus provides for the capture and recording of video images occurring both before and after a triggering event in a compact low cost assembly which employs no moving parts such as typically employed in prior art recording devices. It should be understood that modifications to the video recording device and the methods for recording herein described will be apparent to those of ordinary skill in the art without departing from the inventive concepts contained herein. Accordingly, the invention is not to be viewed as limited except by the scope and spirit of the appended claims.

What is claimed is:

1. A recording device for capturing image data, said recording device comprising: at least two memories, each of the at least two memories being organized as a circular memory for storing samples of the image data associated with a time period; and a control processor operative to selectively store some of the samples of image data in one of said at least two memories and other of the samples of image data in another of said at least two memories such that (i) each of the samples of image data is stored only once, and (ii) the stored samples of image data associated with a portion of the time period closer to an event correspond to a first resolution and the stored samples of image data associated with a portion of the time period further from said event correspond to a second resolution different than the first resolution.

2. The device of claim **1**, wherein said device further comprises:

at least one first sensor type operative to generate the data; and

at least one second sensor type operative to generate a signal representing the event;

wherein each image represented by the stored data associated with the portion of the time period closer to the event has the first resolution responsive to the signal.

3. The device of claim **2**, wherein said at least one second sensor type includes an accelerometer.

4. The device of claim **1**, further comprising:

a capture switch;

wherein the control processor is operative to store only a predetermined amount of data within said memory following user activation of said capture switch.

5. The device of claim **1**, wherein said control processor is further operative to compress the data associated with the portion of the time period closer to the event at a first compression ratio and to compress the data associated with the portion of the time period further from the event at a second compression ratio different than the first compression ratio, prior to the storage of the data within said memory.

6. The device of claim **1**, wherein said second resolution is less than said first resolution.

7. The device of claim **1**, wherein said control processor is operative to store the data only in approximately one-half the memory following the event.

8. The device of claim **1**, further comprising a tamper resistant housing configured to house the control processor and the memory.

9. The device of claim **8**, wherein said housing is portable.

10. The device of claim **1**, wherein said control processor is further operative to purge the contents of said at least one memory upon user activation of a switch.

11. The device of claim **1**, wherein the first resolution is exponentially higher than the second resolution.

12. The device of claim **1**, wherein the control processor is operative to encrypt the data prior to storage in the memory.

13. A recording device for capturing data, said recording device, comprising:

at least one memory for storing image data associated with a time period;

a control processor operative to store the data in the at least one memory, wherein each image represented by the stored data associated with a portion of the time period closer to an event has a first image resolution and each image represented by the stored data associated with a portion of the time period further from the event has a second image resolution different than the first resolution; and

a sampler operative to sample data representing each image associated with the portion of the time period closer to the event at a first image sampling rate to generate the image data which represents each image at the first resolution and to sample data representing each image associated with the portion of the time period

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further from the event at a second image sampling rate to generate the image data which represents each image at the second resolution.

14. The device of claim **1**, wherein the control processor is operative to store only a predetermined amount of data following the event.

15. A method for recording image data, comprising: generating samples of the image data; and selectively storing some of the generated samples of image data in a first circular memory and other of the generated samples of image data in a second circular memory, such that (i) each of the samples of image data is stored only once, and (ii) the stored samples of image data representing images associated with a time period closer to an event correspond to a first resolution and the stored samples of image data representing images associated with a time period further from said event correspond to a second resolution different than the first resolution.

16. The method of claim **15**, further comprising the step of:

compressing said first data and said second data prior to storing said first data and said second data.

17. The method of claim **16**, wherein said compressing is performed with an asymmetric compression routine.

18. The method of claim **16**, further comprising the step of encrypting said first data and said second data prior to storing said first data and said second data.

19. The method of claim **15**, further comprising the steps of:

storing said data at the second resolution prior to the event; and

storing said data at the first resolution subsequent to the event.

20. The method of claim **15**, wherein said first resolution is higher than said second resolution.

21. The method of claim **15**, wherein the first resolution is exponentially higher than the second resolution.

22. A method for recording data, comprising:

storing first image data associated with a time period closer to an event, wherein each image represented by the stored first image data has a first image resolution;

storing second image data associated with a time period further from said event, wherein each image represented by the stored second image data has a second image resolution different than the first resolution;

sampling data representing each image associated with the portion of the time period closer to the event at a first image data sampling rate to generate the first image data; and

sampling data representing each image associated with the portion of the time period further from the event at a second image data sampling rate to generate the second image data.

23. A compact portable device for recording image data with no moving parts, said recording device comprising: at least one first sensor type operative to generate signals corresponding to multiple images associated with a period of time; at least one second sensor type operative to generate a signal representing an event; at least two circular buffer memories for storing the image data; a control processor operative to receive said event signal and to store samples of the image data representing some of the images corresponding to the generated image signals in one of said at least two circular buffer memories and samples of the image data representing other of the images corresponding to the generated image signals in another of said at least two circular buffer memories, wherein (i) each of the samples of image data is stored only once, and (ii) the stored samples of image data representing images associated with a portion of the time period after receipt of said event signal correspond to a first resolution and the stored samples of image data representing images associated with a portion of the time prior to receipt of said event signal correspond to a second resolution different than the first resolution; a portable housing configured to house the control processor and said at least two circular buffer memories; and at least one connector disposed on said housing for outputting the stored samples of image data.

24. The device of claim **23**, further comprising:

a user activated capture switch, wherein the control processor is operative to store only a predetermined amount of data within the at least one circular buffer memory following user activation of the capture switch;

a user activated purge switch, wherein the data stored in the memory is erased following user activation of the purge switch;

a user activated still switch, wherein the control processor is operative to store a single data sample following user activation of the still switch; and

at least one power source for powering the at least one first sensor type, the processor, and the at least one circular buffer memory;

wherein the housing is a tamper resistant housing and is further configured to house the at least one first sensor type.

* * * * *

Appendix FF

US007747143B2

(12) **United States Patent**
DeKeyser et al.

(10) **Patent No.: US 7,747,143 B2**
(45) **Date of Patent: Jun. 29, 2010**

(54) **DIGITAL VIDEO RECORDER**

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(73) Assignee: **Fast Forward Video, Inc.**, Irvine, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1395 days.

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(22) Filed: **Jan. 11, 2002**

(65) **Prior Publication Data**

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Related U.S. Application Data

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(51) **Int. Cl.**
H04N 9/77 (2006.01)

(52) **U.S. Cl.** **386/125**; 386/49; 386/95; 386/68; 386/69; 386/70

(58) **Field of Classification Search** 386/86, 386/95, 46, 68–70, 125
See application file for complete search history.

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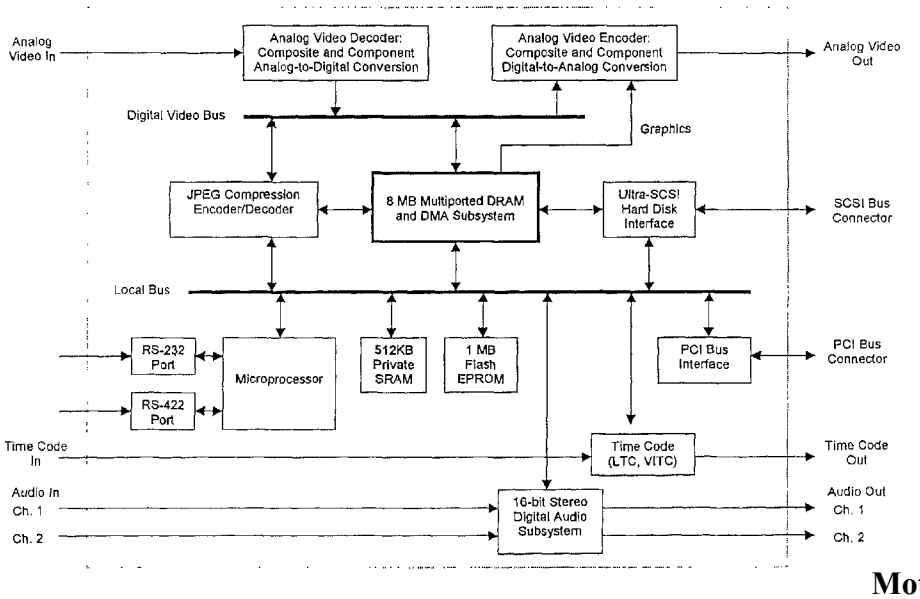
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(57) **ABSTRACT**

A unique high performance digital video recorder having a number of novel features. The recorder's electronics are all on a unitary printed circuit board. The recorder also requires at least one hard disk drive and audio and video input analog signals (from a source such as video camera or broadcast media) as well as a suitable monitor for receiving output audio and video analog signals. A external time code generator (i.e., VITC digital clock) is also required for synchronization. Also required are various manual control devices (i.e., panel controls) for mode selection. The electronics of the preferred embodiment comprise A-to-D and D-to-A converters, a hard disk interface, a JPEG compression encoder/decoder, a multi-port DRAM and DMA subsystem, a microprocessor with RS-232 and RS-422 access ports, various working memory devices and bus interfaces and a 16-bit stereo digital audio subsystem. Novel features of the preferred embodiment include use of an index table for disk addresses of recorded frames, a multi-port memory controller in the form of a field programmable gate array (FPGA), loop recording using dual channels, and dynamic JPEG compression compensation.

8 Claims, 10 Drawing Sheets



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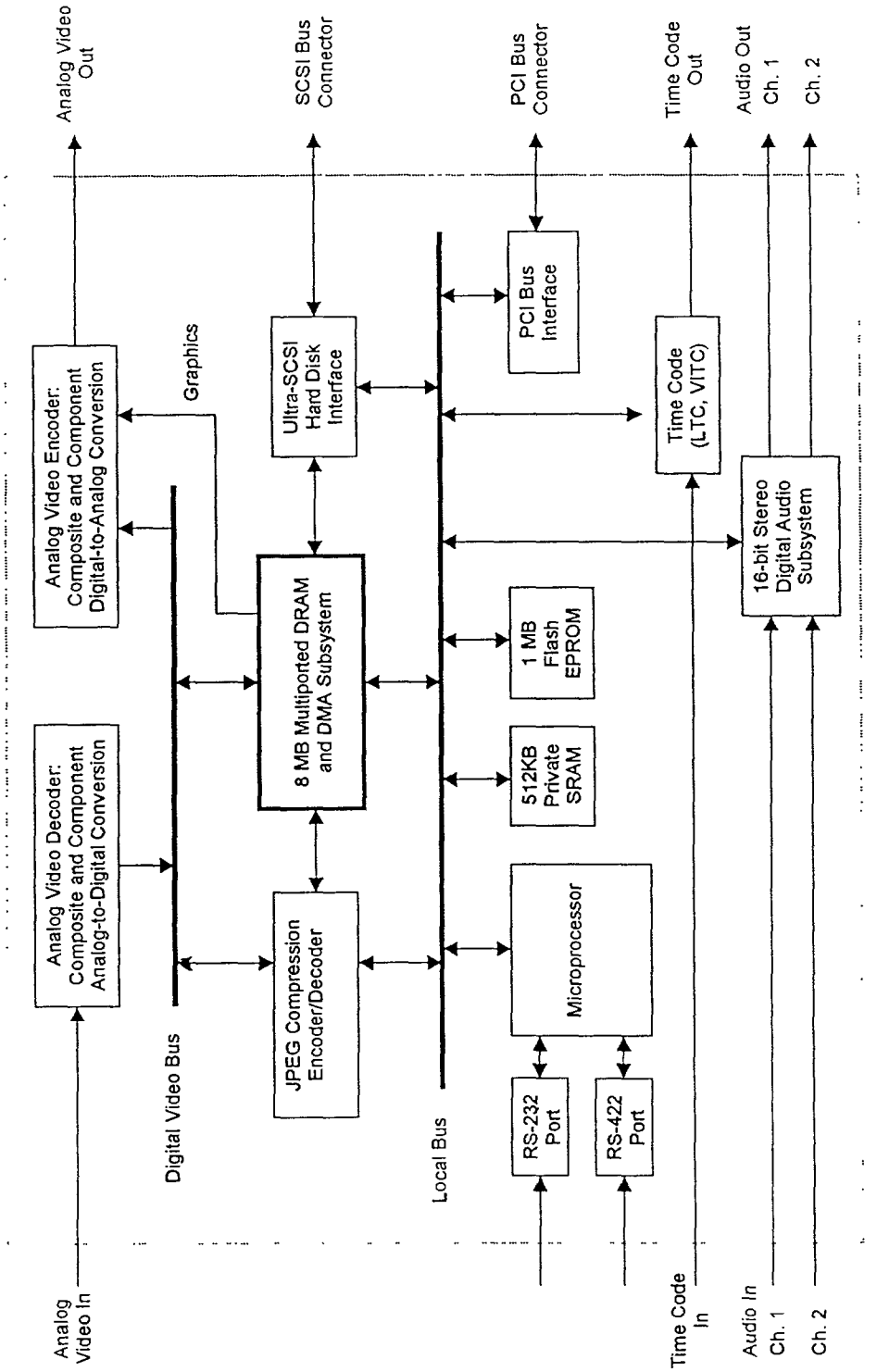

Analog Video Out
SCSI Bus Connector
PCI Bus Connector
Time Code Out
Audio Out
Ch. 1
Ch. 2
Graphics
Analog Video Encoder: Composite and Component Digital-to-Analog Conversion
Ultra-SCSI Hard Disk Interface
PCI Bus Interface
Time Code (LTC, VITC)
16-bit Stereo Digital Audio Subsystem
8 MB Multiported DRAM and DMA Subsystem
1 MB Flash EPROM
512KB Private SRAM
Analog Video Decoder: Composite and Component Analog-to-Digital Conversion
JPEG Compression Encoder/Decoder
Microprocessor
RS-232 Port
RS-422 Port
Digital Video Bus
Local Bus
Analog Video In
Time Code In
Audio In
Ch. 1
Ch. 2

FIG. 1

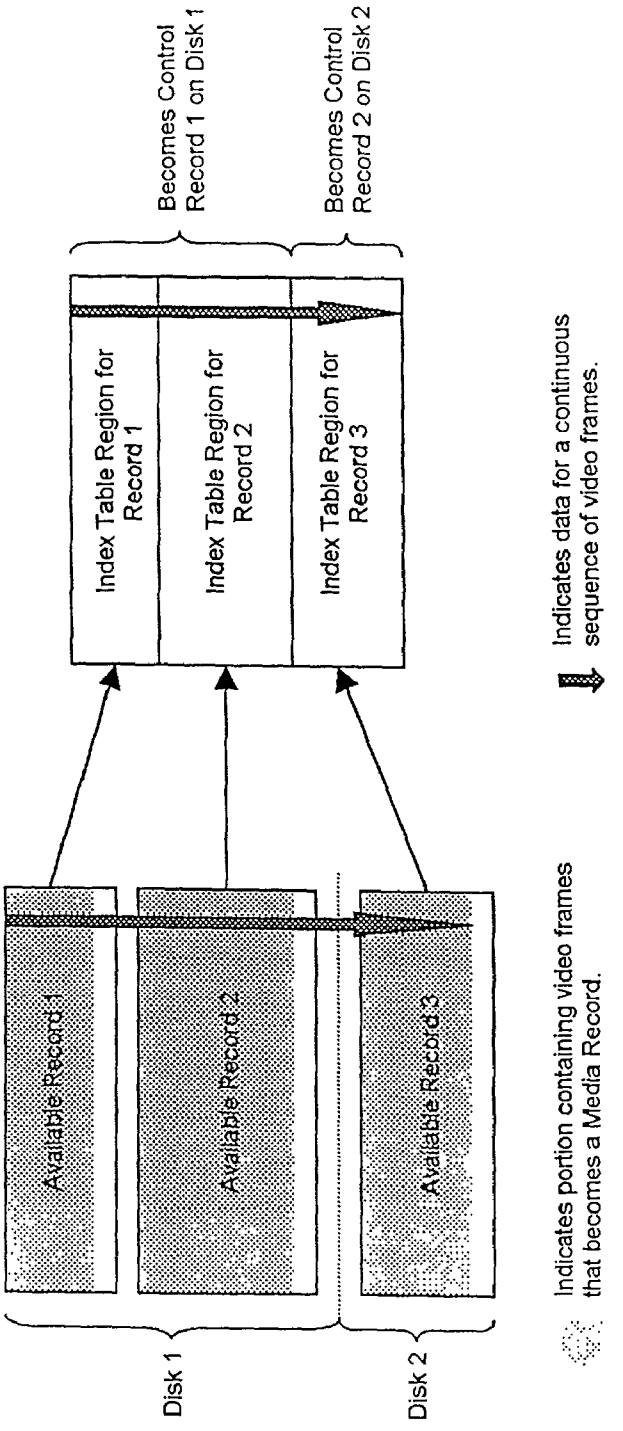

Becomes Control Record 1 on Disk 1
Becomes Control Record 2 on Disk 2
Index Table Region for Record 1
Index Table Region for Record 2
Index Table Region for Record 3
Available Record 1
Available Record 2
Available Record 3
Disk 1
Disk 2
Indicates data for a continuous sequence of video frames.
Indicates portion containing video frames that becomes a Media Record.

FIG. 2

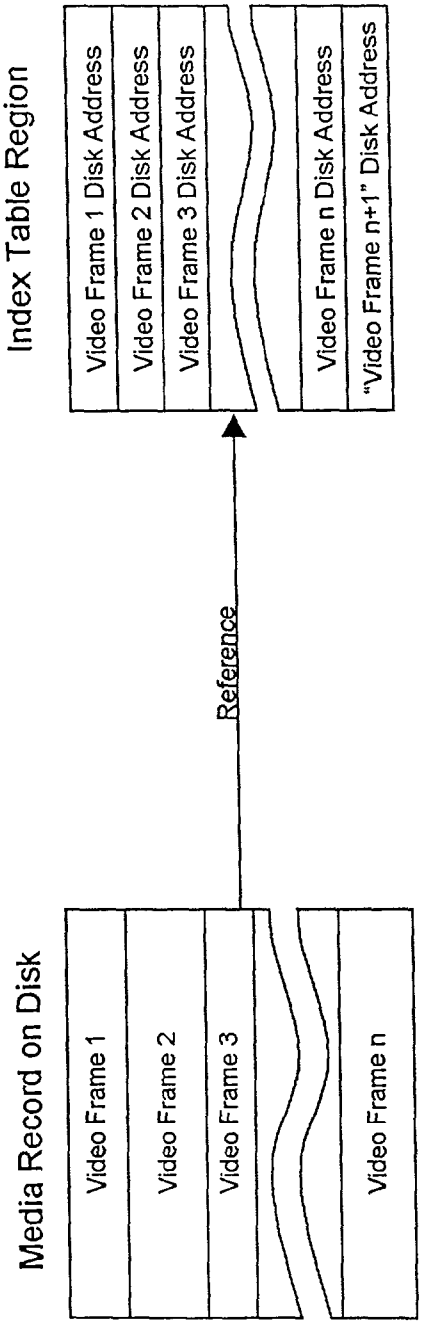

Index Table Region
Video Frame 1 Disk Address
Video Frame 2 Disk Address
Video Frame 3 Disk Address
Video Frame n Disk Address
"Video Frame n+1" Disk Address
Reference
Media Record on Disk
Video Frame 1
Video Frame 2
Video Frame 3
Video Frame n

FIG. 3

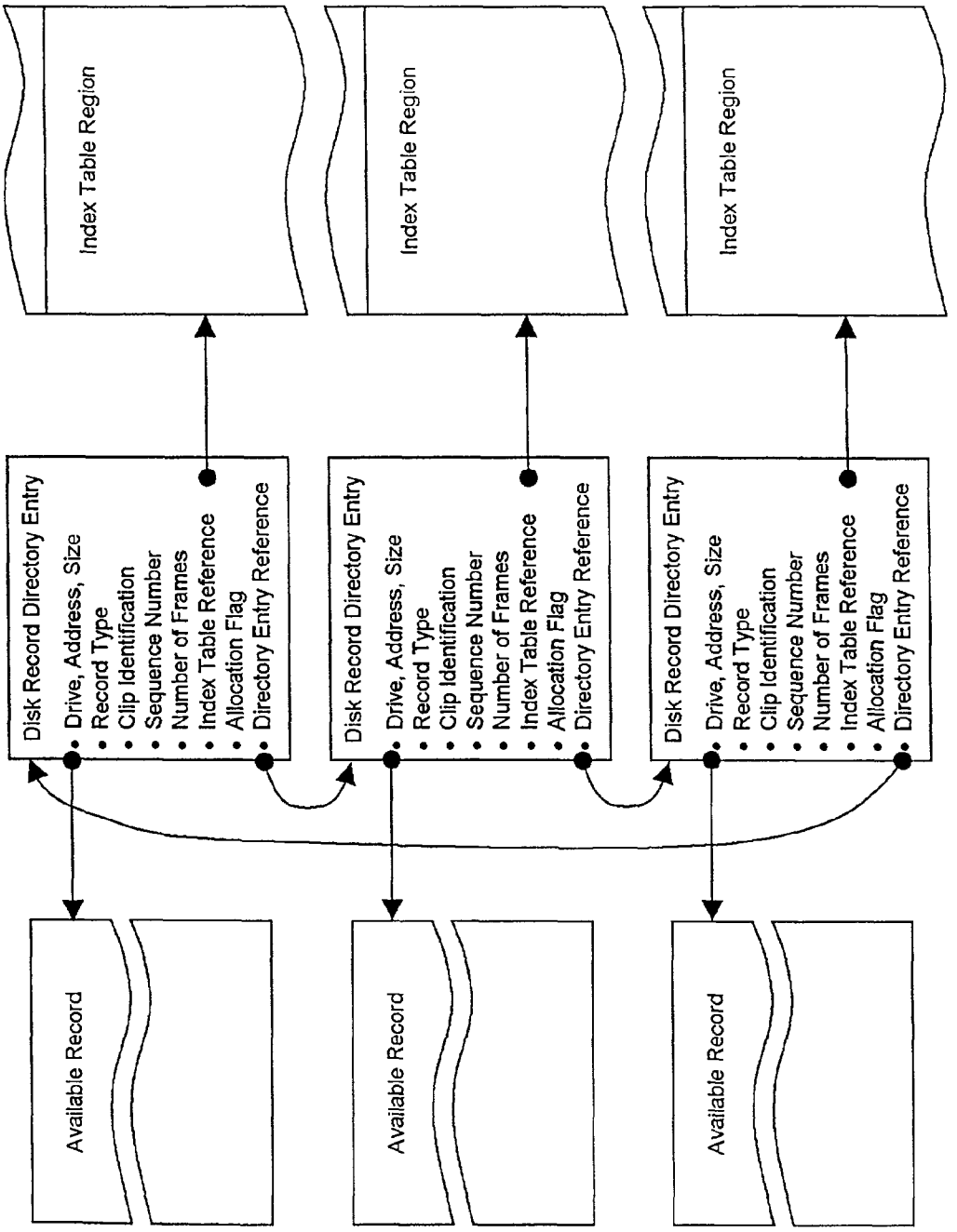

Index Table Region
Index Table Region
Index Table Region
Disk Record Directory Entry
• Drive, Address, Size
• Record Type
• Clip Identification
• Sequence Number
• Number of Frames
• Index Table Reference
• Allocation Flag
• Directory Entry Reference
Disk Record Directory Entry
• Drive, Address, Size
• Record Type
• Clip Identification
• Sequence Number
• Number of Frames
• Index Table Reference
• Allocation Flag
• Directory Entry Reference
Disk Record Directory Entry
• Drive, Address, Size
• Record Type
• Clip Identification
• Sequence Number
• Number of Frames
• Index Table Reference
• Allocation Flag
• Directory Entry Reference
Available Record
Available Record
Available Record

FIG. 4

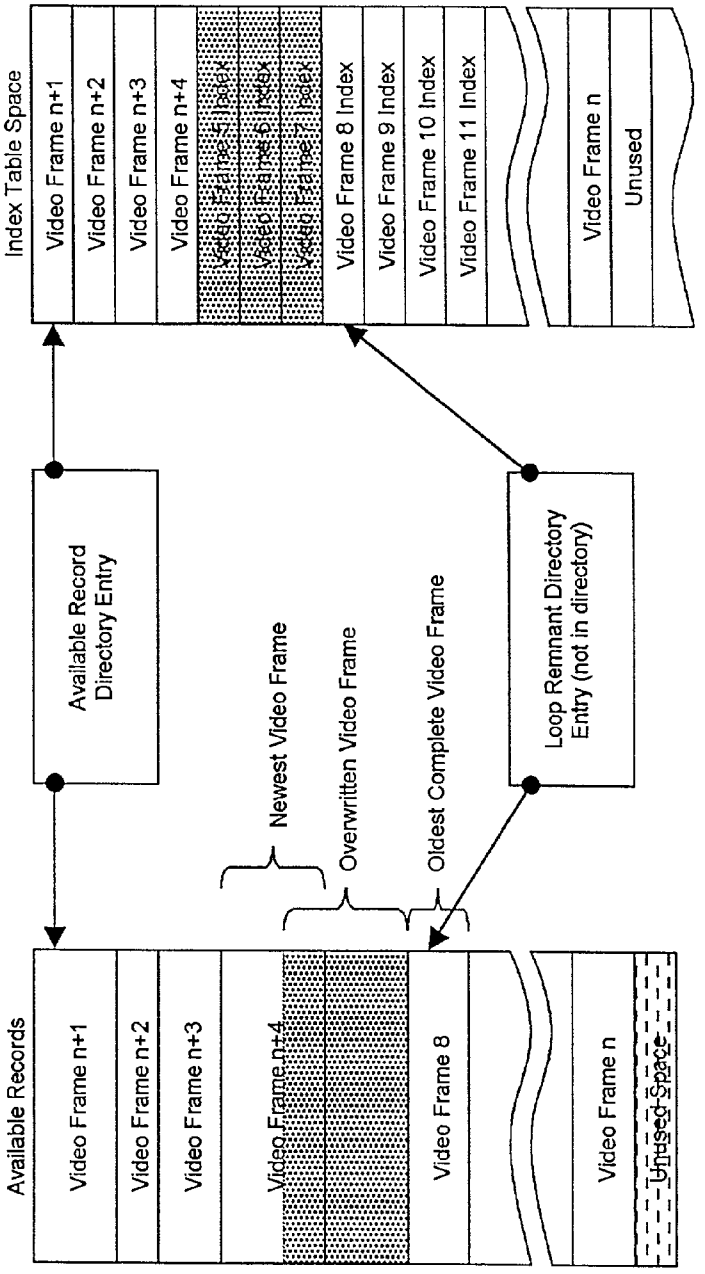

Index Table Space
Video Frame n+1
Video Frame n+2
Video Frame n+3
Video Frame n+4
Video Frame 5 Index
Video Frame 6 Index
Video Frame 7 Index
Video Frame 8 Index
Video Frame 9 Index
Video Frame 10 Index
Video Frame 11 Index
Video Frame n
Unused
Available Record Directory Entry
Loop Remnant Directory Entry (not in directory)
Newest Video Frame
Overwritten Video Frame
Oldest Complete Video Frame
Available Records
Video Frame n+1
Video Frame n+2
Video Frame n+3
Video Frame n+4
Video Frame 8
Video Frame n
Unused Space

FIG. 5

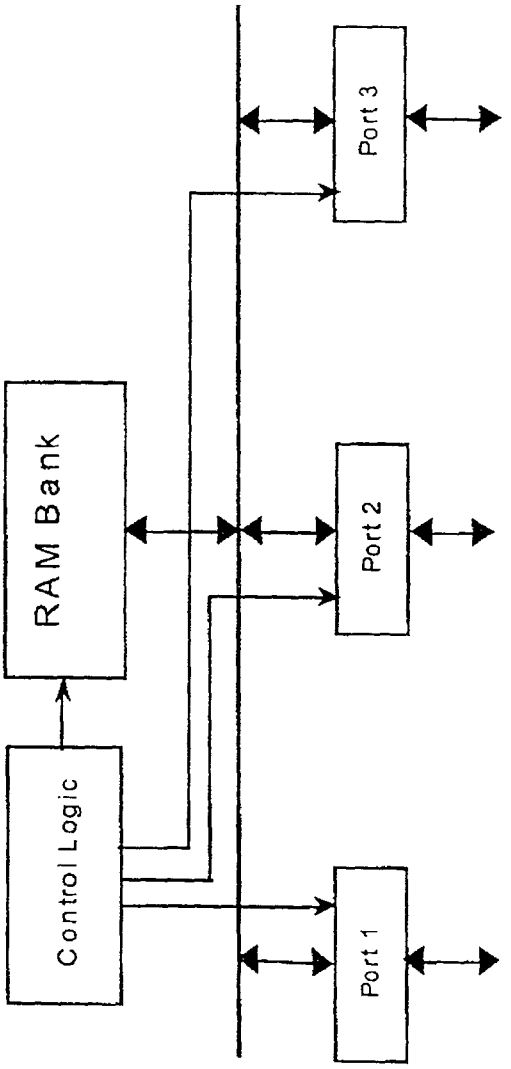


FIG. 6

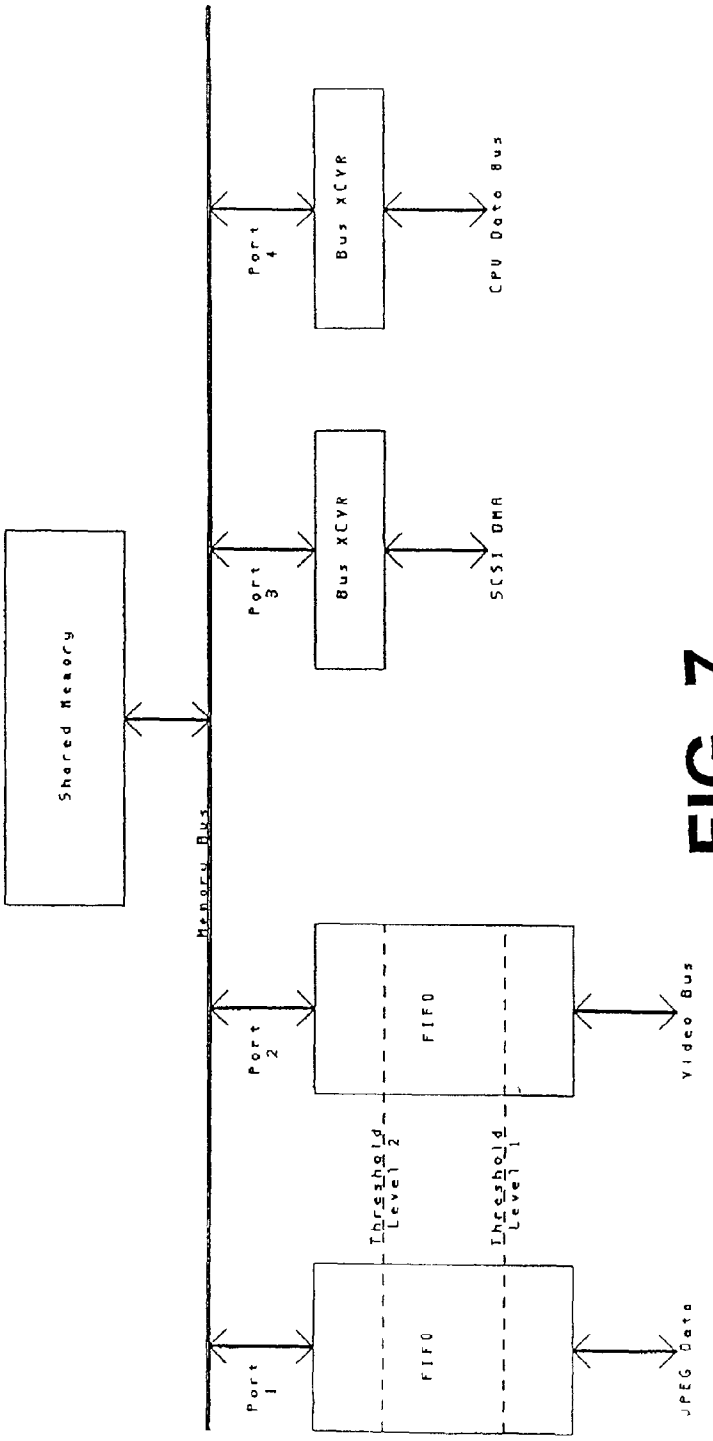

Shared Memory
Memory Bus
Port 1
Port 2
Port 3
Port 4
FIFO
FIFO
Threshold Level 2
Threshold Level 1
Bus XCVR
Bus XCVR
JPEG Data
Video Bus
SCSI DMA
CPU Data Bus

FIG. 7

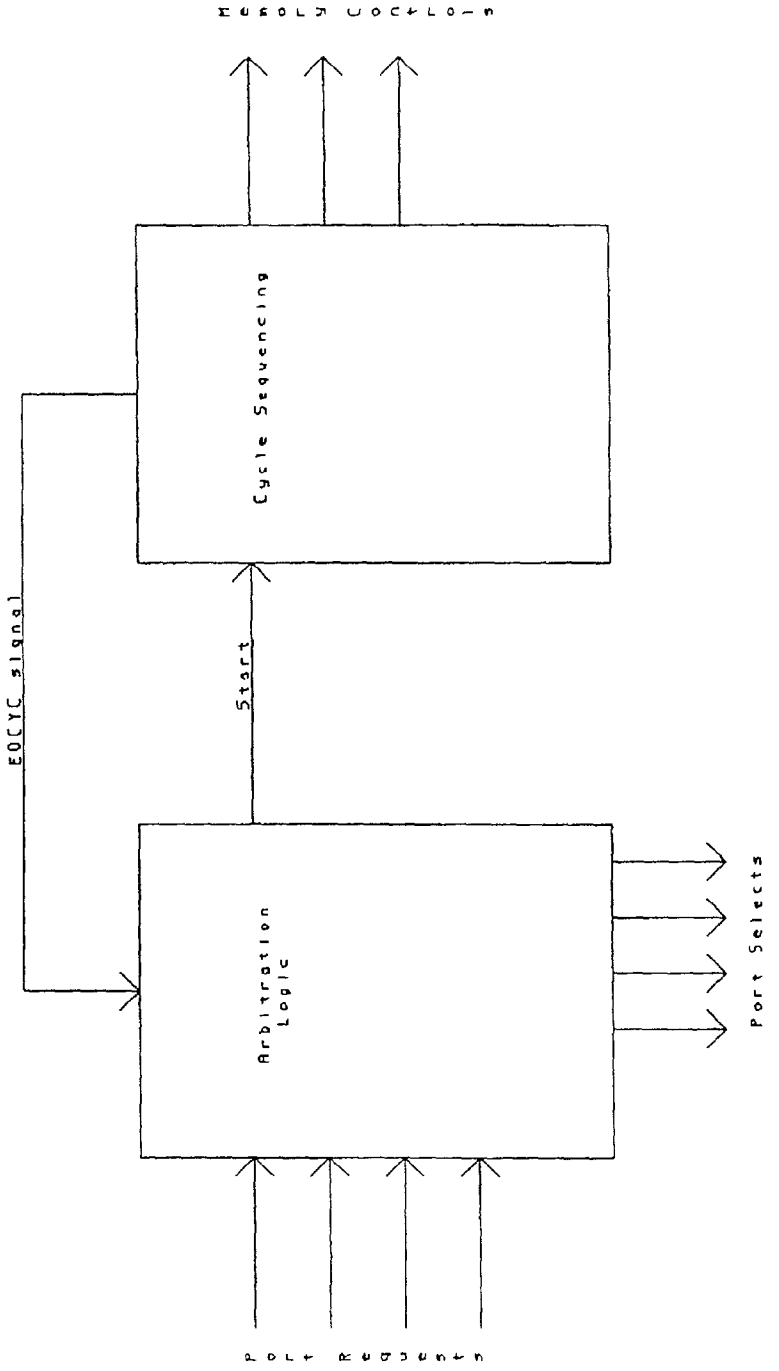

Cycle Sequencing
Start
EOCYC signal
Arbitration Logic
Port Selects

FIG. 8

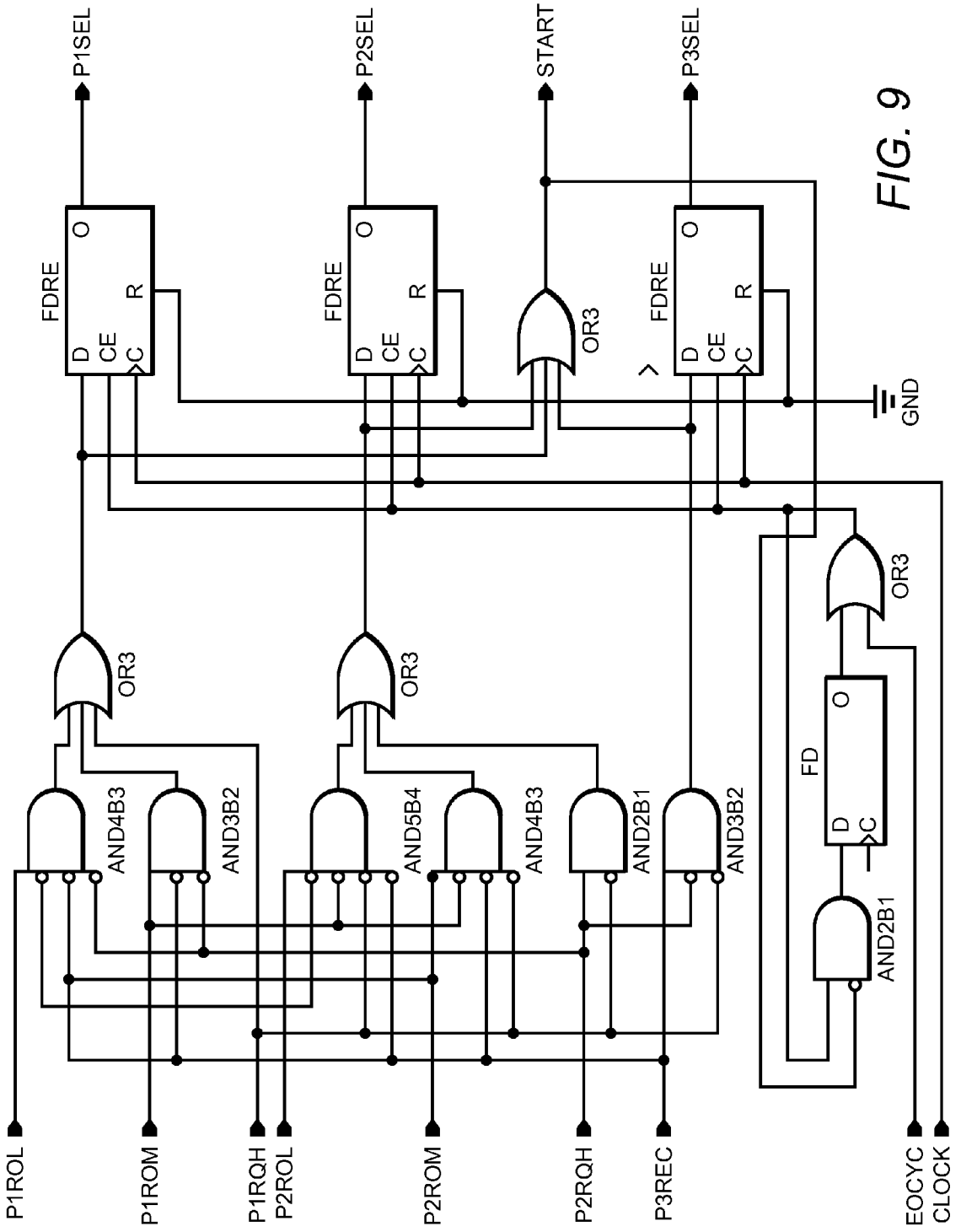

P1SEL
P2SEL
START
P3SEL
FDRE
O
R
D
CE
C
OR3
GND
AND4B3
AND3B2
AND5B4
AND4B3
AND2B1
AND3B2
FD
AND2B1
P1ROL
P1ROM
P1RQH
P2ROL
P2ROM
P2RQH
P3REC
EOCYC
CLOCK

FIG. 9

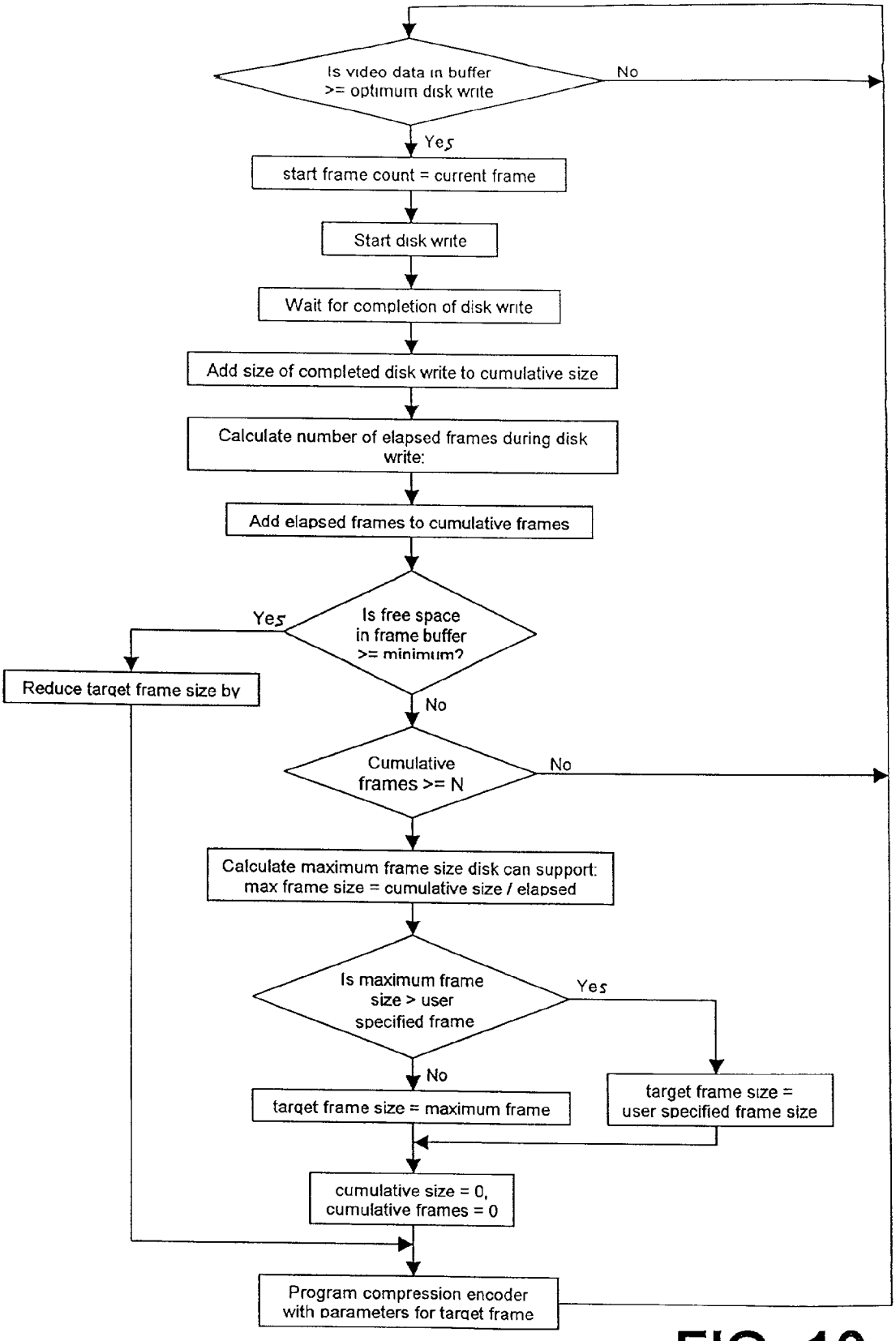


FIG. 10

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DIGITAL VIDEO RECORDER

CROSS-RELATED APPLICATION

This application takes priority from Provisional Patent Application Ser. No. 60/261,932 filed Jan. 15, 2001.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to certain improvements in digital video recording.

2. Background Art

Compressed video frames are variable in size depending on the complexity of the picture. Therefore, the recorder must maintain a directory of video frame disk addresses to support cueing (jumping to an arbitrary frame), random access playback (switching seamlessly without hesitation or interruption among material recorded at different physical locations on disk), and "feature" playback (fast forward and reverse scan).

Typically, this frame directory is kept on disk. With this approach, when a user submits a cue command, the recorder must read the directory first to determine the disk address, then read the frame from disk. This latency results in a visible hesitation or requires that the cue command be received some period in advance of the required cue. There is a need to overcome such latency.

Conceptually, recording and playing motion video to and from hard disk is simply performing the conversion from its analog (or uncompressed digital) format to a continuous compressed data stream and managing this continuous stream of data as a series of "writes" or "reads to" or "reads from" hard disk.

The hard disk is the slowest component in the system. To achieve the performance threshold that broadcast quality playback requires, it is necessary to interface to the hard disk at maximum efficiency. The data transfer method must be tailored to the hard disk's characteristics. With modern hard disks, the highest performance interface is achieved with burst data transfers of a size that matches the disk's cache memory. There is a need to implement burst data transfers appropriate for video data at maximum efficiency.

The user configures a recorder to record video at a specified compression ratio, for example, 4:1. The disk may not be able to sustain this specified data rate when the user has installed a low performance disk or if the image data frequency changes from simple pictures (black frames, for example) to complex ones. For example, one may watch MTV for a few minutes for excellent examples of video that stress JPEG compression rate-averaging algorithms. If the disk falls far enough behind, the result is catastrophic: The record stream skips frames, losing them irretrievably. There is a need to control compression so that such catastrophic results are averted.

Certain applications benefit from the ability to record continuously. In surveillance, for example, it is useful to record until an alarm occurs, then to stop some time after the alarm. The recorder has captured time before, during, and after the alarm, which can be useful in determining the cause of the alarm. There is a need to provide support for such a loop recording mode.

SUMMARY OF THE INVENTION

To overcome directory-based latency, the recorder of the present invention reads the disk addresses of all recorded frames into memory on startup and maintains this index table as material is recorded and deleted. The in-memory index table eliminates a disk access before loading the required frame. The benefit is instantaneous cueing (latency of only one frame time), on-the-fly changes to the playback sequence, and generally quick response to user motion control. The cost is providing adequate memory to contain the address of every frame (at 108,000 frames per hour). The invention provides adequate index table space to support random access within eight hours of recorded video, expandable to more than forty hours with an "extended time module" daughter card.

The invention's memory controller, implemented in the preferred embodiment in a Xilinx FPGA, accommodates the disk's data transfer requirements by performing this burst DMA transfer in programmable size data blocks. A memory controller makes extensive use of the "extended data out" (EDO) feature of dynamic random-access-memory to enhance data transfer speeds.

Further, the memory controller must arbitrate access among several additional diverse devices which share the same memory. The controller must also support the unique data transfer characteristics of these other devices without compromising the burst DMA timing required by the hard disk interface.

1) Compressed video DMA must move continuously, with possible extreme peaks in the data rate. Average data rate is at least 5 megabytes per second for broadcast quality;
2) The graphics overlay requires memory accesses at fixed intervals in sync with the video raster, fixed data rate of about 5 megabytes per second;
3) The uncompressed video channel, when used, requires fixed timing at 27 megabytes per second;
4) The CPU has latency restrictions and must complete memory access within stringent limits. The amount of data transferred by the CPU includes digital audio, running at 192 kilobytes per second;
5) The memory requires refresh cycles with a maximum latency restriction.

The invention's firmware supports a "loop record" mode where the recorder first fills available space, then continues recording by overwriting the oldest video. To continue this process indefinitely is difficult because the video frames vary in size and the index table, like the video frames themselves, must be maintained in a circular manner. Further, the recorder must be able to stop at any moment and be able to play back the video as expected (oldest to newest) regardless of how it is actually stored on disk.

Another application that takes advantage of loop recording and adds another level of complexity is "time delay", where the device continuously records a stream of video and plays the same stream back some fixed interval of time later. The invention's firmware supports this application where two circuit boards share a common disk array. One board is dedicated to recording, the other board to playback. The two circuit boards communicate over a serial link. The recording board passes the information required for playback to the playback board. This configuration can also be used for "instant replay" type applications because the playback board can randomly access and play back the majority of the video frames stored on disk by the recording board.

BRIEF DESCRIPTION OF THE DRAWINGS

The aforementioned objects and advantages of the present invention, as well as additional objects and advantages thereof, will be more fully understood hereinafter as a result of a detailed description of a preferred embodiment when taken in conjunction with the following drawings in which:

FIG. **1** is a block diagram of the architecture of the video recorder of a preferred embodiment of the invention;

FIG. **2** is a block diagram representation of the relation between hard disks and index tables used in the preferred embodiment;

FIG. **3** is a block diagram representation of the relation between individual video frames and index table regions;

FIG. **4** is a block diagram representation of the relation between available records, disk record directory entries and index table regions;

FIG. **5** is a block diagram representation of the relation between available records and index table space for use in logs records;

FIG. **6** is a general block diagram of an arbitration assembly for multi-port access to a single memory device;

FIG. **7** is a block diagram similar to that of FIG. **6**, but for a 4-port memory system;

FIG. **8** is a block diagram of memory control logic employed in the system of FIG. **7**;

FIG. **9** is a logic schematic of a simplified arbiter; and

FIG. **10** is a flow chart describing a dynamic metering algorithm for controlling the recorder's compression and coding rate.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

The present invention comprises a unique high performance digital video recorder having a number of novel features. The recorder's electronics are all on a unitary printed circuit board, a block diagram of which is provided in FIG. **1**. The recorder also requires at least one hard disk drive and audio and video input analog signals (from a source such as video camera or broadcast media) as well as a suitable monitor for receiving output audio and video analog signals. A external time code generator (i.e., VITC digital clock) is also requires for synchronization. Also required are various manual control devices (i.e., panel controls) for mode selection as will be discussed hereinafter. The electronics of the preferred embodiment comprise A-to-D and D-to-A converters, a hard disk interface, a JPEG compression encoder/decoder, a multi-port DRAM and DMA subsystem, a microprocessor with RS-232 and RS-422 access ports, various working memory devices and bus interfaces and a 16-bit stereo digital audio subsystem. The novel features of the preferred embodiment comprise use of an index table for disk addresses of recorded frames, a multi-port memory controller in the form of a field programmable gate array (FPGA), loop recording using dual channels, and dynamic JPEG compression compensation. Each of these features will now be described in sufficient detail to enable those having ordinary skill in the relevant art to make and use the invention without undue experimentation.

Index Table

During recording, individual frames of video are compressed and stored sequentially into contiguous regions of unused disk space, called "Available Records". A particular recording of a continuous sequence of video frames, called a "clip", may span many Available Records across many individual disk drives, up to the total amount of disk space available (see FIG. **2**). The recording process uses all Available Records on one particular disk drive before continuing onto another disk drive. For each Available Record, the recording process is provided with the disk drive unit number, the size of each addressable block on that disk drive (or "block size"), and the starting and ending disk addresses of the recordable area of the Available Record.

Given the starting disk address and block size, along with the size of each video frame derived from the video compression process as frames are stored into memory, the recording process is able to calculate the starting disk address for each video frame, as well as the starting disk address for the next video frame to be stored (see FIG. **2**). It is these starting disk addresses that are placed into the index table. For the last video frame in each Available Record, the "starting address" for the "next" video frame is also placed into the index table, although video is not actually stored at this disk location. (if the recording process continues, this video frame would be stored at the starting address of a new Available Record since the recording process is able to calculate that the video frame is too large for the space left in the current Available Record.) The region used to store video frames within an Available Record becomes a "Media Record" (see FIG. **2**). Thus for each Media Record, the corresponding region of the index table consists of a sequential set of disk addresses, the number of which is one more than the number of video frames in the Media Record (see FIG. **3**). This allows the starting disk address and number of disk blocks for each frame of video on disk to be known during the playback process prior to the frame being retrieved from disk.

The associated index table region for each Media Record is also stored on the same disk as the Media Record as a "Control Record". (The recording process insures there will be space for the Control Records left on the disk drive.) While conceptually there could be a Control Record for each Media Record, in the preferred embodiment the index table and the derived Control Record are both continuous and contiguous for all Media Records of a single clip on a single disk drive (see FIG. **2**). This maintains the proper sequence for the subset of the clip's video frames stored on that disk drive. (The various Control Records and Media Records of a clip are associated by using a unique clip identification number, or "Clip ID". The proper sequence of Control Records and Media Records is maintained using a sequential "Sequence Number". These numbers are also stored with each Control Record and Media Record, along with the number of video frames represented or contained within the Record. It is important to note that each video frame consists of two video fields, and that the audio associated with a video frame may be stored with the video frame or separately in "Audio Records". Since frames of audio are of a fixed size, there is no need for a separate index table for audio data.)

Prior to initiating playback of any particular clip, all Control Records for that clip are loaded into the index table to allow for random frame access. While this must happen at least just prior to initiating playback, for increased performance, the circuit card software loads all Control Records into the index table upon startup, and maintains the index table as video frames are recorded and deleted, and as disk drives are added and removed. When a Control Record is loaded into the index table or stored after recording, the Media Records and related index table regions are associated using an implementation specific identifier called an index table "reference".

In the invention, the index table is implemented within a reserved area of memory and managed by an implementation specific set of software routines, which include index table memory management. The software interface to the index table includes:

1. Initializing the index table for use upon startup.

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2. Loading a Control Record into the index table and obtaining the associating index table references.
3. Obtaining the disk address of any video frame given the reference and frame number within the frame range (including the ending "next" frame address).
4. Deleting video frames from a referenced index table region.
5. Deleting a referenced index table region.

The software interface to the index table used during recording is more complex. Since the index table memory region is managed internally, the interface provides mechanisms to let the recording process know if the index table is out of free space, or if an index table region boundary will require an Available Record to be fragmented into two or more Media Records. The interface for recording includes:

1. "Opening" free index table space for use during the recording process.
2. Appending frame addresses to the index table sequentially during recording.
3. Overwriting previously stored frame addresses (used during loop recording).
4. Removing previously stored frame addresses (used for video tape emulation and frame buffer transfer features).
5. Indicating the free space available in the index table region for recorded video frame addresses.
6. Freeing used index table space when aborting a recording in progress.
7. "Closing" index table space at the end of the recording process.
8. Obtaining references for associating index table regions to Records.
9. Writing a Control Record to a disk drive from the index table.

Loop Recording

In order to record video frames to disk, the recording process of the inventive circuit card needs to have both unused space on disk (i.e., one or more Available Records) and unused (free) space in the index table uniquely allocated for its use. This space must be uniquely allocated to the recording process to prevent other processes from concurrently writing to these spaces, creating a memory conflict and corrupting the recorded data. While, conceptually, all the free space needed or available could be allocated just prior to recording, the inventive firmware allows unused space to be allocated both prior to initiating recording (Available Records are pre-allocated and become "Reserved Records") or just prior to being needed during the recording process. This latter case allows other processes to obtain disk space for use while recording is in progress.

The invention manages and allocates disk space by maintaining in memory a directory of records on disk. The disk record directory contains the following for each record on disk:

1. The disk drive unit number containing the disk record.
2. The disk block address of the start of the disk record.
3. The disk block size of the disk record.
4. The type of the disk record (e.g., Available Record, Media Record, Control Record).

During recording, the disk record directory also contains the following for each allocated Available Record being recorded to:

1. The allocation flag.
2. The reference to the next Available Record in the recording allocation sequence.
3. The reference to the index table region associated with the video frames recorded into the Available Record.
4. The number of video frames recorded into the Available Record and represented in the associated index table region.

The recording process allocation firmware allocates and links in additional Available Records prior to their use by filling in the reference to the Available Record just allocated into the directory entry of the Available Record into which video data is currently being recorded. This continues until there are no more Available Records left, at which time the linkage is either terminated (loop record disabled) or referenced back to the first Available Record directory entry (loop record enabled). As recording into an Available Record is initiated, the reference for the start of the index table region to be used is placed into the Available Record's directory entry. The recording process then updates the number of frames in the Available Record's directory entry, as video frames are stored on disk. Note that if a recording does not use an allocated Available Record, it is deallocated when recording is terminated.

As mentioned previously, after a recording is completed, the disk record directory also contains the following for each resulting Control Record and Media Record in the clip:

The unique clip identification number (Clip ID) for the clip.

The Sequence Number of the disk record within the clip.

The disk record directory thus provides the information the recording process needs to seamlessly record sequential video frames in proper order to disk across multiple Available Records. It also provides the information the recording process needs to "loop" video frame recording when it reaches the end of available disk space and overwrite previously recorded video frames in a continuous manner. FIG. **4** shows an example of the relationships between disk record directory entries, Available Records and index table regions for a loop across three Available Records.

The uniqueness of the invention's firmware comes with the addition of the requirement to loop within the allocated index table space as well as within the allocated disk space. Fundamentally, a loop condition is created when either the available disk space or the available index table space is exhausted. Looping then overwrites frames by either overwriting the actual video frames on disk, or by overwriting the frame disk block addresses in the index table, or both. In addition, the overwrite process must maintain synchronization between the loss of video frames on disk and the loss of their disk block addresses ("indices") in the index table. Otherwise, a condition would exist where some portion of the index table contains disk block addresses that do not align to the start of compressed video frames on disk. This then would cause random access playback features to fail since the compressed video frame format is no longer aligned to be properly decompressed. FIG. **5** shows an example where a loop has just occurred. Here, a larger set of four video frames has overwritten a smaller set of seven video frames. Although the indices for frames 5 through 7 have not been overwritten in the index table, since these frames have been overwritten on disk, their indices must be deallocated from the index table as well.

The invention's recording process deallocation firmware manages the deallocation of both video frames on disk and their indices in the index table as they are overwritten during recording. The deallocation process also currently employs a simplification to the general case by looping both the video frames on disk and their indices in the index table at the same time when either the space on disk or space in the index table is exhausted. This causes the loop boundary to always exist at the start of the space on disk and start of space in the index

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table concurrently. This avoids the necessity in the general case of joining index table fragments at the loop boundary.

Since the recording process places information regarding the video frames currently being recorded into the Available Record's directory entry, the deallocation firmware maintains a copy of the Available Record directory entry for the deallocation point. This copy is called the "loop remnant" directory entry because it refers to the remnant of the oldest video that still remains in the Available Record being overwritten (see FIG. **5**). The deallocation firmware updates the disk block address, index table reference and number of frames in the loop remnant directory entry as video frames and indices are deallocated. (Note that the disk block address of the Available Record in its entry in the directory is never changed, since this would corrupt the directory.) When recording is finally terminated, the loop remnant directory entry represents the start of the video loop (i.e., refers to the oldest sequence of video frames). If the overwrite point is not on an Available Record boundary, the Available Record containing the overwrite point is split into two disk records, the first being the newest portion of video frames (represented by the Available Record directory entry with a smaller size), and the second being the oldest portion of video frames (represented by the loop remnant directory entry copied into the disk record directory). The associated portions of the index table are likewise split to become two Control Records. The portions of the Available Records used by the recording are converted into Media Records.

With the time delay mode enabled, the recording board sends video frame information to the playback board via a serial communications link. This information consists of two parts, the disk address of the individual video frame and information that identifies the Available Record directory entry associated with the video frame location. This information allows the playback board to create its own index table for the newly recorded material and generate the data structures required for video playback. Like the recording board, the playback board also has to deallocate video frames from the playback data structures and indices from the index table as loop recording overwrites video frames. Since the playback board can access any of the newly recorded video frames on disk, the playback deallocation firmware actually deallocates a number of frames ahead of the actual overwrite point. This prevents the playback board from accessing information that is in the process of being overwritten. Also, since there is some delay associated with the transmission of video frame information across the serial communications link, the playback board is able to access video frames up to some number of frames behind the current recording position. The playback firmware accounts for the condition where playback encounters these resulting endpoints by keeping the playback position within existing video through properly advancing the playback frame position depending on the playback mode (e.g., stopped or playback at a particular frame rate). This allows the playback board to continue playback indefinitely without interruption.

Memory Controller

It is common in digital systems to have a requirement wherein several processes need access to a common memory. A typical means of solving such a requirement is illustrated in FIG. **6**. A single ported commercial memory device, or bank of such devices is provided with several access paths, or externally implemented ports, by which data from several sources can flow in and out. Control logic must arbitrate between the processes requiring access to the memory, and select a single port for connection to the memory bank for each access cycle.

Quite often, the mechanism by which access to the memory is allocated is either performed on a demand basis, or according to a fixed time-plan. With the demand method, the process requiring usage of the memory generates a "request" signal, to which the control logic responds with a "grant" when the port is to be given access. With the time-plan method, access is granted at fixed time intervals on a repetitive periodic basis. These mechanisms are very suitable for certain types of processes which either generate memory requests in an unpredictable fashion, such as random CPU accesses, or in a very regular, completely predictable pattern, as with screen refresh in graphics subsystems.

The present invention implements a new method for allocating shared memory bandwidth, which is particularly efficient at managing the relatively unpredictable high-bandwidth data flows found in variable-rate digital video streams. This mechanism can be considered as a variation of the demand-driven method, and operates by making measurements of each data flow in progress. A dynamic estimate is thereby developed, which is used to predict the urgency of each port's requirements. This estimate is fed to the arbiter as a multi-level request. The arbiter then uses the estimates to select one of the contending ports for access on the next memory cycle. This procedure allows the allocation pattern of memory cycles to dynamically adjust to unpredictable data-flow requirements

FIG. **7** shows a 4-port memory system where multi-level arbitration is used on two of the ports, numbered 1 and 2. This is similar to the configuration of the video recorder board. Data flowing to or from the two ports in question is first directed through staging First-In-First-Out (FIFO) data buffers connected to the memory bus.

Let us first consider the case where the video data is flowing into the memory. As the data in the FIFO accumulates, a multi-level request is presented to the arbitration logic. This request is derived from the data level in the FIFO and therefore reflects an estimate as to how soon the FIFO might be expected to overflow, thus resulting in data loss and corruption of the video stream. If no data is in the FIFO, the request level is "0", for no request. If some data is in the FIFO, but the level is below a minimum (marked as threshold 1 in the figure), the request level is "1", or low priority. In this case, the arbiter might service the port only when no other is requesting service. If the data level in the FIFO is between threshold levels 1 and 2, a mid-priority level "2" request is presented; whereas a data level above threshold 2 results in a high-priority level "3" request. In this last case, the arbitration logic could service the port on the next memory cycle regardless of requests from other ports.

If the data flow is reversed such that data is flowing out of the memory into the FIFO, and then to the video hardware, then the request priorities associated with the FIFO data levels are reversed as well. Level "0" would then correspond to a full FIFO whereas a nearly empty FIFO, with data level below threshold 1, would generate a level "3" request.

FIG. **8** is a block diagram of memory control logic associated with the system of FIG. **7**. The arbitration block receives the requests from the ports. In the case of ports 1 and 2, these requests will be multi-level. It then generates the port selection signals to connect whichever port it selects for the next memory cycle to the memory bus, and also a start signal to the cycle sequencing block. The sequencing block generates the

signals needed to control the memory chips, and sends the EOCYC (end of cycle) signal back to the arbiter to enable port select.

In FIG. **9**, the implementation of a simplified arbiter is shown. This logic will select one of 3 requesting ports of which ports 1 and 2 have multi-level requests. The multi-level requests are signaled by 3 lines for each port, P1RQL, P1RQM, and P1RQH, or P2RQL, P2RQM, and P2RQH respectively for port 1 and port 2. The port request logic drives only one of the 3 lines active at a time: RQL for a level 1 request, RQM for level 2, and RQH for level 3. Port 3 has only a single request line, P3REQ. The arbitration logic will select the highest priority requesting port according to the following fixed precedence, highest to lowest: P1RQH>P2RQH>P3REQ>P1RQM>P2RQM>P1RQL>P2RQL. It should be noted that the actual arbitration and sequencing logic provides additional features to help optimize system performance. These include arbitration for 5 ports, cycle sequencing for burst transfers, and arbitration fairness. This last feature prevents a single port from taking all successive memory cycles, and places an upper limit on latency to grant memory service to a requesting port.

The following illustrates how multi-level port request logic, selection logic, and the cycle sequencing, work together to implement dynamic arbitration in the invention:

Requesting Port	Arbitration Logic	Sequencing Logic
1. Port logic examines data flow and develops an estimate of the urgency for port service. It presents a multi-level request to arbitration representing this level of urgency.	2. Arbitration examines requests from all ports, and selects the one which appears to have the highest urgency level. Port selection signals are activated, and start of cycle is signaled to Cycle Sequencing.	3. Sequencing generates control signals to cycle memory and transfer data.
4. The selected port transfers data to/from memory under control of the cycle sequencing logic.		5. The data transfer is completed and the cycle is terminated.
	6. Arbitration selects a port for the next cycle.	

Dynamic Metering of Compressed Video Data Rate to Maximum Disk Bandwidth

The user configures the invention to record video at a specified compression ratio. Two factors influence the level of compression the user may desire: 1) image quality is to a point inversely related to the level of compression, lower compression resulting in a higher quality image; and 2) maximum recording duration is directly proportional to the level of compression. In many applications maximum image quality is the primary concern. In these cases, the user typically configures the recorder for the minimum possible compression.

Any specified compression level translates directly into a target data rate since incoming video is digitized to a fixed resolution, say 720 by 486 pixels at 2 bytes per pixel. The North American standard for motion video runs at 29.97 frames per second, so this yields an uncompressed data rate of 720×486×2×29.97=20,974,204.8 bytes per second. A specified compression ratio of 4:1, for example, translates to a target data rate of (20,974,204.8/4), or about 5 megabytes per second.

In JPEG (Joint Photographics Experts Group) compression, the method used in the inventive recorder, one particular parameter controls the level of compression. This parameter is the amount of quantization the compression encoder applies to the pixel values during the succession of transformations and encoding schemes specified in the JPEG compression method.

Maintaining a constant output data rate while compressing a series of changing images is problematic because it is impossible to predict the results from a given level of quantization: The performance depends on the image. The same quantization parameters produce compressed images that vary in size by an order of magnitude between, for example, a black frame and a complex, highly detailed image.

Fortunately, the compression encoder used in the invention's circuit board embodies a bit-rate control mechanism that varies the quantization parameters automatically on an image by image basis, statistically monitoring the results to converge on a specified target data rate. Since motion video usually contains long series of similar images, this method is effective over an extended period of time. A rapid change in the image due to a quick event in the program or editing, however, generates an instantaneous peak in the size of compressed frames and consequently in the short-term data rate.

The installed disk drive(s) may be unable to write the compressed data stream without interruption in the event the user has configured a data rate beyond the disk's capability or in the event of an extended peak in the compressed data rate for the reasons outlined above. In demanding applications, this results in a catastrophic failure: The only way the recorder can recover is to skip frames, losing them irretrievably.

To overcome this problem, the invention's firmware includes an algorithm that statistically monitors the performance of the disk compared to the video frame rate to determine the disk's actual maximum data rate in the context of current conditions. The algorithm also checks the state of the first-in, first-out (FIFO) memory buffer between the compression encoder and the disk to insure the buffer is not in danger of overflowing. If the disk is unable to sustain the user-configured data rate, the firmware reprograms the compression encoder's target data rate to the maximum data rate the disk can support. The firmware repeats this process continuously, dynamically adjusting for changing video data rate and disk performance. As conditions change, the data rate converges on the user-specified compression level or the maximum data rate the disk can sustain over time, whichever is less. Most important, this algorithm prevents the recoder from the unacceptable deficiency of dropping frames during recording.

The flow chart of FIG. **10** details this dynamic metering algorithm as implemented in the inventive recorder.

Having thus disclosed a preferred embodiment of the invention, it being understood that numerous modifications and additions are contemplated and that the scope of protection afforded hereby is to be limited only by the appended claims and their equivalents,

Having thus disclosed a preferred embodiment of the invention, it being understood that numerous modifications and additions are contemplated and that the scope of protection afforded hereby is to be limited only by the appended claims and their equivalents, what is claimed is:

1. A method of recording a video sequence having a first video frame and a second video frame, comprising:

providing a random access memory having a plurality of memory locations corresponding to a plurality of memory addresses;

using a linked list to allocate different first and second regions, each region comprising contiguous ones of the

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memory locations, where the first region and the second region are separated by at least one intervening region of memory locations;

compressing the first and the second video frames into a first variable sized compressed frame and a second variable size compressed frame having a different size than the first compressed frame;

writing the first compressed frame to a first memory location having a first memory address within the first region, and writing the second compressed frame to a second memory location having a second memory address within the second region;

storing a first frame address and second frame address in a frame index corresponding to the first and second memory addresses in the first and second regions, respectively, where the compressed frames are written; and

allowing the second video frame to be cued within a single frame latency time while playing back the first video frame from the first region by obtaining the second frame address from the frame index, retrieving the second compressed frame from the second region, decompressing the second compressed frame, and playing back the second video frame.

2. The method of recording of claim **1**, wherein the frame index identifies the first and second compressed frames using at least one of frame number, time, and date.

3. The method of recording of claim **1**, wherein the first frame address to which the first compressed frame is written is a start address for a video clip.

4. The method of recording of claim **1**, wherein the step of using the linked list to allocate the regions of memory locations comprises identifying a largest one of the regions.

5. The method of recording of claim **1**, wherein the frame index comprises an frame index table stored in a random access memory.

6. The method of recording of claim **5**, further comprising protecting the first compressed frame from being overwritten by a third variable sized compressed frame via writing the third compressed frame at a memory location corresponding to at least one of the memory addresses of the first selected regions other than the first frame address.

7. The method of recording of claim **1**, further comprising looping the memory by creating additional compressed frames from subsequent video frames of the video sequence, and overwriting the first compressed frame with one of the additional compressed frames having a size different from that of the first compressed frame at the first memory location.

8. A method of storing and playing back a video recording having 1 though n variable length video frames, where n is at least 9 comprising: storing each of the n video frames in n different memory locations, respectively; using a random access frame index to store pointers to each of the n memory locations; using the frame index to obtain a frame address referencing one of the n different memory location; and using the frame address to directly locate, access, decompress, and playback any individual ones of the n video frames out of sequence within a single frame latency time while playing back any one of the other video frames.

* * * * *

Appendix GG

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(54) **DIGITAL CAMCORDER DESIGN AND METHOD FOR CAPTURING HISTORICAL SCENE DATA**

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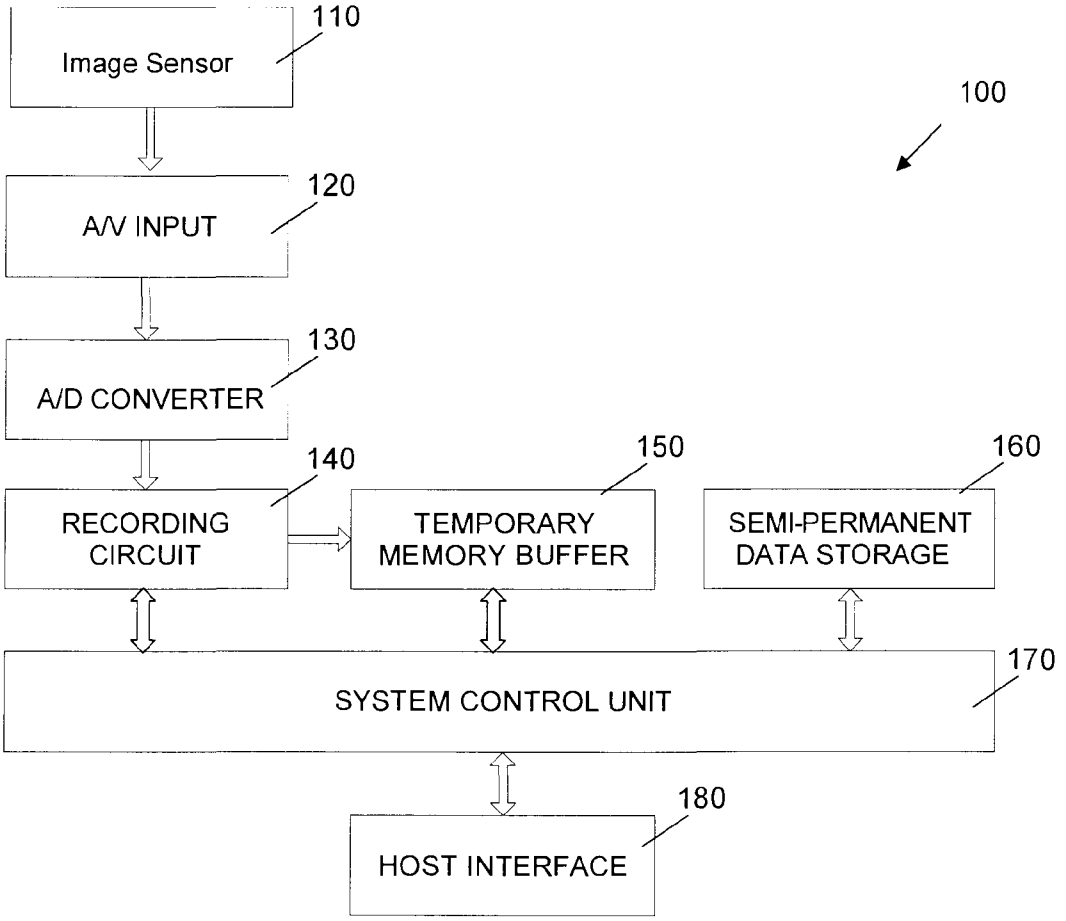
Publication Classification

(51) **Int. Cl.**
H04N 5/91 (2006.01)

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(57) **ABSTRACT**

A method for video recording includes producing a first video data by an image sensor in a video recording device, storing the first video data in a temporary memory buffer in the video recording device, selecting at least a portion of the first video data in a semi-permanent data storage, and copying the selected portion of the first video data from the temporary memory buffer to the semi-permanent data storage in the video recording device.



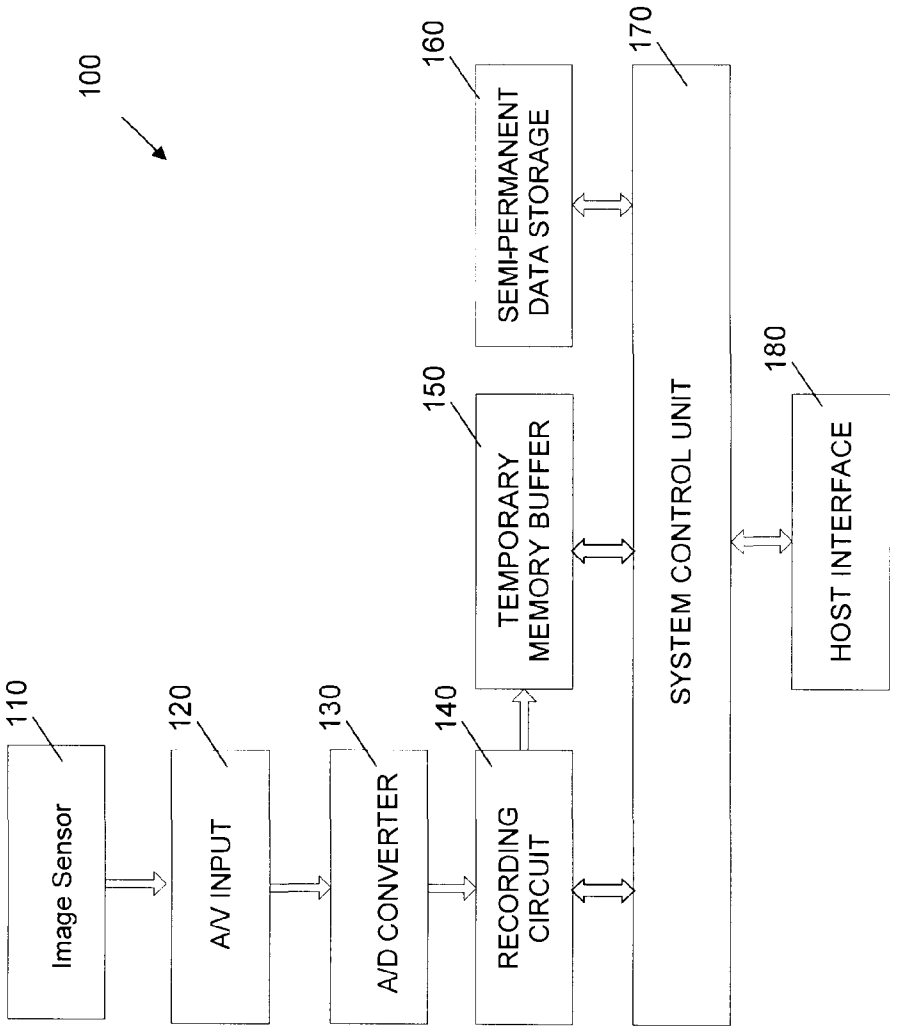
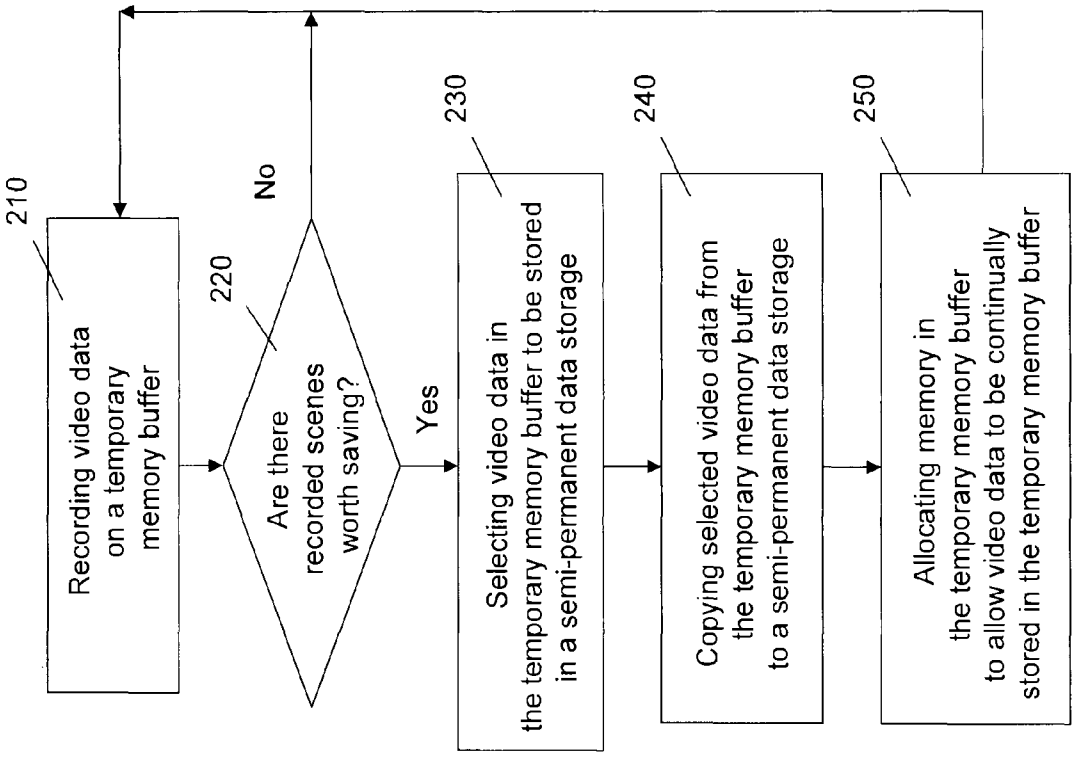

100
110
Image Sensor
120
A/V INPUT
130
A/D CONVERTER
140
RECORDING CIRCUIT
150
TEMPORARY MEMORY BUFFER
160
SEMI-PERMANENT DATA STORAGE
170
SYSTEM CONTROL UNIT
180
HOST INTERFACE

Figure 1

Figure 2


210
Recording video data on a temporary memory buffer
220
Are there recorded scenes worth saving?
No
Yes
230
Selecting video data in the temporary memory buffer to be stored in a semi-permanent data storage
240
Copying selected video data from the temporary memory buffer to a semi-permanent data storage
250
Allocating memory in the temporary memory buffer to allow video data to be continually stored in the temporary memory buffer

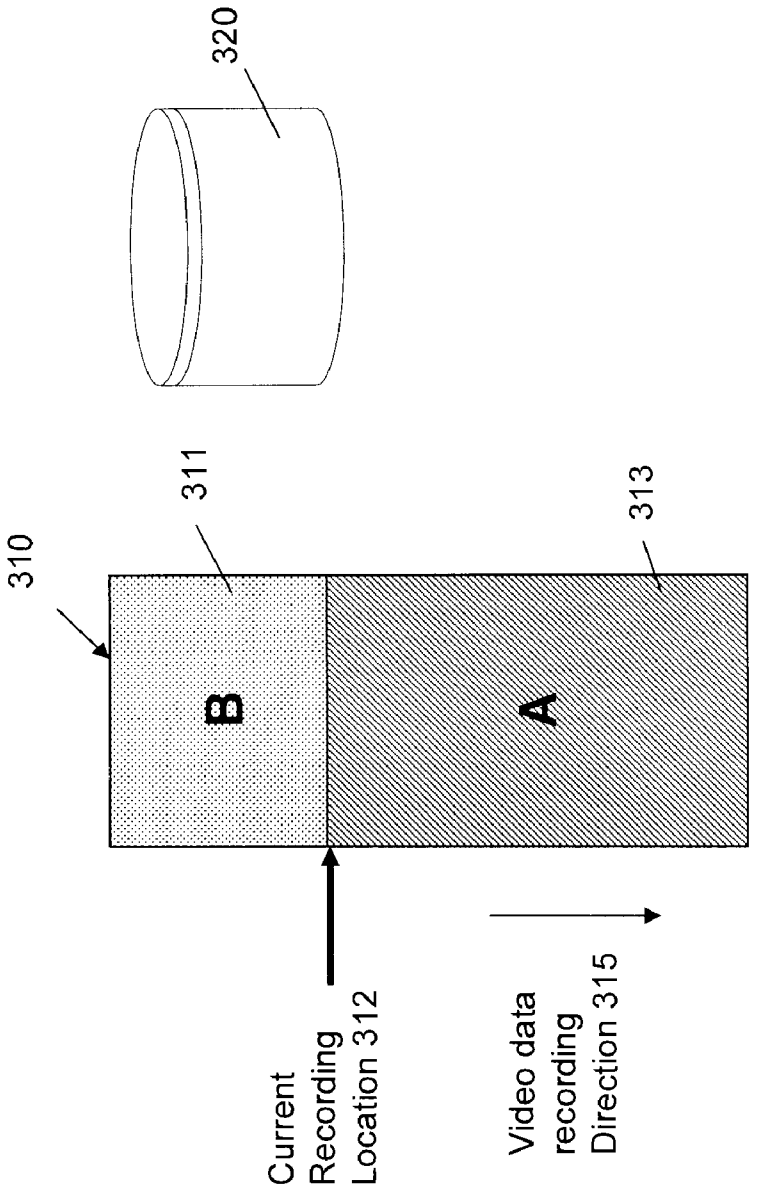

320
311
313
310
B
A
Current Recording Location 312
Video data recording Direction 315

Figure 3A

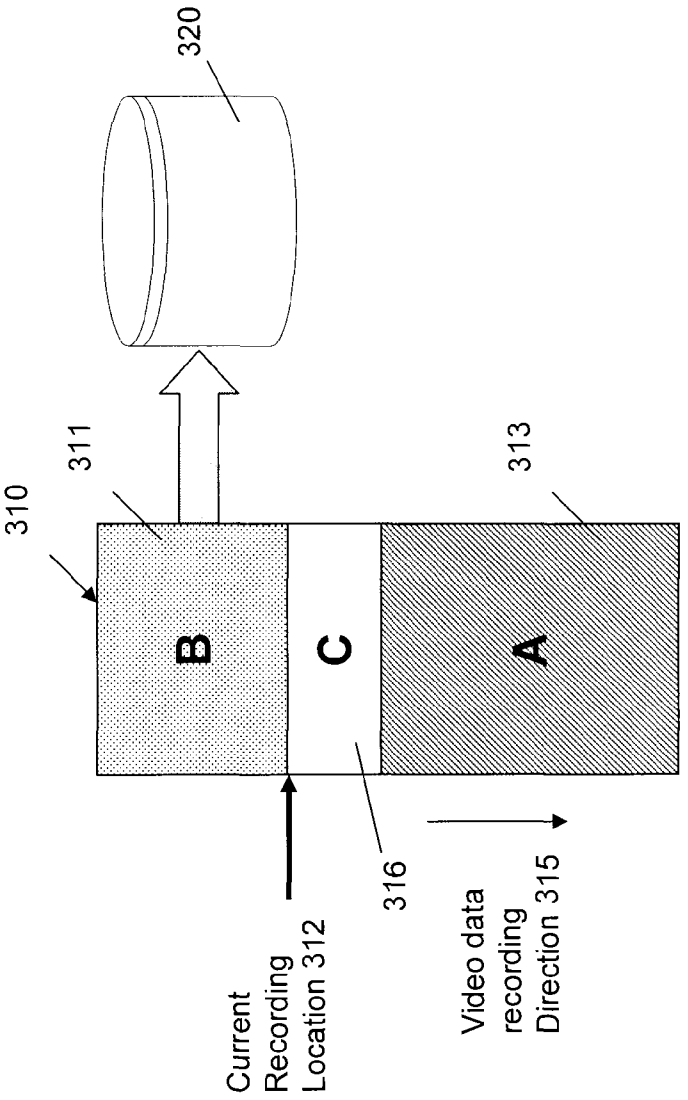

320
311
313
310
B
C
A
316
Current Recording Location 312
Video data recording Direction 315

Figure 3B

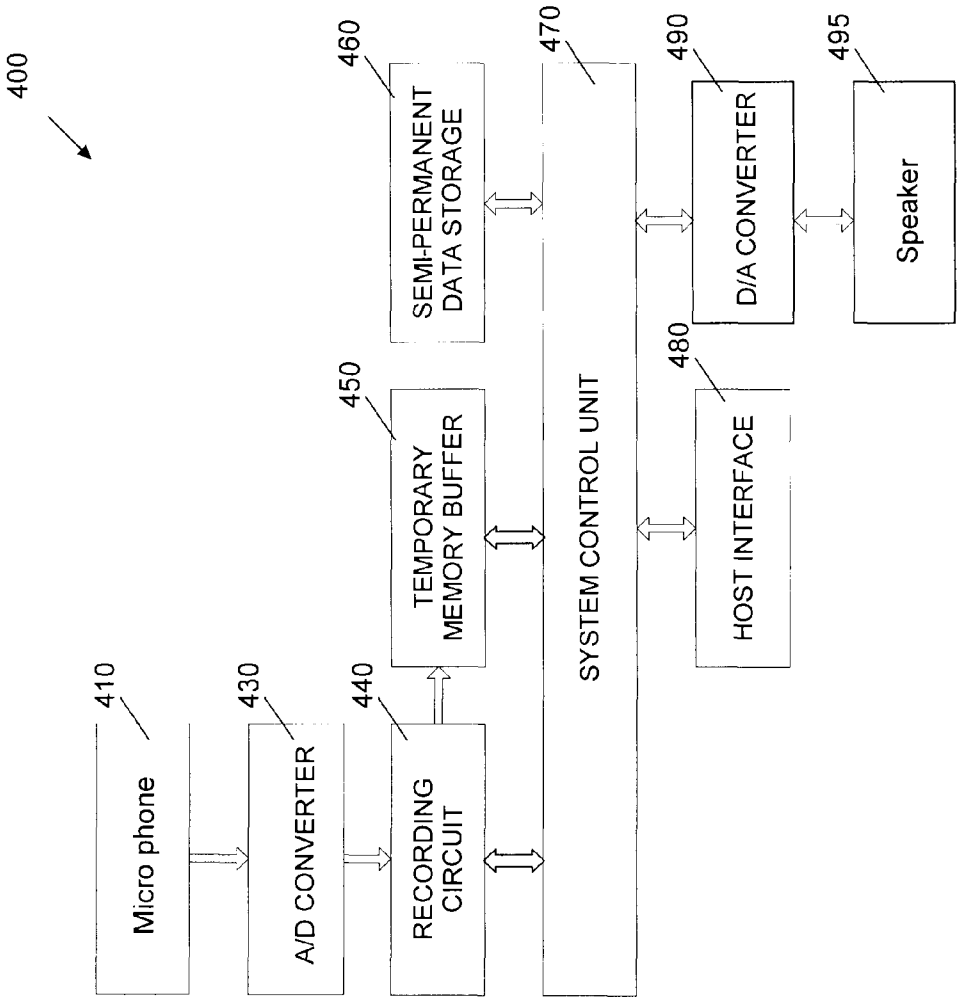
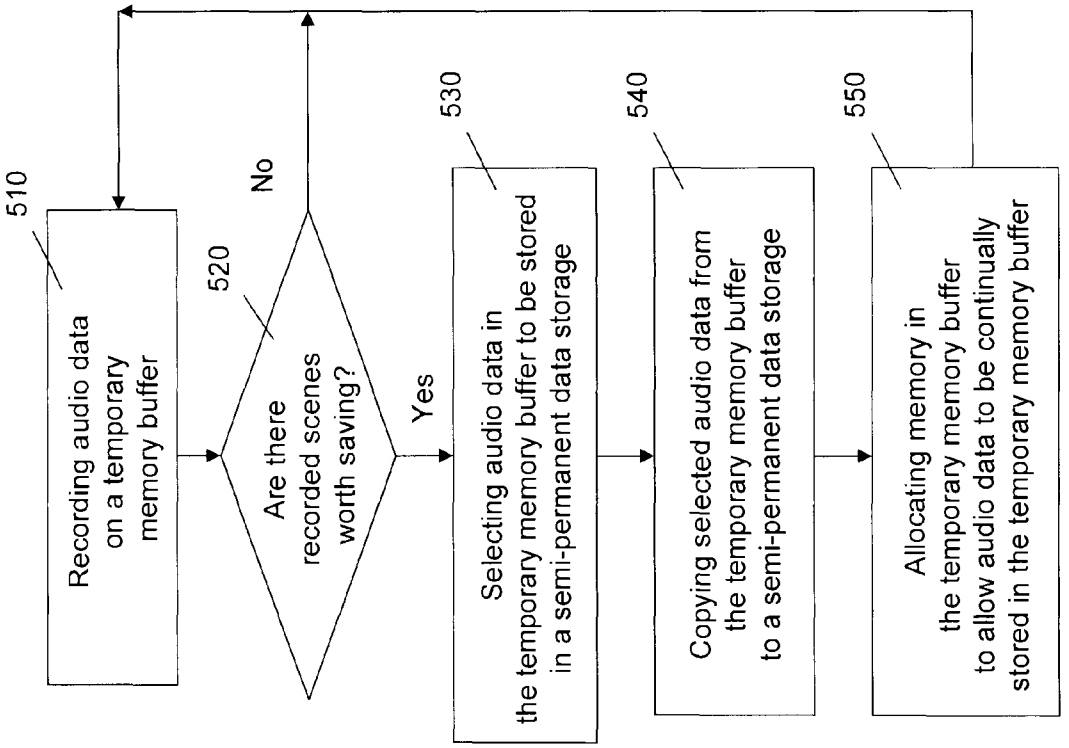

400
410
Micro phone
430
A/D CONVERTER
440
RECORDING CIRCUIT
450
TEMPORARY MEMORY BUFFER
460
SEMI-PERMANENT DATA STORAGE
470
SYSTEM CONTROL UNIT
480
HOST INTERFACE
490
D/A CONVERTER
495
Speaker

Figure 4

Figure 5


510
Recording audio data on a temporary memory buffer
520
Are there recorded scenes worth saving?
No
Yes
530
Selecting audio data in the temporary memory buffer to be stored in a semi-permanent data storage
540
Copying selected audio data from the temporary memory buffer to a semi-permanent data storage
550
Allocating memory in the temporary memory buffer to allow audio data to be continually stored in the temporary memory buffer

DIGITAL CAMCORDER DESIGN AND METHOD FOR CAPTURING HISTORICAL SCENE DATA

CROSS REFERENCES TO RELATED APPLICATIONS

[0001] This application claims the benefit of priority under 35 U.S.C. Section 120 of the Provisional U.S. Patent Application Ser. No. 60/721,112, entitled "DIGITAL CAMCORDER DESIGN AND METHOD FOR CAPTURING HISTORICAL SCENE DATA", filed Sep. 28, 2005 and U.S. Provisional Patent Application Ser. No. 60/721,111, titled "DIGITAL AUDIO RECORDER DESIGN AND METHOD FOR CAPTURING HISTORICAL DATA", filed Sep. 28, 2005. The content of these patent applications is incorporated herein by reference.

BACKGROUND

[0002] This application relates to a video or audio recording device.

[0003] Video photography is a popular way for people to capture and preserve valued memories. Video camcorders have become prolific in the consumer market space. To capture a scene of interest, a photographer turns on a camcorder and presses a button to set the camcorder to a "record" mode. The scenes are captured by an image sensor and converted to video data in the video camcorder. The video data are typically recorded on a replaceable storage device such as magnetic tape, DVD-R, CD-R, etc. The camcorder can also be set at an "Idle mode" in which no scene images are being captured. One drawback with current camcorders is that a photographer often misses a scene or a moment worth recording because the photographer can often not react fast enough to record a scene. Another drawback of the video recording using the current camcorders is that a photographer often has to record long periods of uninteresting scenes without knowing whether anything worthwhile will occur.

SUMMARY

[0004] In one aspect, the present invention relates to a method for video recording. The method including producing a first video data by an image sensor in a video recording device; storing the first video data in a temporary memory buffer in the video recording device; selecting at least a portion of the first video data in a semi-permanent data storage; and copying the selected portion of the first video data from the temporary memory buffer to the semi-permanent data storage in the video recording device.

[0005] In another aspect, the present invention relates to a method for audio recording. The method includes producing a first audio data by a micro phone in an audio recording device; storing the first audio data in a temporary memory buffer in the audio recording device; selecting at least a portion of the first audio data in a semi-permanent data storage; and copying the selected portion of the first audio data from the temporary memory buffer to the semi-permanent data storage in the audio recording device.

[0006] In another aspect, the present invention relates to a video recording device including an image sensor configured to produce a first video data and a second video data; and a recording system in electronic communication with the image sensor, wherein the recording system is configured to store the first video data in a temporary memory buffer in a first video recording mode and to store the second video data in a semi-permanent data storage in a second video recording mode, wherein at least a portion of the first video data is configured to be copied from the temporary memory buffer to the semi-permanent data storage. Implementations of the system may include one or more of the following. The semi-permanent data storage can be selected from the group of a magnetic tape, a recordable disk, a hard drive, a DVD-R, and a CD-R. The temporary memory buffer can be selected from the group of random access memory (RAM), dynamic random access memory (DRAM), static random access memory (SRAM), EEPROM, and a flash memory. The method can further include writing the most recent portion of the first video data over the oldest portion of the first video data in the temporary memory buffer. The first video data can be more than the capacity of the temporary memory buffer. The step of selecting can include determining if at least a portion of the first video data is worth storing in a semi-permanent data storage, and if at least a portion of the first video data is determined to be worth storing in a semi-permanent data storage, selecting at least the portion of the first video data. The method can further include producing a second video data by the image sensor; and storing the second video data in the temporary memory buffer in the video recording device while the selected portion of the first video data is copied from the temporary memory buffer to the semi-permanent data storage in the video recording device. The method can further include producing a second video data by an image sensor in a video recording device and storing the second video data in the semi-permanent data storage without storing the second video data in the temporary memory buffer.

[0007] Implementations of the system may include one or more of the following. The semi-permanent data storage can be selected from the group of a magnetic tape, a recordable disk, a hard drive, a DVD-R, and a CD-R. The temporary memory buffer can be selected from the group of random access memory (RAM), dynamic random access memory (DRAM), static random access memory (SRAM), EEPROM, and a flash memory. At least one of the semi-permanent data storage and the temporary memory buffer can be configured to be removed from the video recording device and inserted into the video recording device such that the one of the semi-permanent data storage and the temporary memory buffer is in electronic communication with the recording system. The temporary memory buffer can include a circular buffer that allows the recording system to write the most recent portion of the first video data over the oldest portion of the first video data in the temporary memory buffer. The video recording device can further include a user interface that allows a user to select at least a portion of the first video data to be copied to the semi-permanent data storage. The temporary memory buffer can include a data pointer configured to indicate the current recording location in which the next video data is to be written in the temporary memory buffer.

[0008] The disclosed system and methods include the following advantages. The disclosed system and methods allow a photographer to not miss scenes or moments worth recording. The disclosed system and methods provide a video camcorder a novel "temporary recording mode" in addition to the conventional "idle mode" and "record

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mode". The "temporary recording mode" allows scenes to be continually recorded in a temporary memory buffer without storing the video data in semi-permanent data storage on the camcorder. The disclosed system and methods allow historical scenes captured in the "temporary recording mode" to be reviewed by the photographer. The photographer can make decision after the recording of the scenes whether the recorded video data is worth storing on the semi-permanent data storage such as a magnetic tape, DVD-R, CD-R. Only noteworthy scenes can be selectively recorded in the semi-permanent data storage while uninteresting scenes can be discarded. The disclosed system and methods allow interesting scenes to be recorded without filling up the memories in the video recording system with uninteresting video data. The disclosed system and methods are compatible with a variety of digital camcorders including those that use the MiniDV format as well as HD camcorders that use MPEG-2 or MPEG-4 compression.

[0009] The disclosed system and methods also provides an improved audio recording device that can continually record audio signals on a temporary memory buffer in a temporary recording mode. After an audio signal has been recorded, the user can decide the save the temporarily recorded audio signal in the semi-permanent data storage on the audio recording device. The disclosed system and methods allow a user to save historically recorded and audio signals without unnecessarily recording too much uninteresting audio data and filling up the memories in the audio device.

[0010] The details of one or more embodiments are set forth in the accompanying drawing and in the description below. Other features, objects, and advantages of the invention will become apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. **1** is a block diagram of the video recording device in accordance with the present specification.

[0012] FIG. **2** illustrates a process for capturing a historically captured scene data using the video recording device of FIG. **1**.

[0013] FIGS. **3**A illustrate an arrangement of data structure compatible with the video recording device of FIG. **1**.

[0014] FIGS. **3**B illustrate a data copying process from the temporary memory buffer to the semi-permanent data storage in the video recording device of FIG. **1**.

[0015] FIG. **4** is a block diagram of the audio recording device in accordance with the present specification.

[0016] FIG. **5** illustrates a process for capturing a historically captured audio data using the audio recording device of FIG. **4**.

DETAILED DESCRIPTION

[0017] FIG. **1** illustrates a video recording device **100**. Examples of the video recording device **100** include digital or analog camcorders. The video recording device **100** can include an image sensor **10** that can be based on CCD, CMOS, or other types of sensors. The image sensor **110** can include sensors for capturing light in different spectral ranges such as red, green, blue, infrared, or UV. The video recording device **100** can include an optical system that can project a scene to form an image at the image sensor **110**. The video recording device **100** can include an A/V input circuit **120** that receives and processes the analog video signal from the image sensor **110** and an Analog-to-Digital (A/D) converter **130** that can convert the analog video signals to digital video signals. The video signals can include image signals and audio signals. The digital video signals can be represented in a series of image frames that correspond to a series of captured scenes. The video recording device **100** can further include an image processor that can conduct image processing operations as color plane construction from the color filter array, tone calibration, color calibration, noise compensation, image correction, image compression, and transformation to a specified video standard, etc. The image processing operations can be specified by predetermined criteria set by the manufacturer or by the user of the video recording device **100**.

[0018] The video signal (in digital or analog format) can be transferred to a recording circuit **140** that is in electronic communications with a temporary memory buffer **150** and a semi-permanent data storage **160** via a system control unit **170**.

[0019] The temporary memory buffer **150** and the semi-permanent data storage **160** can be detached and replaced. Examples of the temporary memory buffer **150** include a random access memory (RAM), dynamic random access memory (DRAM), static random access memory (SRAM), electrically erasable programmable read-only memory (EEPROM) such as a flash memory, and so on. Examples of the semi-permanent data storage **160** can include magnetic tape for digital or analog recording format (e.g. Mini-DV magnetic tape, Digital 8 mm magnetic tape, Hi-8 mm magnetic tape, or 8 mm magnetic tape, etc.), DVD-R, CD-R, hard drives, etc.

[0020] In some embodiments, the temporary memory buffer **150** can be overwritten by data many times. The data stored in the temporary memory buffer **150** does not need to retain its contents when the video recording device **100** is powered "off". The semi-permanent data storage **160** can store digital data that can retain its content either the video recording device **100** is powered "on" or "off".

[0021] The recording circuit **140** can include a recording head that is compatible with the type of semi-permanent data storage **160** such as magnetic tape, DVD-R, CD-R, hard drives. For example, the recording head can include a magnetic head for writing data on a magnetic tape or on a hard drive. The recording head can also include a laser head for writing data on a DVD-R or a CD-R disk. The video recording system **100** can also include mechanisms for receiving and holding the temporary memory buffer **150** and the semi-permanent data storage **160**. The recording circuit **140** can control the writing of video data in the temporary memory buffer **150** or the semi-permanent data storage **160** in response to the video signal. The recording circuit **140** can also the read of the video data stored in temporary memory buffer **150** or the semi-permanent data storage **160**. A host interface **180** in electronic communication with the system control unit **170** allows the video data stored on the temporary memory buffer **150** and the semi-permanent data storage **160** to be transmitted to external devices.

[0022] The video recording device **100** is illustrated in a flow chart in FIG. **2**. After being switched on, the video

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recording device **100** can be automatically set to an "idle mode". Similar to conventional camcorder devices, the video recording device **100** can include a "record mode" in which video data produced by the image sensor **110**, the A/V input **120**, and A/D converter **130** can be recorded directly onto the semi-permanent data storage **160**. The "record mode" can be used by a photographer who is sure that the scenes are interesting and worth recording.

[**0023**] The video recording device **100** can also include a "temporary record mode". The photographer can set the video recording device **100** into the "temporary record mode" by pushing a button, an icon on a touch screen, or by voice instruction using a voice recognition system. The video data produced by the image sensor **110**, the A/V input **120**, and A/D converter **130** is stored in the temporary memory buffer **150** (step **210**). The photographer can use the "temporary record mode" when scenes are not worth recording at the moment but some interesting worth recording might occur. For example, a mother can set the video recording device **100** in the "temporary record mode" when her baby is playing at home in case the bay may produce some interesting expressions or actions that are worth recording.

[**0024**] In some embodiments, an implementation the temporary memory buffer **150** is shown in FIG. **3**A, the temporary memory buffer **310** can be a circular (or ring) memory buffer. The video data can be continually stored to the temporary memory buffer **310** in a sequence as denoted by a video data recording direction **315**. The video data stored in the temporary memory buffer **310** can include a video data portion **311** ("B" in FIG. **3**A) that includes the most recently recorded video data, and a video data portion **313** ("A" in FIG. **3**A) that were oldest video data. A data pointer **312** indicates the current recording location, that is, the data location in which the next video data is to be written in the temporary memory buffer **310**. In the continually recording mode, the current recording location is normally at the end of the most recent video data **311**. The temporary memory buffer **310** can be substantially filled with the video data. New video data received by the temporary memory buffer **310** can be automatically written over the oldest video data portion **313**. The data pointer **312** concurrently moves down to the end of the video data portion **311** to update the current recording location **312**. When the bottom of the temporary memory buffer **310** is reached, the recording circuit **140** continues writing at the top of the temporary memory buffer **310**.

[**0025**] The maximum duration of a video clip that can be stored in the temporary memory buffer **310** can be determined by at least the following two factors:

[**0026**] 1) the size of temporary memory buffer;

[**0027**] 2) the compression technique used on the digital audio and video data.

[**0028**] For example, the data rate of a standard MiniDV video format is approximately 3.6 MB/second. A temporary memory buffer **310** with 54 MB storage capacity can hold video data for 15 seconds of historical scenes. The HD digital video has data rates in the range from about 2 MB/second to about 4 MB/second depending on format and compression ratio. A temporary memory buffer **310** having a 128 MB storage capacity can hold about 30 to 60 seconds of video data in the HD digital video format. The duration of the video clip that can be stored in the temporary memory buffer **310** can be increased by using larger capacity memories in the temporary memory buffer **310**.

[**0029**] The photographer can determine whether the video data stored in the temporary memory buffer **310** is worth saving (step **220**). For example, the baby may have made an interesting sound or made a nice smile when the baby is recorded in the "temporary record mode" by a parent. The parent can decide some or all the video data in the video data portion **311** and **313** is worth saving in the semi-permanent data storage **160**. The parent may select a portion of the video data in the video data portions **311** and **313** (step **230**) and copy the selected video data portion to the semi-permanent data storage **160** (step **240**), as shown in FIG. **3**B.

[**0030**] The photographer may be able to preview the video data portions **311** and **313** to determine which portion of the video data is to be copied to the semi-permanent data storage **160**. The video recording device **100** can also include user interface features to allow the photographer to copy the selected video data portion on the semi-permanent data storage **160**.

[**0031**] In some embodiments, a portion **316** of the temporary memory buffer **310** can be reserved to keep recording while the selected video data is being copied from the temporary memory buffer **150** to the semi-permanent data storage **160** (step **250**). New scenes can be continually captured by the image sensor **110** and stored in the temporary memory buffer **150** while the selected image data is copied. This technique can prevent "glitches" in the video data for a continuous series of image scenes.

[**0032**] In some embodiments, once the photographer decides that some portion of the video data stored in the temporary memory buffer **310** is worth saving, the video recording device can automatically kick into the "record mode" in which the additional video data produced by the image sensor **110**, the A/V input **120**, and A/D converter **130** is stored in the semi-permanent data storage **160**. The copying of the selected video data can occur simultaneously or asynchronously relative to the recording of the additional video data.

[**0033**] In some embodiments, the selected video data is transferred to the semi-permanent data storage **160** and deleted from the temporary memory buffer **150**. The freed up memory space can be immediately used for the recording of the new video data. In one implementation, the data pointer **312** for the current recoding location can also be moved to make use of the freed-up memory space.

[**0034**] It should be understood that the above disclosed system and methods are limited to the specific described examples. For example, the disclosed system and methods are compatible with both digital and analog video data that can be stored in the temporary memory buffer **150** and the semi-permanent data storage **160**.

[**0035**] The disclosed methods and design can similarly be applied to an audio recording device. FIG. **4** illustrates an audio recording device **400**. Examples of the audio recording device **400** include digital or analog camcorders. The audio recording device **400** can include a microphone **410**. The audio recording device **400** can include a microphone **410** and an Analog-to-Digital (A/D) converter **430** that can

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convert the analog audio signals to digital audio signals. The digital audio signals can be represented in a series of image frames that correspond to a series of captured scenes. The audio recording device **400** can further include a digital processor that can conduct processing operations on the audio signals. The audio processing operations can be specified by predetermined criteria set by the manufacturer or by the user of the audio recording device **400**.

[**0036**] The audio signal (in digital or analog format) can be transferred to a recording circuit **440** that is in electronic communications with a temporary memory buffer **450** and a semi-permanent data storage **460** via a system control unit **470**. A host interface **480** is in electronic communication with the system control unit **470**. The host interface **480** is used to connect the device to a host computer and is used to transfer the audio clips from the semi-permanent memory to the host computer. Examples of the actual host interface that could be used include, but are not limited to, USB or IEEE1394 (sometimes referred to as FireWire). The system control unit **470** allows transmitting the video data stored on the temporary memory buffer **450** and the semi-permanent data storage **460** to be transmitted to external devices. A digital-to-analog converter **490** can be connected with system control unit **470** that can receive digital audio data from the temporary memory buffer **450** and the permanent data storage **460**. The analog audio signal output by the D/A converter can be sent to a speaker **495** for playing the audio signal to a listener.

[**0037**] As shown in FIG. **5** and similar to the previous description about video recording device **100** in relation to FIGS. **3**A and **3**B, the audio recording device **400** allows audio data produced by a microphone **410** and an A/D converter **430** to be stored in a temporary memory buffer **450** (step **510**). The user can determine if the audio data stored in the temporary memory buffer **450** is worthwhile saving (step **520**). The audio signals stored in the temporary memory buffer **450** can be selected (step **530**) and copied to a semi-permanent data storage **460** (step **540**) if some audio signal worth saving has be recorded. A portion of the memory can be allocated in the temporary memory buffer **450** to allow smooth copying of the audio data from the temporary memory buffer **450** to the semi-permanent data storage **460** while audio data is continually recorded in the temporary memory buffer **450**. The arrangement allows a user to save historically recorded and audio signals without unnecessarily recording too much uninteresting audio data and filling up the memories in the audio device.

[**0038**] The temporary memory buffer **450** and the semi-permanent data storage **460** can be detached and replaced. Examples of the temporary memory buffer **450** include a random access memory (RAM), dynamic random access memory (DRAM), static random access memory (SRAM), electrically erasable programmable read-only memory (EEPROM) such as a flash memory, and so on. Examples of the semi-permanent data storage **460** can include EEPROM (flash memories, memory sticks and memory cards), magnetic tapes, hard drives, etc. Because audio data size tend to be smaller, similar types of storage devices can used for the temporary memory buffer **450** and the semi-permanent data storage **460**.

[**0039**] Although specific embodiments of the present invention have been illustrated in the accompanying drawings and described in the foregoing detailed description, it will be understood that the invention is not limited to the particular embodiments described herein, but is capable of numerous rearrangements, modifications, and substitutions without departing from the scope of the invention. The following claims are intended to encompass all such modifications.

What is claimed is:

1. A method for video recording, comprising:

producing a first video data by an image sensor in a video recording device;

storing the first video data in a temporary memory buffer in the video recording device;

selecting at least a portion of the first video data in a semi-permanent data storage; and

copying the selected portion of the first video data from the temporary memory buffer to the semi-permanent data storage in the video recording device.

2. The method of claim 1, wherein the semi-permanent data storage is selected from the group of a magnetic tape, a recordable disk, a hard drive, a DVD-R, and a CD-R.

3. The method of claim 1, wherein the temporary memory buffer is selected from the group of random access memory (RAM), dynamic random access memory (DRAM), static random access memory (SRAM), EEPROM, and a flash memory.

4. The method of claim 1, further comprising:

writing the most recent portion of the first video data over the oldest portion of the first video data in the temporary memory buffer.

5. The method of claim 1, wherein the first video data is more than the capacity of the temporary memory buffer.

6. The method of claim 1, wherein the step of selecting comprises:

determining if at least a portion of the first video data is worth storing in a semi-permanent data storage; and

if at least a portion of the first video data is determined to be worth storing in a semi-permanent data storage, selecting at least the portion of the first video data.

7. The method of claim 1, further comprising:

producing a second video data by the image sensor; and

storing the second video data in the temporary memory buffer in the video recording device while the selected portion of the first video data is copied from the temporary memory buffer to the semi-permanent data storage in the video recording device.

8. The method of claim 1, further comprising:

producing a second video data by an image sensor in a video recording device; and

storing the second video data in the semi-permanent data storage without storing the second video data in the temporary memory buffer.

9. A method for audio recording, comprising:

producing a first audio data by a micro phone in an audio recording device;

storing the first audio data in a temporary memory buffer in the audio recording device;

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selecting at least a portion of the first audio data in a semi-permanent data storage; and

copying the selected portion of the first audio data from the temporary memory buffer to the semi-permanent data storage in the audio recording device.

10. The method of claim 9, further comprising:

producing a second audio data by microphone in an audio recording device; and

storing the second audio data in the semi-permanent data storage without storing the second audio data in the temporary memory buffer.

11. The method of claim 9, further comprising:

writing the most recent portion of the first audio data over the oldest portion of the first audio data in the temporary memory buffer.

12. The method of claim 9, wherein the temporary memory buffer is selected from the group of random access memory (RAM), dynamic random access memory (DRAM), static random access memory (SRAM), EEPROM, and a flash memory.

13. The method of claim 9, wherein the step of selecting comprises:

determining if at least a portion of the first audio data is worth storing in a semi-permanent data storage; and

if at least a portion of the first audio data is determined to be worth storing in a semi-permanent data storage, selecting at least the portion of the first audio data.

14. A video recording device, comprising:

an image sensor configured to produce a first video data and a second video data; and

a recording system in electronic communication with the image sensor, wherein the recording system is configured to store the first video data in a temporary memory buffer in a first video recording mode and to store the second video data in a semi-permanent data storage in a second video recording mode, wherein at least a portion of the first video data is configured to be copied from the temporary memory buffer to the semi-permanent data storage.

15. The video recording device of claim 14, wherein the semi-permanent data storage is selected from the group of a magnetic tape, a recordable disk, a hard drive, a DVD-R, and a CD-R.

16. The video recording device of claim 14, wherein the temporary memory buffer is selected from the group of random access memory (RAM), dynamic random access memory (DRAM), static random access memory (SRAM), EEPROM, and a flash memory.

17. The video recording device of claim 14, wherein at least one of the semi-permanent data storage and the temporary memory buffer is configured to be removed from the video recording device and inserted into the video recording device such that the one of the semi-permanent data storage and the temporary memory buffer is in electronic communication with the recording system.

18. The video recording device of claim 14, wherein the temporary memory buffer comprises a circular buffer that allows the recording system to write the most recent portion of the first video data over the oldest portion of the first video data in the temporary memory buffer.

19. The video recording device of claim 14, further comprising a user interface that allows a user to select at least a portion of the first video data to be copied to the semi-permanent data storage.

20. The video recording device of claim 14, wherein the temporary memory buffer comprises a data pointer configured to indicate the current recording location in which the next video data is to be written in the temporary memory buffer.

* * * * *

Appendix HH

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(54) MULTI-STAGE MEMORY BUFFER AND AUTOMATIC TRANSFERS IN VEHICLE EVENT RECORDING SYSTEMS

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(21) Appl. No.: **11/297,669**

(22) Filed: **Dec. 8, 2005**

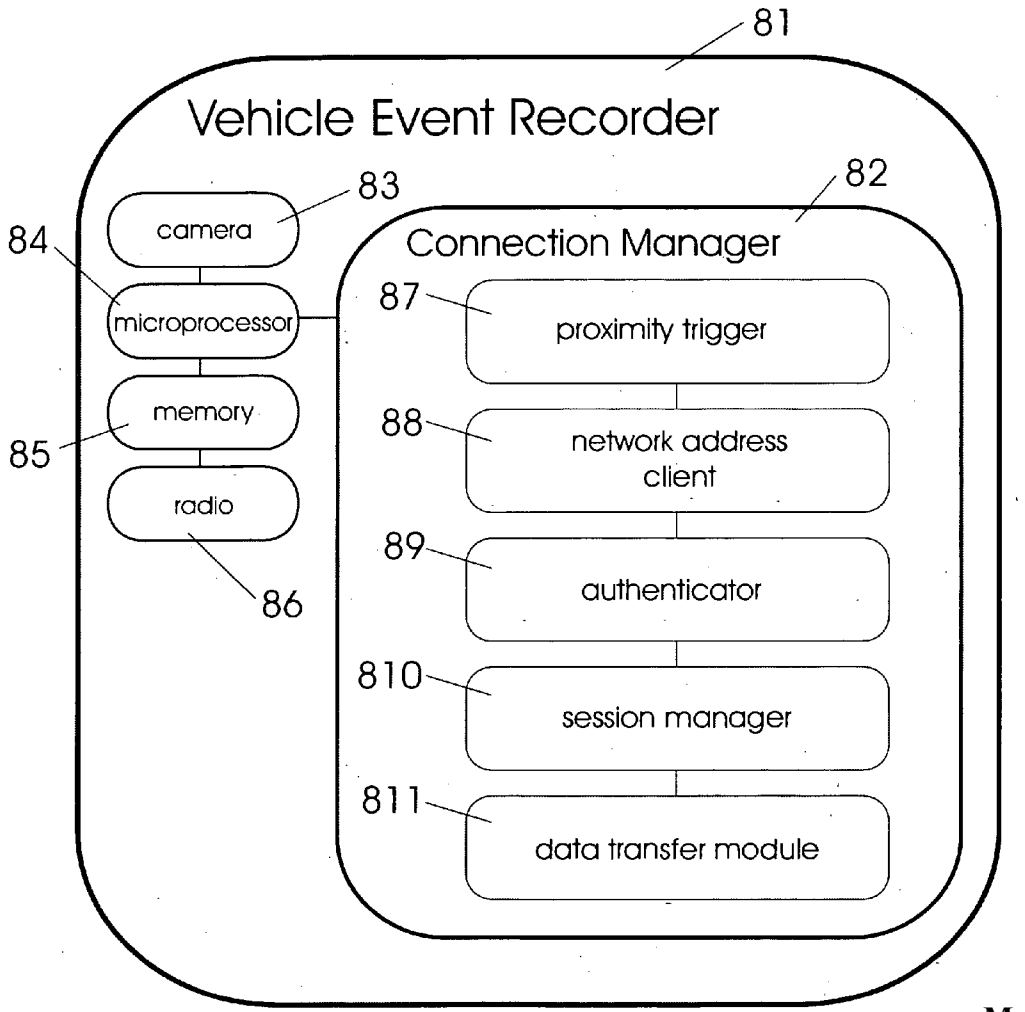
Publication Classification

(51) **Int. Cl.**
G06F 12/00 (2006.01)

(52) **U.S. Cl.** **345/564**

(57) **ABSTRACT**

Vehicle event recorder systems are arranged with three stage memories and special mechanism to manage those memories including transfer of data there between. Namely, a managed loop memory receives data from a video camera in real-time and continuously overwrites expired data implicitly determined no longer useful. Data in a managed loop memory is only passed to a more stable memory, a high-capacity buffer memory, in response to an event having occurred. An event trigger produces a signal, which causes data transfer between the managed loop memory and an on-board, high-capacity buffer memory. The high-capacity buffer memory is suitable for storing video series associated with a plurality of events. Finally, a permanent data store is arranged to receive data from the high-capacity buffer memory whenever the system returns and falls within a predetermined proximity of a download station.



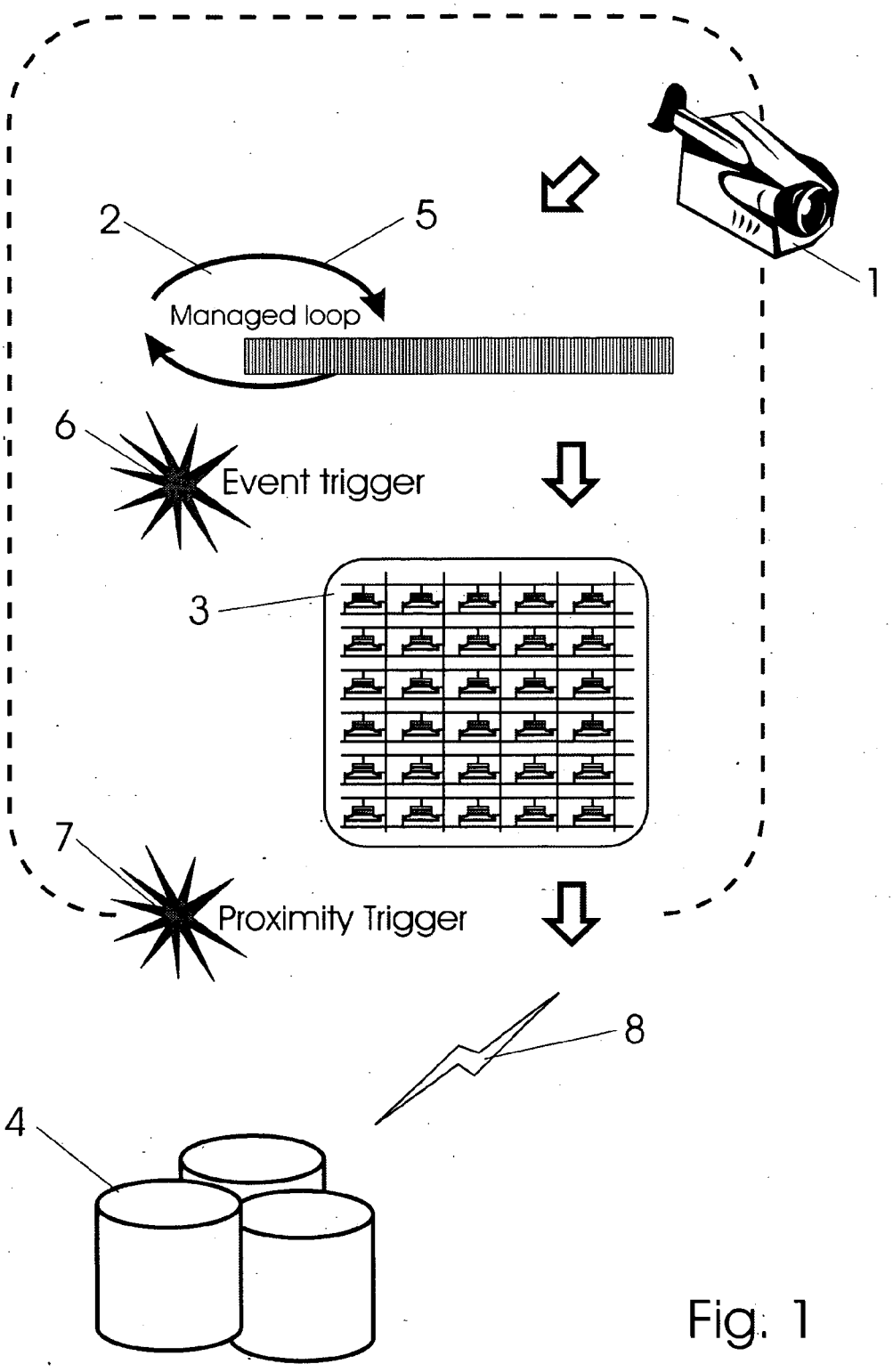


Fig. 1

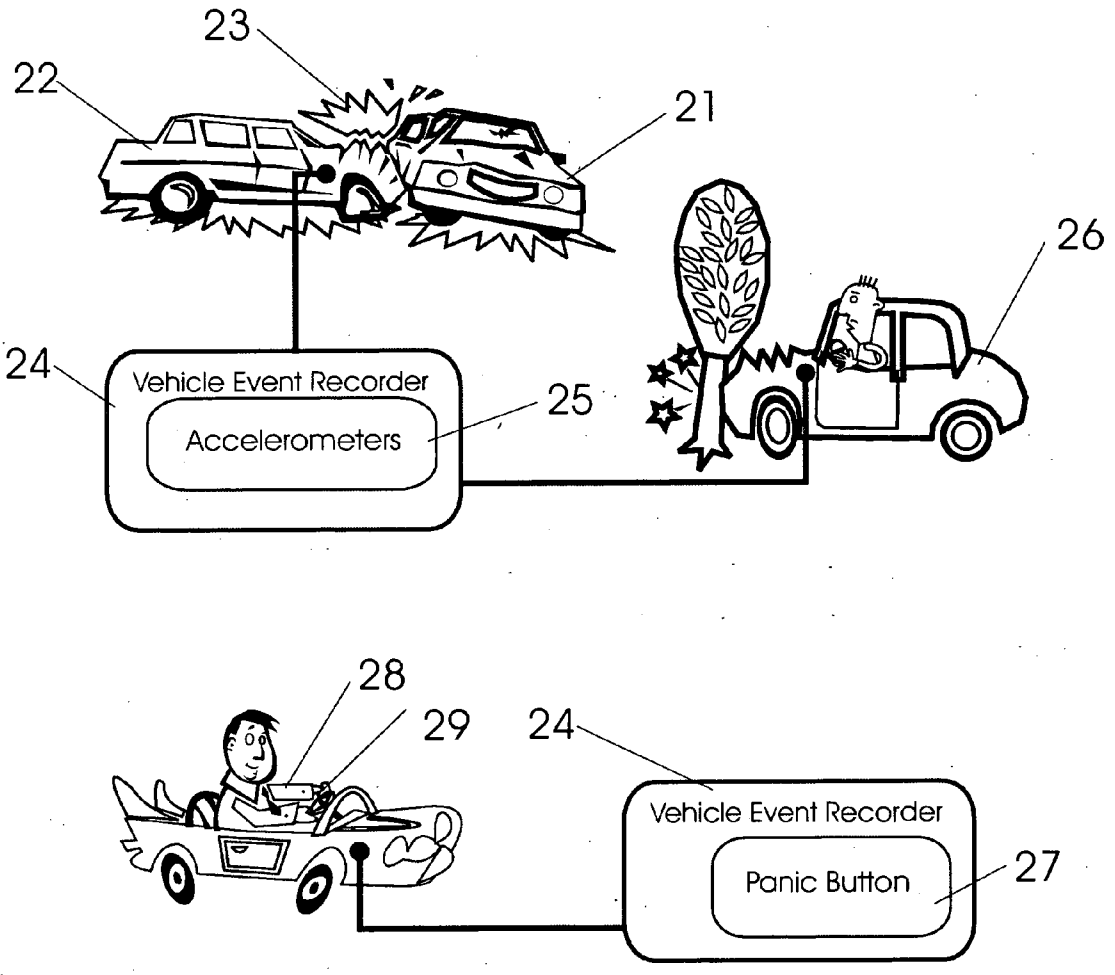

23
22
21
26
24
Vehicle Event Recorder
Accelerometers
25
28
29
24
Vehicle Event Recorder
Panic Button
27

Fig. 2

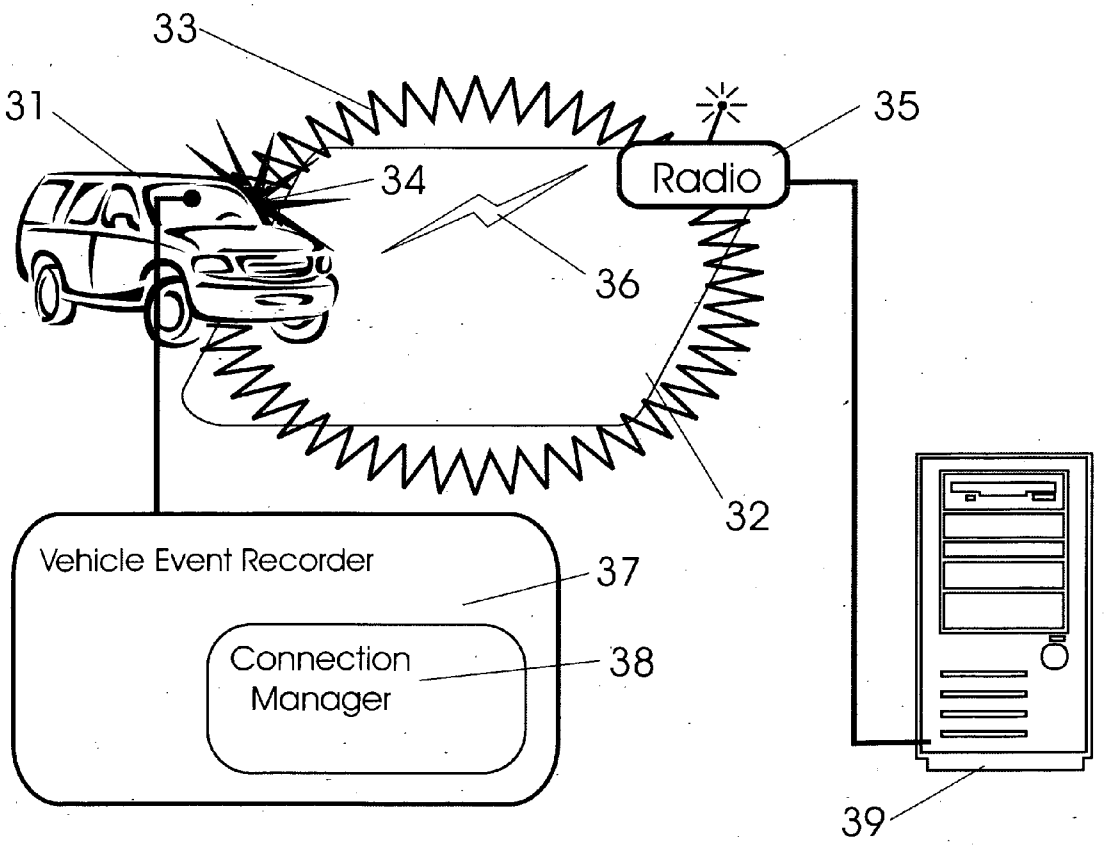

33
31
35
34
Radio
36
32
Vehicle Event Recorder
37
Connection
Manager
38
39

Fig. 3

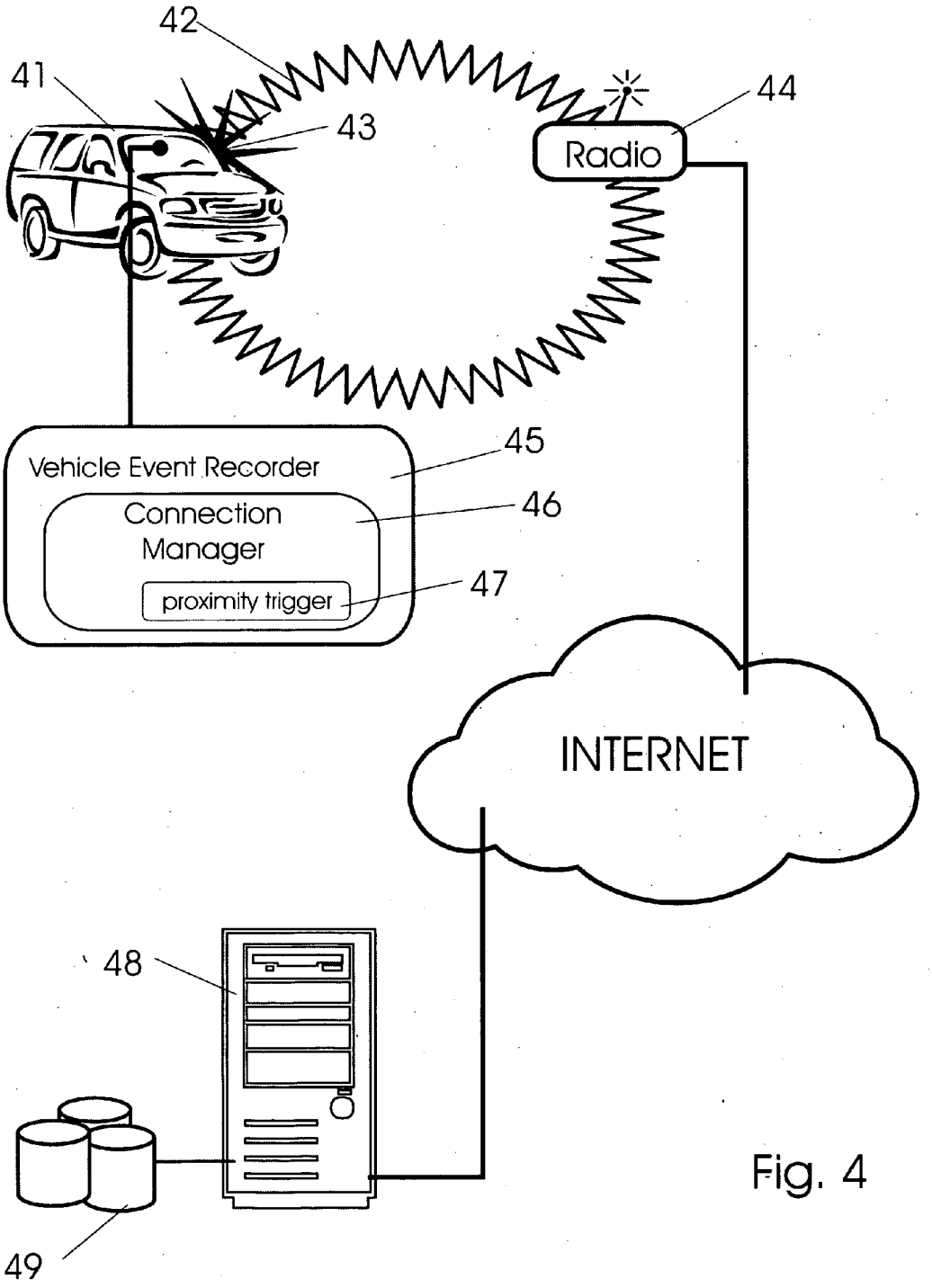

42
41
43
44
Radio
Vehicle Event Recorder
45
Connection Manager
46
proximity trigger
47
INTERNET
48
49

Fig. 4

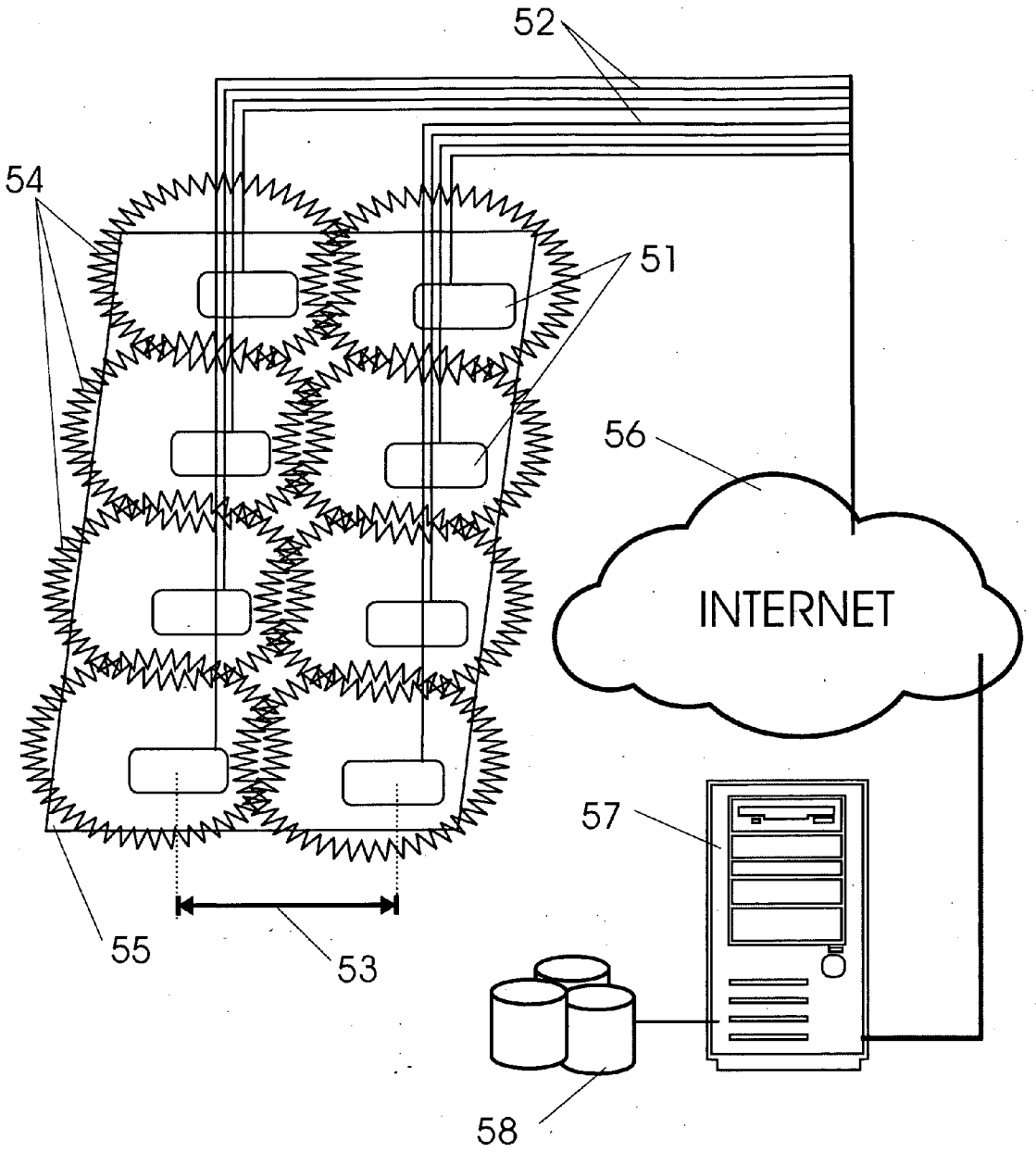


Fig. 5

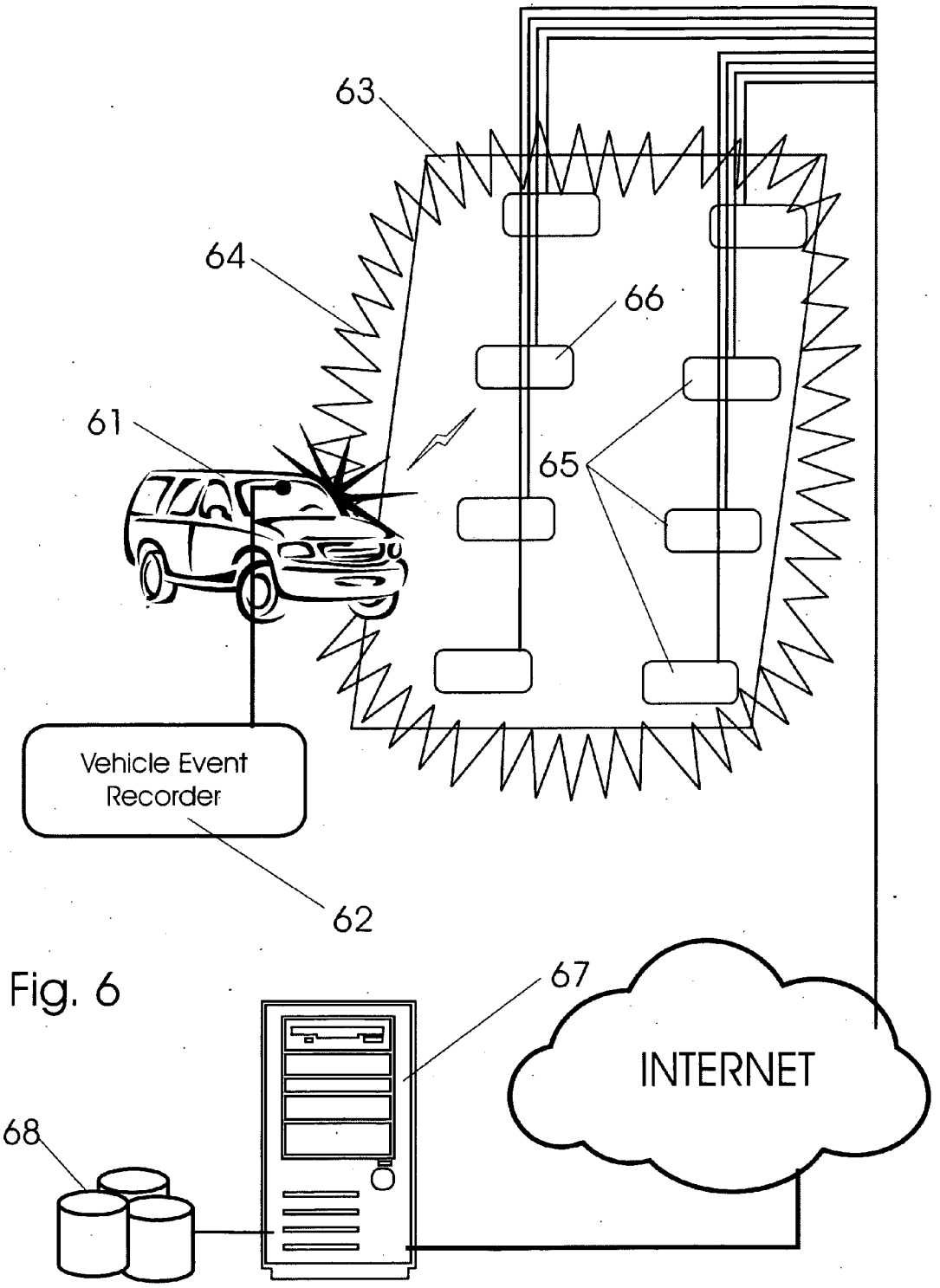


Fig. 6

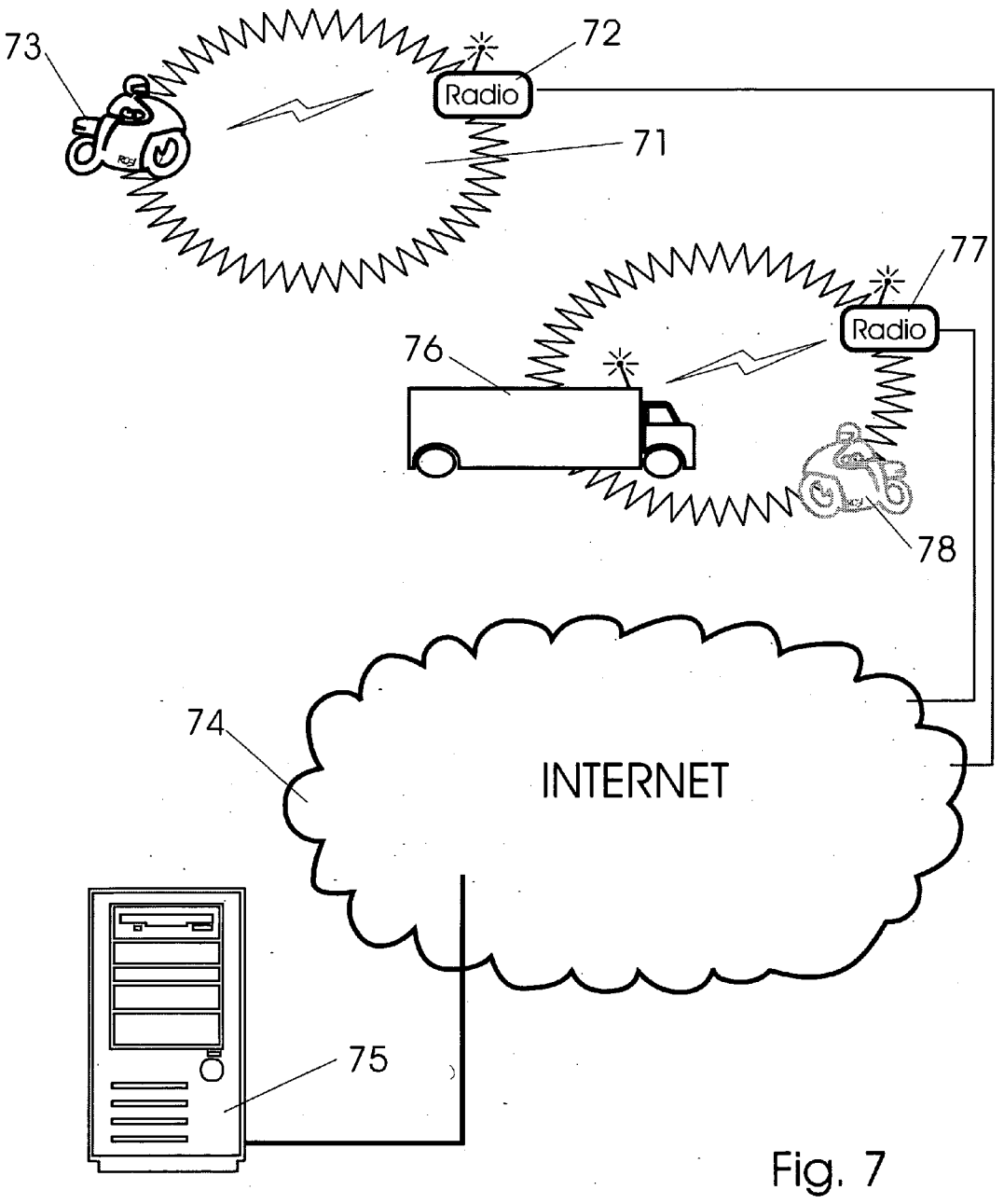


Fig. 7

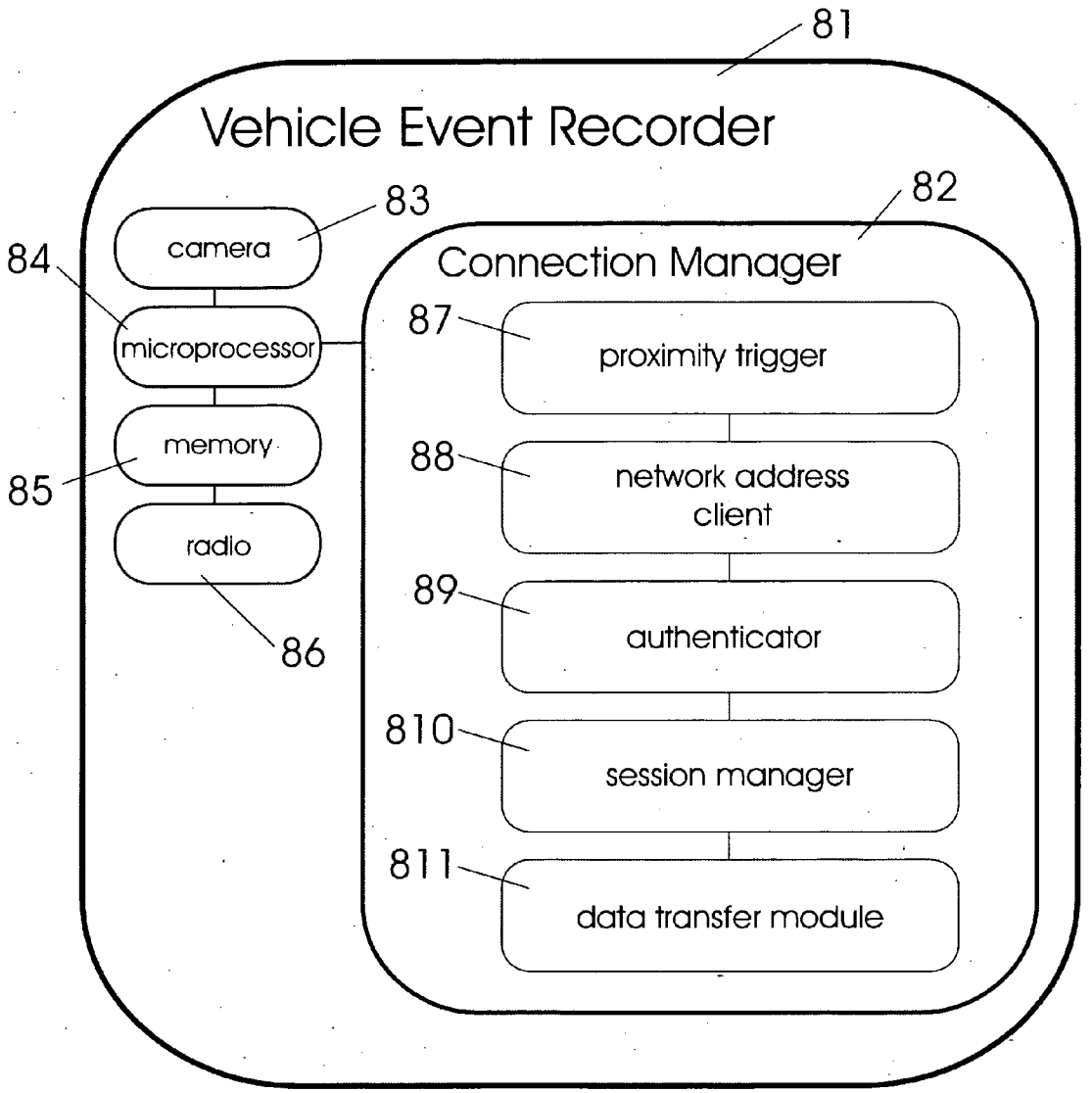

81
Vehicle Event Recorder
83
82
camera
84
Connection Manager
microprocessor
87
proximity trigger
memory
88
network address client
85
radio
89
authenticator
86
810
session manager
811
data transfer module

Fig. 8

MULTI-STAGE MEMORY BUFFER AND AUTOMATIC TRANSFERS IN VEHICLE EVENT RECORDING SYSTEMS

BACKGROUND OF THE INVENTIONS

[0001] 1. Field

[0002] The following inventions disclosure is generally concerned with memory management in video event recorder systems and specifically concerned with a multi-stage memory strategy which permits highly automated data transfer with maximized efficiency for application-specific configurations.

[0003] 2. Prior Art

[0004] Inventor Schmidt presents in U.S. Pat. No. 5,570,127, a video recording system for a passenger vehicle, namely a school bus, which has two video cameras one for an inside bus view and one for a traffic view, a single recorder, and a system whereby the two cameras are multiplexed at appropriate times, to the recording device. Schmidt suggests using video recording devices having video input ports, which are well known to skilled artisan. He does not include any for proposal for unique memory management; but rather clearly indicates that the known memories which are suitable for general-purpose video recording are similarly suitable for his inventions.

[0005] Thomas Doyle of San Diego, Calif. and QUALCOMM Inc. also of San Diego, present an invention for a method and apparatus for detecting fault conditions in a vehicle data recording device to detect tampering or unauthorized access, in U.S. Pat. No. 5,586,130. The system includes vehicle sensors for monitoring one or more operational parameters of the vehicle. Inventor Doyle includes non-volatile RAM as part of his system for handling all memory function. While non-volatile RAM is highly useful in most applications, non-volatile RAM has certain lifetime issues when the number of rewrites is very high.

[0006] A "computerized vehicle log" is presented by Dan Kikinis of Saratoga Calif. in U.S. Pat. No. 5,815,093. The vehicle accident recording system employs a digital camera connected to a controller in non-volatile memory, and an accident sensing interrupter. These systems include complex relationships between a plurality of memories. Kikinis' systems include program memory ROM, RAM, data memory, multi-sectored flash memory, memory tapes, disk drives, among others. In the non-volatile memory, oldest images are overwritten by newer images until an accident is detected. At that time, the memory is blocked from further overwrites. Mr. Kikinis instructs that in preferred embodiments, the system has a communications port whereby stored images are downloaded after an accident to a digital device capable of displaying images. This feature is described in greater detail in the specification which indicates download to a server having specialized image handling and processing software thereon. Further at column 5, lines 60 to 67, Kikinis indicates that a user connects an output medium to a transfer terminal and activates vehicle log program software to download data from data memory to the output medium.

[0007] A vehicle crash data recorder is presented by inventor Ferguson of Bellaire, Ohio in U.S. Pat. No. 6,185,490. The apparatus is arranged with a three stage memory to record and retain information. And further it is equipped with series and parallel connectors to provide instant on-scene access to accident data. It is important to note that Ferguson finds it important to include the possibility of on-site access to the data. Further, that Ferguson teaches use of a wired connection in the form of a serial or parallel connector. This teaching of Ferguson is common in many advanced systems configured as vehicle event recorders.

[0008] A traffic accident data recorder and traffic accident reproduction system and method is presented as U.S. Pat. No. 6,246,933. A plurality of sensors for registering vehicle operation parameters including at least one vehicle mounted digital video, audio camera is included for sensing storing and updating operational parameters. A re-writable, non-volatile memory is provided for storing those processed operational parameters and video images and audio signals, which are provided by the microprocessor controller. Data is converted to a computer readable form and read by a computer such that an accident can be reconstructed via data collected.

[0009] U.S. Pat. No. 6,298,290 presented by Abe et al, teach a memory apparatus for vehicle information data. A plurality of sensors including a CCD camera, a collision sensor, vehicle speed sensors, brake pressure sensor, acceleration sensor, are all coupled to a control unit. Further, the control unit passes information to a flash memory and a RAM memory subject to an encoder. Information collected is passed through a video output terminal. This illustrates another hardwire system and the importance placed by experts in the art on a computer hardware interface. This is partly due to the fact that video systems are typically data intensive and wired systems are necessary as they have bandwidth sufficient for transfers of large amounts of data.

[0010] U.S. Pat. No. 6,389,339 granted to Inventor Just, of Alpharetta, Ga. teaches a vehicle operation monitoring system and method. Operation of a vehicle is monitored with an on-board video camera linked with a radio transceiver. A monitoring service includes a cellular telecommunications network to view video data received from the transceiver to a home-base computer. These systems are aimed at parental monitoring of adolescent driving. The mobile modem is designed for transmitting live video information into the network as the vehicle travels about its service route.

[0011] Inventor Lambert teaches in U.S. Pat. No. 6,421,080 a "digital surveillance system with pre-event recording". Pre-event recording is important in accident recording systems, because detection of the accident generally happens after the accident has occurred. A first memory is used for temporary storage. Images are stored in the temporary storage continuously until a trigger is activated which indicates an accident has occurred at which time images are transferred to a more permanent memory.

[0012] Systems taught by Gary Rayner in U.S. Pat. No. 6,389,340 are directed to cameras for automobiles which capture video images and store the recorded images locally on a mass storage system. An operator, at the end of the vehicle service day, puts a connector into a device port and downloads information into a server system having specialized application software whereby images and other information can be played-back and analyzed at a highly integrated user display interface. Rayner uses a combination of volatile and non-volatile memory to enable his systems.

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[0013] Notwithstanding, techniques have been discovered which provide very novel arrangements of the memories in vehicle recorder systems, particularly with respect to highly mobile systems party based a light-weight temporary memory.

[0014] While systems and inventions of the art are designed to achieve particular goals and objectives, some of those being no less than remarkable, these inventions have limitations which prevent their use in new ways now possible. Inventions of the art are not used and cannot be used to realize the advantages and objectives of inventions taught herefollowing.

SUMMARY OF THE INVENTIONS

[0015] Comes now, James Plante with inventions of a multi-stage memory and automated transfer in vehicle event recording systems including devices and methods. Vehicle event recorder systems are arranged with multi stage memories and special mechanisms to cause transfer of data between those memories. First, a continuous overwrite memory is arranged as a managed loop. That memory receives data from a video camera in real-time and continuously overwrites expired data. Data is expired when according to a timeline definition, the data is expired. Second, data in the managed loop memory is passed to a more stable longer term buffer memory in response to an event having occurred. An event trigger causes a data transfer from the managed loop to the buffer memory. Third, the buffer memory is arranged as an on-board buffer memory suitable for storing data of a video series associated with a plurality of events. Finally, a permanent data store is arranged to receive data from the high-capacity buffer memory whenever the system returns and falls within a predetermined proximity of a download station.

[0016] Accordingly, a multi-stage video memory management system includes a managed loop memory, a high-capacity buffer memory, a permanent data store, an event trigger; and a proximity trigger. The managed loop memory is arranged to continuously receive video data from a video camera and record this data in real-time. The high-capacity buffer memory has sufficient capacity to store a plurality of events—in some versions up to 40 separate events can be stored. The event trigger is arranged to cause video data may be transferred from the managed loop memory to the high-capacity buffer memory in response to an event such as a traffic accident. The permanent data store is a mass memory of high durability and capacity suitable for long-term storage. This memory may be coupled to the high-capacity buffer memory such that video data may be transferred from the high-capacity buffer to the permanent data store in response to said proximity trigger. The permanent memory may be arranged as a remote data store in communication with the buffer memory via public communications networks such as the Internet.

OBJECTIVES OF THESE INVENTIONS

[0017] It is a primary object of these inventions to provide novel memory management in vehicle event recorder systems;

[0018] It is an object of these inventions to provide systems of high utility and efficiency with regard to various memory types and their particular associated attributes;

[0019] It is a further object to provide vehicle event recorders with multistage memory and management systems.

[0020] A better understanding can be had with reference to detailed description of preferred embodiments and with reference to appended drawings. Embodiments presented are particular ways to realize these inventions and are not inclusive of all ways possible. Therefore, there may exist embodiments that do not deviate from the spirit and scope of this disclosure as set forth by appended claims, but do not appear here as specific examples. It will be appreciated that a great plurality of alternative versions are possible.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

[0021] These and other features, aspects, and advantages of the present invention will become better understood with regard to the following description, appended claims and drawings where:

[0022] FIG. **1** is a schematic which illustrates a multi-stage memory buffer between a camera and remotely located mass storage;

[0023] FIG. **2** is an illustration of examples of event trigger actions; and

[0024] FIG. **3** is an illustration of a proximity trigger action;

[0025] FIG. **4** diagrams a system including a final memory in a remote location;

[0026] FIG. **5** illustrates a large area communications space used in conjunction with a proximity trigger;

[0027] FIG. **6** is a schematic diagram illustrating a proximity trigger event in a large area communications space;

[0028] FIG. **7** illustrates two separate communications spaces spatially separated and an authentication system associated with the spaces; and

[0029] FIG. **8** is a block diagram directed to preferred apparatus of these inventions.

GLOSSARY OF SPECIAL TERMS

[0030] Throughout this disclosure, reference is made to some terms which may or may not be exactly defined in popular dictionaries as they are defined here. To provide a more precise disclosure, the following terms are presented with a view to clarity so that the true breadth and scope may be more readily appreciated. Although every attempt is made to be precise and thorough, it is a necessary condition that not all meanings associated with each term can be completely set forth. Accordingly, each term is intended to also include its common meaning which may be derived from general usage within the pertinent arts or by dictionary meaning. Where the presented definition is in conflict with a dictionary or arts definition, one must consider context of use and provide liberal discretion to arrive at an intended meaning. One will be well advised to error on the side of attaching broader meanings to terms used in order to fully appreciate the entire depth of the teaching and to understand all intended variations.

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Vehicle Event Recorder

[0031] A vehicle event recorder is fashioned as an electronic apparatus including video recording equipment, a microprocessor, memory, application-specific programming, and a communications system. A vehicle event recording unit is built into a small housing suitable for mounting within a common vehicle such as a car, truck or bus.

Managed Loop Memory

[0032] 'Managed loop memory' is rewritable memory arranged to receive a continuous input and to continuously record that input in a loop fashion whereby old recorded data is replaced by newly received data.

High Capacity Buffer Memory

[0033] 'High-capacity buffer memory' is memory arranged to receive large data sets, for example those associated with video series images, and to temporarily store those data sets until a time in which they can be transferred to a more permanent memory.

Permanent Data Store

[0034] A 'permanent data store' is a durable data store of very large capacity, and generally includes connectivity to networks and large distributed advanced data management systems including backup protection schemes.

Event Trigger

[0035] An 'event trigger' is a system devised to detect a prescribed physical condition and provide an electronic signal in response thereto; the electronic signal being coupled to another system which may be set into action as a result of having received the event trigger signal.

Proximity Trigger

[0036] A 'proximity trigger' is a system devised to detect a prescribed proximity condition and provide an electronic signal in response thereto; the electronic signal being coupled to another system which may be set into action as a result of having received the proximity trigger signal.

PREFERRED EMBODIMENTS OF THESE INVENTIONS

[0037] In accordance with each of preferred embodiments of these inventions, apparatus for and methods of memory management in vehicle recorder systems are provided. It will be appreciated that each of embodiments described include both an apparatus and method and that the apparatus and method of one preferred embodiment may be different than the apparatus and method of another embodiment.

[0038] Vehicle event recorders of these inventions have special memories and configurations of memories. Further, special couplings between these memories are considered important aspects of these inventions. To better understand this, it is useful to review particulars relating to the objectives associated with vehicle recorder systems used in conjunction with automobiles. Vehicle event recorder systems of these inventions are arranged to capture video of brief time periods rather than extended continuous video series. The nature of this type of recording has implications on preferred memory arrangements. Further, as a vehicle is considered a highly mobile system, memories suitable for lightweight, small footprint mobile systems must be considered. Appropriate 'lightweight' computing/video and memory systems are preferably used with vehicle on-board systems. Finally, the nature of a vehicle with respect to network connectivity is to be considered.

[0039] Unlike common video systems arranged to capture continuous video, vehicle recorder systems are primarily designed to capture certain particular events occurring over very short time periods. For example, in vehicle recorder systems, it is not useful to produce a continuous video record of scenes and events around the vehicle throughout its service day. Rather, only particular events associated with certain vehicle use are of interest. For example, those events associated with vehicle abuse. Further, traffic accidents and other forms of vehicle misuse yield occasions where it is desirable to have a brief video record of the circumstance(s) which led to and resulted from such misuse or accident. Thus the video recorder systems of this disclosure are characterized in that they are intended to capture short video sequences rather than video sequences over extended period of time. This detail has direct implications with regard to choice of memory arrangements. In this case, it is useful to arrange a first memory in a managed loop configuration whereby video is collected in real-time but constantly overwritten with later captured video data. Only when an important event occurs is data preserved by transfer to a high capacity buffer memory.

[0040] As it is desirable in a vehicle recorder system that devices be very small and compact in size, certain memories which cannot be easily implemented as compact systems are not appropriate for vehicle event recorders. In example, large disk drive arrays, which have huge capacity and great redundancy, are memory systems not appropriate for these vehicle event recorder systems. However, memory systems commonly know as 'flash' type memory are highly useful. A flash type memory can be useful to hold video data associated with a plurality of discrete video events. Thus in preferred versions, a flash type memory buffer is coupled to managed loop memory such that each time an event occurs, data in managed loop memory is transferred to the flash memory. Flash memory having a high-capacity is operable for storing video data associated with many events.

[0041] Finally, attention is directed to the nature of communications connectivity associated with a vehicle which includes computing systems. Since vehicles are not readily suited to be 'plugged into' wired computer network systems, it is useful to implement special consideration when configuring a memory strategy for vehicle event recorders. Thus, an on-board memory may have a special relationship with a remote network memory. These two memories may be coupled to each other only at specific times, for example, when a vehicle has returned to a download station.

[0042] With a better understanding of the vehicle event recording application at hand, one will appreciate that an ideal memory system is more complex than simple deployment of inexpensive flash memory in conjunction with a video camera which is the common arrangement of light-duty video cameras such as inexpensive handheld devices and those used in cell phones. In vehicle recorder systems, it is preferred that we have a three stage memory: comprising: a high-speed, managed to loop memory, a high-capacity buffer memory, and a final durable data store system.

[0043] One gains a better understanding of these systems in consideration of the appended drawing figures with

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associated reference numerals. In particular with reference to FIG. **1**, a three stage memory system suitable for vehicle event recorders is presented. A video camera **1**, is arranged to capture video images and convert those images to electronic signals which may be processed by a computer and stored in electronic memories. The vehicle event recorder system is comprised of memory systems including: a managed loop memory **2**, a high-capacity buffer memory embodied as a flash type device **3**, and a durable, long-term, data store memory **4**.

[**0044**] Is not merely the unique arrangement of these three memories and the fashion by which they are in communication with one another which makes up the essence of these inventions, but rather, it is important to consider the couplings between these memories and mechanisms by which data transfers occur between these memories.

[**0045**] As mentioned, the first memory is arranged as a managed loop memory. Images from the video camera are continuously recorded in the managed loop memory in a step which overwrites old data which is no longer needed. In some simple arrangements, this managed loop **5** is provided as a FIFO or 'first-in, first overwritten' scheme. In preferred high-performance arrangements, the managed loop is embodied as a timeline dilation scheme. All video data collected by the camera is stored only in the managed loop memory until a time when an event trigger **6** occurs. When an event trigger occurs, a memory transfer operation is executed. Data in the managed loop memory is transferred to a high-capacity buffer memory in response to an event having been detected. Thus the relationship between the managed loop memory and the high-capacity buffer memory can be characterized in that they are coupled by way of the event trigger which causes a transfer of data therebetween.

[**0046**] Flash memory has a capacity which may accommodate video data associated with several events. While flash memory is suitable for preserving data collected throughout the vehicle service day, it is not unlimited, nor permanent and data stored there is preferably transferred to a more durable long-term memory. Thus the high-capacity buffer memory is coupled to a durable data store by way of a proximity trigger **7**. When the vehicle returns to download station (parking facility) at the end of the day, the proximity trigger detects that a vehicle has arrived at the download station and causes a wireless transfer **8** of data between the high-capacity buffer memory and the data store. The proximity trigger may be embodied within a wireless communications system whereby the mere presence of a vehicle in a designated parking lot causes a download transaction to occur automatically.

[**0047**] In review, video data from a video camera is continuously put into managed loop memory until an event trigger occurs which causes a data transfer from the managed loop memory to a flash type memory buffer. The flash memory has suitable capacity to accommodate several of these data transfers each being associated with a different event. Finally, when the vehicle returns to an appropriate download station a proximity trigger causes all data in the high-capacity buffer to be transferred to a network memory more durable and permanent in nature.

[**0048**] It is again noted that these inventions not only include three stages of particular memory configuration uniquely arranged in communication with one another, but in addition, include mechanism by which memory transfers occurs between these stages. More particularly, attention is drawn to the primary elements herein described as the event trigger and the proximity trigger. An event trigger is a system provided to sense and detect occurrence of some event of interest. An event of interest may be for example an automobile traffic accident. In this case accelerometers respond to abrupt changes in motion and provide the video event recorder with a signal to indicate that video data should be preserved and transferred to the high capacity buffer memory. While accelerometers provide excellent means of detecting abrupt motion in vehicles, there are additional systems which operate as useful event triggers. For example, a user initiated system may include a tactile switch which may be voluntarily engaged or operated by a user to indicate that some video sequence should be preserved. Thus, a so-called "panic button" system may operate as an event trigger as well as accelerometers.

[**0049**] With reference to FIG. **2**, a traffic accident between two automobiles car **21** and car **22** equipped with a vehicle event recorder system **24** having accelerometers **25** arranged as an event trigger. When a collision **23** occurs, the accelerometer initiates a data transfer between managed loop memory and a buffer memory to preserve video data collected immediately before and after the traffic accident. In similar fashion, car **26** equipped with a vehicle event recorder and accelerometer type event trigger illustrates that video of single vehicle accidents are captured as well.

[**0050**] In another scenario, a vehicle event recorder system equipped with a "panic button" type event trigger **27** may be engaged manually by a driver **28**. When a driver sees some event which he determines should be recorded, he pushes a tactile button **29** arranged as an event trigger to initiate a data transfer between managed loop memory and buffer memory to preserve video associated with the observed event.

[**0051**] Thus event triggers of these inventions may be fully automated such as accelerometers or may also include manual type event triggers such as those embodied as panic buttons. In either case, a signal is provided to the system which causes data in the managed loop memory to be preserved and transferred to the buffer memory where it may be temporarily preserved.

[**0052**] The above examples with reference to the drawings describe how video data is transferred from a first stage memory to a second stage memory; both of these memories being on-board memory. The following description is directed to the relationship between the on-board buffer memory and a long-term durable data store which may be maintained as part of a remote network system. Of particular importance in these systems, is a proximity trigger arranged to detect a proximal relationship between a vehicle event recorder and a communications station and further causes data in an on-board memory to be transmitted wirelessly to a network data store. FIG. **3** illustrates. A vehicle **31**, returns at the end of a service day to a special parking facility **32**. The parking facility is equipped with necessary equipment and communications means to serve as a data download facility. A communications space **33** which envelopes the parking area is served with a wireless communications system such as WiFi radio or other radio with suitable communications protocol. When the vehicle enters **34** this

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communications space this condition is detected by a proximity trigger which then the initiates a download action. A radio communications system **35** defines the extent of the communications space by way of its range. When a vehicle pierces the boundary of the communications space, data in the on-board buffer memory is transferred wirelessly **36** to a more permanent data store automatically without input or explicit action from the driver. This is achieved because the vehicle event recorder **37** is equipped with a connection manager module **38**. The connection manager, detects the presence of a radio signal and negotiates an authorized communications connection with the radio server. When a proper communications link is established, data is passed from the on-board buffer memory to server **39** where data may be stored indefinitely or used in further processes or analysis.

[**0053**] It is useful to point out special versions of these systems which include the public Internet. Vehicle **41** enters download space **42**, merely by entering **43** the communications space served by radio **44**. Vehicle even recorder **45**, includes connection manager **46** comprised of proximity trigger **47**. The proximity trigger may include a radio signal strength detector to indicate a vehicle has entered into the communications space. Upon entry, video data is passed from an on-board memory to a remote system, which has no particular location relationship with the download station. That is, the third stage memory may be located anywhere within the network. A communications station need only be connected to the Internet. A remote server **48** arranged to facilitate download operations can be anywhere in the world. Such remote server can be in further communication with a mass data store **49** such as a redundant disk array.

[**0054**] Since proximity trigger systems depend on the extent of a communications space, it is useful to further consider means which gives rise to this space. Namely, a radio transmitter or network of radio transmitters which have finite and limited service range. To establish an extended communications space, it is possible to arrange a plurality of radio transmitters each displaced in position with respect to another to form an array. FIG. **5** illustrates an advanced communications space having such extended range and associated array of radio transmitters. A plurality of radio transmitters **51** may each be coupled to the Internet by hardwire connection **52**. Each radio transmitter may be separated from another by a distance **53** to provide a spatially distributed arrangement of radio transmitters. Each radio transmitter having a communications range **54** associated therewith operates together in conjunction with the others to provide a large space coverage. An extended parking lot **55**, may be as large as several acres and suitable for accommodating hundreds of automobiles. When a vehicle equipped with a vehicle event recorder as described in these inventions enters the parking lot, a proximity trigger detects the proximity and initiates a download action where data in an on-board buffer memory is transmitted into the Internet **56** and further to a specially arranged download server **57** and permanent data store **58**.

[**0055**] A more complete understanding of this is realized in view of FIG. **6** which illustrates vehicle **61** with a video event recorder **62** entering an extended communications space. When a vehicle drives onto the large parking lot **63**, it pierces the communications envelope **64** to fire the proximity trigger. Distributed radio transmitters **65** forming a transmitter array are each available for communication with a cooperating radio of the vehicle event recorder system. Recorded video data is passed from an on-board memory in the vehicle event recorder to at least one nearby radio **66** in the radio network. Video data information is further passed, for example, by way of the Internet, to server computer **67**, and still further to durable data store **68**.

[**0056**] FIG. **7** illustrates an important aspect of these inventions which relates to separate communications spaces coupled to a single server. A first communications space **71** is established by radio transmitter **72**. A particular vehicle **73** associated with this particular communications space, may enter the space to cause an automated video data transfer by way of proximity trigger. Video data is passed via the Internet **74** to remotely located server **75** for safe and long-term storage. An unrelated vehicle **76** having no relationship whatever with the first vehicle **73** may enter a different communications space established by radio transmitter **77** to similarly cause an automated download a video data to the same server. It is an important feature of proximity triggers of these inventions that particular vehicles and particular communications spaces may be coupled to a single server but that the vehicle event recorders communicate independently with their appropriate communications space. That is, a proximity trigger can be arranged to be responsive in a first communications space, but not responsive in another unauthorized communications space. Thus an unauthorized vehicle **78** enters the communications space associated with radio transmitter **77**, the vehicle **78** not being a member of that communications space, would not be able to do a data download action there. The proximity trigger of vehicle **78**, may detect a radio signal from transmitter **77**, but no authorization for establishment of a communications link would be available. It is the function of a connection manager to only establish communications links when proper authorization is established.

[**0057**] The entirety of these vehicle event recorder systems is better understood in view of the illustration of FIG. **8** which is a block diagram particularly detailing the connection manager. A vehicle event recorder **81** is a system to be mounted within the vehicle and includes at least a connection manager **82**, camera **83**, microprocessor **84**, memory **85**, and a radio transmitter **86**. The connection managers further comprised of a proximity trigger **87**, a network address client **88**, and authenticator **89**, a session manager **810**, in a data transfer module **811**. When the vehicle event recorder mounted in a vehicle enters a communications space, the proximity trigger detects such condition and solicits from the radio server an assignment of a network address. Once a network address is assigned the authenticator provides necessary handshaking to identify the particular vehicle event recorder to the communications station whereby authorization can be established. Once proper authorization is established, a session manager organizes transfer of data to and from the vehicle event recorder with respect to the network. A data transfer module includes means for transmitting data from the vehicle event recorder to the network, and may additionally include means for transmitting data in the other direction. Firmware updates from the server may be passed to the vehicle event recorder among other information useful at the vehicle event recorder.

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[0058] In review, primary elements of vehicle event recorders of these inventions include a three stage memory system comprising: a managed loop memory in communication with a buffer memory by way of an event trigger; the buffer memory being in communication with a permanent data store by way of a proximity trigger. Data captured at a video camera is continuously written to the managed loop memory until an event trigger causes a data transfer of video information associated with a particular event to the on-board buffer memory. When a vehicle drives into a predetermined communications space, a proximity trigger activates a further download from the buffer memory to a permanent data store.

[0059] While described systems and examples are presented in great detail, is useful to further consider the primary elements of these systems independently with continued description as follows:

Managed Loop Memory

[0060] A managed loop memory is arranged to capture video data of very limited time periods. For example, a managed loop memory can be arranged to capture only 120 frames of video data captured at four frames per second. Thus, the capacity of a managed loop memory may only be associated with a video timeline of 30 seconds. When this memory is full, i.e. after thirty seconds of video, the old data in the memory is necessarily discarded and overwritten.

[0061] Managed loop memory may be embodied as semiconductor memory, for example as a DRAM type volatile memory. DRAM memory has the advantage that it is quite fast and suitable for use in conjunction with video systems, which tend to produce large amounts of data in short periods of time. Since a managed loop memory, is one which will be subject to millions of re-write operations over the course of a lifetime, selection of the particular physical system must consider the large number of rewrite operations. DRAM is suitable for use in this fashion. Flash memory, while new modern versions are becoming very fast, suffers from the fact that it can only be rewritten a few million times. Thus, flash type memory is not particularly suitable for use in a managed loop memory system.

[0062] Another alternative is possible. Ferroelectric memory systems are now commercially available which have sufficient speed, rewrite lifetime, and capacity to serve these video systems. While not as common as DRAM, Ferroelectric memory systems are becoming more mainstream. These high-performance memories are available off-the-shelf and can be deployed with vehicle event recorder systems as a managed loop memory. These memories have the advantage that they are non-volatile. This is particularly useful in vehicle accidents of a severe nature where a total loss of power results in loss of video data stored in memory. DRAM systems may fail to preserve most important data in this way. Ferroelectric systems however, capture full detail of events up to the time when power is lost.

[0063] Managed loop memories of these inventions are arranged to continuously capture video data. When the memory is full and new video data continues to be received, old video data is written over in a loop operation. The loop may be arranged as a FIFO loop, where the first data in is the first data to be overwritten. Such system is well known in the loop memory arrangements of the arts. Because of the special nature of vehicle event recorder systems, it is sometimes desirable to capture video at various frame rates surrounding a particular event. That is, at some point in time such as when a vehicle accident occurs it is preferred that video is captured at a maximum frame rate. At times further from an event moment, it is acceptable to collect video at reduced frame rates. A non-FIFO managed loop system may be deployed with a special overwrite scheme to effect various frame rates to preserve data in an extended timeline fashion. This is particularly useful where managed loop memories are of limited size.

High-Capacity Buffer Memory

[0064] A high capacity buffer memory is preferably provided as a flash type memory system. Flash memory is cheap and lightweight. Very inexpensive devices can hold enough video data to accommodate a great plurality of events. That is, a single cheap flash memory can hold the video data of 40 or more 30 second events. While not infinitely re-writable, flash may be re-written over a million times and so it serves well to use flash memory in these systems second memory stage, the high capacity buffer.

[0065] Flash memory buffers are coupled to managed loop memory whereby it is available on receipt of signal from an event trigger to copy data from the managed loop memory and store it for extended time periods.

[0066] It is alternatively possible to arrange a buffer memory system about a micro disk drive system. Small disk drives are available such that they may cooperate with these small footprint vehicle recorder systems. Disk drive memories have very high capacity suitable for a memory arranged as a buffer which can accommodate a plurality of events. However, disk drives remain a bit too expensive and sensitive to shock. While these may serve as alternatives, flash memory systems appear to have advantages not found in disk drive systems.

Permanent Data Store

[0067] A database may be arranged as a remote durable system which can accommodate a nearly infinite data set of many millions of video events. These durable memory systems may include backup means of redundant arrays of independent disks. Such data stores may be remotely located with respect to any download and communications spaces associated with particular vehicle event recorders. A single permanent data store may be in communication with a great plurality of vehicle event recorders. Permanent data store facilities of these inventions are related to various buffer memories in that a transfer of video data from the buffer memory to permanent data store occurs in response to a proximity trigger which detects the presence of a vehicle event recorder in a predetermined communications space.

Event Trigger

[0068] An event trigger is a mechanism which detects a prescribed physical condition and sets a data transfer action into motion in response thereto. An event trigger causes a data transfer between a managed loop memory stage and an on-board buffer memory stage. An event trigger may be arranged to detect a condition such as an automobile crash. When a car crashes, it generally suffers an abrupt motion detectable via motion transducers such as accelerometers.

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As such, an accelerometer can provide a signal to cause a data transfer in response to a traffic accident.

[0069] It is possible to arrange an event trigger as responsive to aggressive driving such as abrupt swerving motions. Event triggers might be arranged in conjunction with excessive braking maneuvers. Thus, not only accidents but other general vehicle misuse might be captured in recorded video as various types of event triggers cause data to be transferred to a buffer and preserved. Another physical condition suitable for use as an event trigger is that a user push button has been activated. Event triggers may also be arranged in conjunction with position detectors and timers. A position detector could be set to capture a video series at any of pre-selected locations determined of interest. A GPS detects that a vehicle is in a particular prescribed location (for example a known dangerous intersection) a trigger event can be fired in response thereto. Similarly, a timed event trigger could be activated on a preset time interval for some versions.

Proximity Trigger

[0070] When a vehicle enters a predetermined communications space, a proximity trigger can detect that condition and initiate a data transfer between the on-board buffer memory and a network data store.

[0071] A proximity trigger is embodied as part of a connection manager system. A vehicle event recorder includes a module which manages wireless communications connections between the vehicle event recorder and a computer server system. A proximity trigger may respond to detection of a radio signal of predetermined strength. When a vehicle enters a space in which radio communications service is available, the proximity trigger can set forth a download action where data is transferred from the buffer to the network data store. A proximity trigger may be arranged with respect to a large area communications space. A group of radio transmitters might cooperate together to form a single space which operates in conjunction with the proximity detection. Thus a proximity trigger can be arranged to detect when a vehicle event recorder is within a large communications space served by several radios each having their own and separate radio signal.

[0072] Additional important elements of these vehicle recorder systems include the systems characterized as a connection manager. A connection manager is a module within a vehicle event recorder which manages communications connections with authorized radio transmitters. A connection manager is comprised of a proximity trigger; a network address client; authenticator; session manager; and a data transfer module. A network address client is a system which receives a network address assignment. When a vehicle event recorder comes into contact with a communications space, it attempts to make a communications connection with the radio. A first step includes assignment of a unique network address to the vehicle event recorder. In this way, the network can more efficiently exchange messages with the vehicle event recorder. While a simple DHCP client is preferred, other forms of network address management may suffice. Alternatives include: Appletalk, IPX; BOOTP; or RARP among others.

[0073] An authenticator is provided to assure data transfers occur only between authorized parties. Once a network address is established, a vehicle event recorder attempts to log-in to the system by identifying itself and providing a credential. If the credential is accepted, and log-in is permitted, then a session manager initiates a communications session. A communications session includes data transfer both to and from the vehicle event recorder. A data transfer module includes a routine to flush the on-board data buffer and transmit the video information contained therein to a permanent data store. Data may also be uploaded to the vehicle recorder system including matters such as firmware updates, traffic and road condition information, et cetera. After data is appropriately transferred, the session manager does housekeeping tasks to close the communications link, clear and reset the memory for use another day, and indicate a completed and successful transaction has occurred permitting the vehicle to leave the communications space freely.

[0074] The examples above are directed to specific embodiments which illustrate preferred versions of devices and methods of these inventions. In the interests of completeness, a more general description of devices and the elements of which they are comprised as well as methods and the steps of which they are comprised is presented here following.

GENERAL DESCRIPTIONS OF APPARATUS OF THESE INVENTIONS—IN REVIEW

[0075] In most general terms, apparatus of these inventions may precisely be described as including:

[0076] A multi-stage video memory management system including: a managed loop memory, a high-capacity buffer memory, a permanent data store, an event trigger; and a proximity trigger. The managed loop memory continuously receives video data from a video camera and records such data in real-time. The high-capacity buffer memory receives from time-to-time in response to an event trigger, data from managed loop memory. The permanent data store is a mass memory of high durability and capacity suitable for long-term storage. This data store is sometimes in communication (for example by radio) with the high-capacity buffer memory such that video data is transferred in response to the proximity trigger.

[0077] While the immediately preceding description is directed to the most essential elements, it is important to consider these elements in relation to the more complete system which may be generally described as follows:

[0078] Vehicle event recorder systems including: a camera arranged to convert optical signals to electronic signals, memory, a radio transceiver, a connection manager, and a microprocessor. The microprocessor is connected to the camera to receive electronic image signals in video series. The microprocessor manages the memory whereby processed electronic signals are written to and stored. The microprocessor also transfers data stored in memory to external systems via the radio transceiver(s).

[0079] A connection manager includes: a proximity detector; an network address client; an authenticator; a session manager; and a data transfer module. The proximity detector is arranged to detect whether the system is near a prescribed communications space radio such that a connection may be established and a network address assigned. An authenticator includes mechanism responsive to a connection having

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been made and provides determination whether communication is with a recognized and approved entity. A session manager is arranged to establish a communications connection with a downloader service hosted at a remote server and to initiate data transfer. A data transfer module includes means to convey recorded data in the vehicle event recorder memory to a remote server.

[0080] One will now fully appreciate how various memory systems may be deployed and put in communication with each other to effect a highly efficient memory management system in view of specific applications and objectives relating to vehicle recorder systems. Although the present inventions have been described in considerable detail with clear and concise language and with reference to certain preferred versions thereof including best modes anticipated by the inventors, other versions are possible. Therefore, the spirit and scope of the invention should not be limited by the description of the preferred versions contained therein, but rather by the claims appended hereto.

It is claimed:

1) A multi-stage video memory management system comprising:

a managed loop memory;

a high-capacity buffer memory;

a permanent data store;

an event trigger; and

a proximity trigger,

said managed loop memory arranged to continuously receive video data from a video camera and record this data in real-time,

said high-capacity buffer memory has a capacity at least three times managed loop memory, is coupled to said managed loop memory such that video data may be transferred from the managed loop memory to the high-capacity buffer memory in response to said in event trigger;

said permanent data store being a mass memory of high durability and capacity suitable for long-term storage coupled to said high-capacity buffer memory such that video data may be transferred from the high-capacity buffer to the permanent data store in response to said proximity trigger.

2) A video memory management system of claim 1, said event trigger is an electronic signal generated as an indicator that a prescribed event has occurred.

3) A video memory management system of claim 2, said prescribed event is further defined as a vehicle collision.

4) A video memory management system of claim 2, said event trigger includes a motion sensor and a threshold, whereby when said threshold is exceeded the trigger is toggled and provides a binary output to indicate that state thus causing a data transfer.

5) A video memory management system of claim 2, said event trigger includes a panic button, whereby when said panic button is engaged the event trigger is toggled and provides a binary output to indicate that state thus causing a data transfer.

6) A video memory management system of claim 1, said proximity trigger is an electronic signal generated as an indicator that a prescribed proximity condition exists.

7) A video memory management system of claim 6, said proximity trigger is a mechanism which detects the proximity between a vehicle event recorder and a download station and provides a signal to initiate a data transfer from the high-capacity buffer to the permanent data store.

8) Vehicle event recorder systems comprising:

at least one video camera arranged to convert optical signals to electronic signals;

rewritable memories operable for storage of digital data;

a radio transceiver;

a connection manager; and

a microprocessor,

said microprocessor is coupled with said camera whereby the microprocessor receives electronic signals from the camera, and further coupled to said memories whereby processed electronic signals may be written to and stored in said memories and further coupled such that the microprocessor can transfer data stored in said memories to an external data storage system via said radio transceiver, said connection manager is arranged to detect whether the vehicle event recorder is near a communications space radio whereby a communications connection may be established, and further to initiate data transfer to move recorded data in the rewriteable memories to a remote server.

9) Vehicle event recorder systems of claim 8, said rewritable memories include a managed loop memory and a high capacity buffer memory.

10) Vehicle event recorder systems of claim 9, data is transferred from said managed loop memory to said high capacity memory in response to an event trigger signal.

11) Vehicle event recorder systems of claim 8, said connection manager is comprised of:

a proximity detector;

an network address client;

an authenticator;

a session manager; and

a data transfer module,

said proximity detector arranged to detect whether the VER is near a communications space radio whereby a communications connection may be established,

said network address client operable for soliciting and receiving a network address,

said authenticator comprising a mechanism responsive to receipt of a network address which provides a determination whether a communication is with a recognized and approved entity,

said session manager is arranged to establish a communications connection with a downloader service hosted at a remote server and to initiate the data transfer module, and

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said data transfer module includes means to move recorded data in the rewriteable memory to remote server.

12) Vehicle event recorder systems of claim 11, said proximity detector includes a signal strength threshold which determines the vehicle event recorder is receiving a signal of the type used in a communications space and is proximate enough to maintain a communications connection.

13) Vehicle event recorder systems of claim 11, said proximity detector is a position determining means which determines whether or not the vehicle event recorder is in a predetermined position which corresponds to a communications space.

14) Vehicle event recorder systems of claim 11, said proximity detector includes a binary output arranged to activate the authenticator.

15) Vehicle event recorder systems of claim 11, said network address client is fashioned as a DHCP client.

16) Vehicle event recorder systems of claim 11, said session manager is arranged to contact a server via the Internet.

17) Vehicle event recorder systems of claim 14, said session manager contacts a server via TCP/IP and XML web transactions.

18) Vehicle event recorder systems of claim 11, said session manager further includes means to close the communications connection with the remote server and return the systems to a ready state where said memories are flushed and renew for further use.

19) Vehicle event recorder systems of claim 11, said data transfer module further includes means to delete local memory after a successful transfer has occurred.

20) Methods of transferring vehicle event video data captured at an incident scene to a remote server comprising the steps:

capturing a time series of images in the camera of a vehicle event recorder;

storing said series of images in a rewritable, non-volatile memory of the vehicle event recorder,

moving the vehicle to a communications space whereby a radio transceiver of the vehicle event recorder is proximate to the transceiver of the communications space and a connection may be established,

providing a communications connection between the vehicle event recorder and the server,

transferring data from said vehicle event recorder to a remote server, and

termination said communications connection in response to a successful download.

21) Methods of claim 18, further comprising the step rewriting video data to a loop memory whereby expired data is replaced by newly captured data.

22) Methods of claim 19, further comprising the step transferring video data from said loop memory to buffer memory in response to a signal provided by an event trigger.

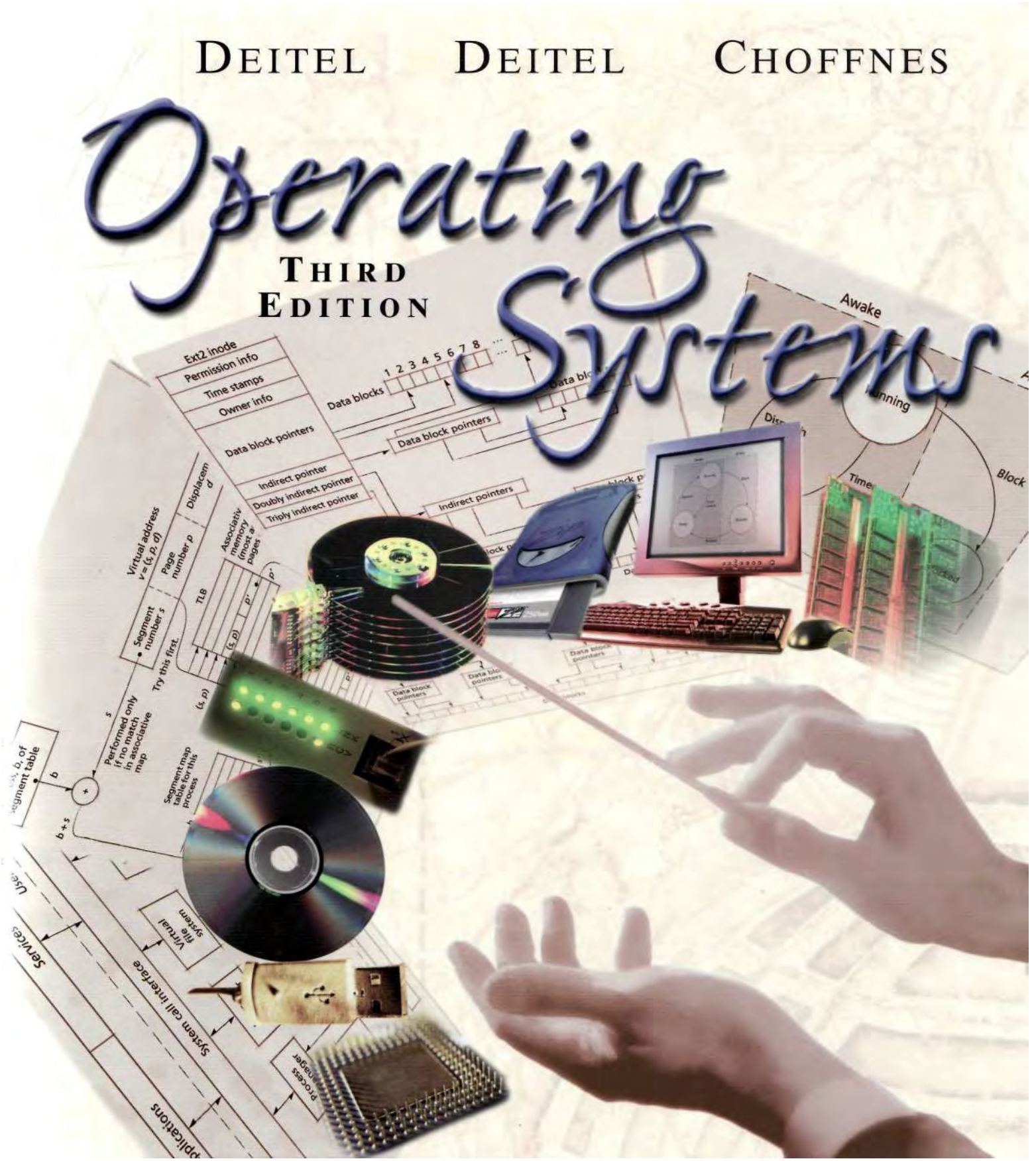
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Appendix II

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Operating Systems

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Operating Systems

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Chapter 13

File and Database Systems

Objectives

After reading this chapter, you should understand:

- *the need for file systems.*
- *files, directories and the operations that can be performed on them.*
- *organizing and managing a storage device's data and free space.*
- *controlling access to data in a file system.*
- *backup, recovery and file system integrity mechanisms.*
- *database systems and models.*

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13.1 Introduction

Most computer users are familiar with the concept of file as a named collection of data that is manipulated as a unit. Files typically reside on secondary storage devices such as disks, CDs or tapes, though they can exist exclusively in volatile main memory. In this chapter, we discuss how systems organize and access file data so that it can be retrieved quickly from high-latency secondary storage devices. We also discuss how operating systems can create an interface that facilitates navigation of a user's files. Because secondary storage often contains files storing sensitive information for several users, we discuss how systems control access to file data. Many systems use files to store important information such as inventories, payrolls and account balances; we discuss how file systems can protect such data from corruption or total loss from disasters such as power and disk failures. Finally, we discuss how systems that manage large amounts of shared data can benefit from databases as an alternative to files.

13.2 Data Hierarchy

Information is stored in computers according to a **data hierarchy.** The lowest level of the data hierarchy is composed of bits. Bits are grouped together in **bit patterns** to represent all data items of interest in computer systems. There are 2" possible bit patterns for a string of *n* bits.

The next level in the data hierarchy is fixed-length patterns of bits such as **bytes,** characters and words. When referring to storage, a byte is typically 8 bits. A **word** is the number of bits a processor can operate on at once. Thus, a word is 4 bytes on a 32-bit processor and 8 bytes on a 64-bit processor.

Characters map bytes (or groups of bytes) to symbols such as letters, numbers, punctuation and new lines. Many systems use 8-bit characters and thus can have 2^s. or 256, possible characters in their **character sets.** The three most popular character sets in use today are **ASCII (American Standard Code for Information Interchange). EBCDIC (Extended Binary-Coded Decimal Interchange Code)** and **Unicode®.**

ASCII stores characters as 8-bit bytes and thus can have 256 possible characters in its character set. Due to ASCII's small character size, it does not support international character sets. EBCDIC is often used for representing data in mainframe computer systems, particularly systems developed by IBM; it also stores characters as 8-bit bytes.[1]

Unicode is an internationally recognized standard that is popular in Internet and multilingual applications. Its goal is to use a unique number to represent every character in all the world's languages.[2] Unicode provides 8-, 16- and 32-bit representations of its character set. To simplify conversion from ASCII to Unicode characters, the 8-bit representation of Unicode, called UTF-8 (Unicode character set Translation Format-8 bit), corresponds directly to the ASCII character set. HTML files are typically encoded using UTF-8. UTF-16 and UTF-32 each provide larger character sets, enabling applications to store information containing characters

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Appendix JJ

VIDEOSurveillance: Wireless Mesh Networks

May 6, 2006



The Rockford, Ill., mesh network includes 16 outdoor boxes with mesh nodes and IP video cameras.

Crime, loitering and disorder are decreasing and residents' sense of safety and security is increasing, thanks to a video surveillance system that is part of a wireless mesh network installed in a public housing project by the Rockford Housing Authority northwest of Chicago.

Contained in custom-built, bulletproof enclosures, the Rockford mesh network includes 16 outdoor boxes with mesh nodes and IP video cameras, plus five indoor mesh nodes for live video monitoring. Four police cars are also equipped with mobile mesh nodes so law enforcement authorities can view live video from their cars while on patrol.

Video surveillance like Rockford's is a powerful tool for public safety, and with the increasing need for more security in airports, schools, hospitals and government buildings, the demand for video installations is growing. Being able to connect digital video cameras to computer networks and the Internet has increased the flexibility and accessibility for both collection and distribution of video data. But even though this enables cameras to be installed in more locations, the availability of network ports and cabling is still a limiting factor.

Making video surveillance easier

Wireless mesh networks can eliminate most, if not all, of the issues associated with locations that are too difficult, large or expensive to wire. By providing a wireless network backbone, mesh networks enable cameras to be installed without cables. With the ability to deploy cameras quickly and cheaply, security professionals can extend safety services with minimal additional staff or installation costs. And because the video surveillance runs on an IP network, multiple cameras can also be monitored and controlled simultaneously from any remote location via the Internet.

Mesh networking is addressing a number of previously intractable public safety issues; but it is also helping to overcome the biggest problem remaining in wireless communications: the wires. Ironically, the very devices that provide wireless service to clients need lots of wiring themselves to connect to private networks and the Internet. This wiring is expensive to install and change, and deployment must be carefully planned to minimize disruption. Indeed, the many obstacles associated with wiring are now preventing or delaying the deployment of wireless applications that could deliver a competitive advantage or high return on investment – or both.

Without wires, the network becomes far more adaptable, affordable and flexible. Like the Internet, a wireless mesh network is scalable and reliable. The mesh can configure itself, allowing the installation to occur in hours.

The mesh is also largely self-managing. And with the ability to put Ethernet ports anywhere, wireless mesh offers a breakthrough approach that makes the leap from localized hot spots to fully wireless hot zones and even hot regions that span entire metropolitan areas. The bottom line: a fully wireless network that covers more area yet is less expensive than a wired one.



Video surveillance like Rockford's is a powerful tool for public safety. Being able to connect digital video cameras to computer networks and the Internet has increased the flexibility and accessibility for both collection and distribution of video data.

True Ethernet connectivity

What ultimately determines the usefulness of wireless mesh is its ability to fit in seamlessly with existing network standards. The most ubiquitous networking standard by far is Ethernet, which is supported on virtually every networked device available today as well as a host of other networking and internetworking equipment.

A wireless mesh network that provides true Ethernet connectivity will be fully compatible and interoperable with all Ethernet switching and routing protocols (including IPv6, VPN tunnels, VLANs, OSPF, BGP, RIP, Multicast, MPLS, etc.). This capability allows multiple wireless mesh networks, potentially from different vendors, to be inter-networked at Layer 2 or Layer 3, including both IPv4 and IPv6 protocols.

The ability to create an Ethernet-based "mezzanine" wireless mesh network affords the maximum level of flexibility, compatibility and interoperability. A wireless mesh essentially creates a separate "cloud" operating in either the unlicensed 2.4 GHz or 5 GHz spectrums or 4.9 GHz licensed public safety spectrum that can exist independently with its own set of services and security. Or the mesh cloud can be integrated with an existing public or private network as a subnet or overlay.

Security top priority

Security is a major concern for wireless networks and mesh networks are no exception. Traffic within the mesh must be secured and outside devices, including those that use the mesh's Ethernet services, should be prohibited from accessing internal mesh traffic. Features like digital signatures can be used to ensure that only authorized mesh nodes can participate in the mesh.

User traffic between nodes can also be encrypted to prevent wireless eavesdropping. Industry standards such as 128-bit and 256-bit AES encryption can provide very effective security comparable to the level of security provided by wired networks.

Ethernet is crucial when it comes to wireless mesh solutions in the public safety area. Newer digital cameras with Ethernet connections and support for IP provide even more flexibility because they connect to standard computer networks. The ultimate in flexibility is to connect IP cameras to a wireless network so video

surveillance can be installed virtually anywhere without cabling. The best solution is a wireless mesh that provides standard Ethernet ports on every wireless node; in this way, just about every enterprise-grade IP camera can connect to the wireless mesh network.

The Texas State Fair understands this well. The fair deployed a wireless mesh network that helped apprehend vandals and a thief. Now the wireless mesh network is a staple at the fair – just like the blue-ribbon pecan pie and Budweiser Clydesdales.

Material for this article has been contributed by Magnus Gunnarsson, of Firetide, Inc., Los Gatos, Calif.

Appendix KK

A Brief History of Surveillance Cameras

by Bryan Johnston | Jul 18, 2022



They're everywhere. On telephone poles, traffic lights, dashboards, and buildings. They dot the ceiling and walls in businesses and private homes. There's a good chance one is looking at you *right* now. (So smile!)

It's hard to remember a time when surveillance cameras weren't as common as they are today. In a relatively brief span, they've become ubiquitous. It's believed that there are more than 1 *billion* cameras installed worldwide. It's nearly impossible to escape them.

In fact, Americans are caught on camera an average of 238 times every week. **That's 34 times per day**. The report by Safety.com broke that number down as follows:

- 160 times per week while driving
- 40 times per week at work (although that figure is much higher for those in retail)
- 24 times per week while out running errands and shopping
- 14 times per week through various other channels and activities

11 of the 20 most surveilled cities in the world are in China—they have an estimated 54% of installed security cameras—while New York, London, Seoul, Moscow, Delhi, Chennai, Singapore, Mumbai, and Mexico City round out the rest.

Security cameras, dash cams, traffic cameras, and body cams are a part of everyday life practically everywhere. And it's big business, too. The worldwide surveillance technology market

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was worth about $90 billion in 2021, up from $83 billion the year before.

But how did we get here? When were security cameras invented, and when did they become common?

When Were Security Cameras Invented?

So, where and when does the history of surveillance cameras start? Depends who you ask.

There is some evidence to suggest that the surveillance camera first appeared in Stalin-era Soviet Russia, sometime around 1927. Russian physicist Léon Theremin—most famous for the invention of the world's first electronic musical instrument, called simply a theremin—*may* have created a closed-circuit system using a camera and television, but the Kremlin quickly classified it. Another 15 years would pass before a true surveillance camera came into existence.

But let's slow down.

Moving Pictures

Moving pictures are a relatively recent invention. Eadweard Muybridge created an early prototype called the *zoopraxiscope* in 1878. Inventors Thomas Edison and William Dickson began experimenting with the idea in the 1880s, but it wasn't until 1893 that they made the first public demonstration. It instantly captivated the world. Within just a few years, the motion picture industry was up and running.

French brothers Auguste and Louis Lumiere were the first to screen short films for a paying audience in December 1895. Then, in 1896, Vitascope Hall was the first dedicated movie theatre to open in the US. The world's first feature-length film—called The Story of the Kelly Gang—was made in Australia in 1906. The first Hollywood movie studio opened in 1911, and Charlie Chaplin first appeared on film in 1914.



Smaller, portable, hand-held video cameras appeared by 1939. They were used for surveillance and reconnaissance during World War II. These cameras—both large and small—recorded video footage onto film to be processed and watched later.

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And that brings us back to the history of surveillance cameras.

The First Surveillance System

Nazi-controlled Germany. 1942.

Fifteen years after Theremin possibly built a system in the Soviet Union, an engineer named Walter Bruch designed what many consider the world's first surveillance closed-circuit television (CCTV) system. He built it so Nazi scientists and military personnel could safely observe the launch of V-2 rockets at the Peenemunde Airfield. The American military would later use a similar design to test atomic bombs.

These systems may have set the stage, but they could not *record* what they were seeing. Unless someone sat and watched the monitor 24/7, they weren't much use as a security camera.

Yet.

The First Security Camera

The earliest CCTV security cameras available to the public appeared in 1949. Produced by American company Vericon, they still couldn't record and required constant monitoring.

But just two short years later, in 1951, the videotape recorder (VTR) was invented. Early versions were open-reel devices that allowed a live image to be recorded reel-to-reel on magnetic tape. The first commercially available model was the VR-1000. The recorder debuted in 1956 at a cost of $50,000. It was the size of a desk.



Initially developed for television, the technology quickly jumped to the security industry as well. However, it wasn't practical for private home use. Only large corporations and governments could afford the equipment.

Security details extensively used CCTV security cameras during Queen Elizabeth II's coronation in 1953. In 1960, during a visit by the Thai Royal Family, CCTV again. London Transport installed a few CCTV cameras in the train station in 1961. New York had a few covering Times Square in the

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mid-60s.

The city of Olean, New York, became the first location in the United States to install security cameras along its main street in 1968. The cameras broadcast video directly to the local police station. Other towns and cities would soon follow suit.

But these systems still required either 24/7 monitoring or a technician to watch the VTR—if you could afford one—and change the reels as necessary.

Videocassettes

Introduced in 1969, videocassettes changed the game. They were smaller and cheaper than traditional reels. A plastic case enclosed the recording tape. As a result, cassettes could be quickly and easily switched out.

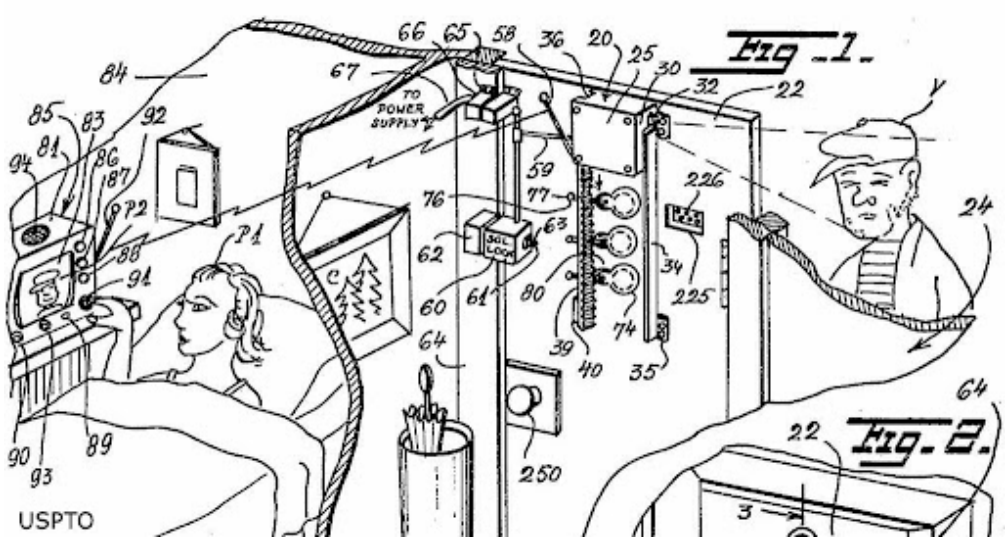


This advancement allowed surveillance and security cameras to go mainstream. The arrival of consumer videocassette recorders (VCRs) in 1971 pushed adoption even further.

The First Video Home Security System

Marie Van Brittan Brown and her husband Albert invented the modern video security system in the late 60s. Hers is the first patent for such a device granted in the United States in 1969.

Concerned about her safety when home alone, she designed an integrated security system. The system included four peepholes, a sliding surveillance camera, a monitor, and two-way audio. With this, she could both see and talk to whoever was knocking at her door. It was the first of its kind in the world.



> *"If you have a 'home security system' protecting your home, you have [Marie Van Brittan Brown] to thank."*
>
> – Sade Baderinwa, Broadcast Journalist

The combination of increasingly sophisticated CCTV networks and VCRs brought surveillance cameras and security systems to the masses starting in the early 1970s. Businesses and individuals could *finally* record security footage, review it later, save it, or record over it.



Retail shops and banks began installing CCTV systems with integrated VCRs extensively in the mid-70s and into the 80s. These were big, bulky, and conspicuous. (Remember those shoulder-mounted camcorders?)

With the development of charge-coupled device (CCD) technology in 1976, surveillance cameras could capture footage in low-light situations. This was a major milestone on the path to the true night vision capabilities we take for granted today.

Over the years, the camera quality got better, the size got smaller, and manufacturers attempted to make them at least slightly less noticeable. Examples of this include the dome camera configuration or the more streamlined bullet camera.

The History of Surveillance Cameras: The Digital Revolution

Surveillance cameras in the late 80s and early 90s still relied on CCTV networks and VCRs. Tapes had to be switched and stored. The system worked, but it was less than ideal.

Enter the digital revolution.

Kodak introduced several digital products in 1987. Digital video compression arrived in 1993 with the release of the Ampex DCT. Apple brought digital image capture to consumers with their QuickTake 100 in 1994.



Digital cameras record video footage on hard drives and flash storage rather than magnetic tape. The footage is of better quality and does not deteriorate over time like a videocassette. Digital surveillance and security cameras can record days, weeks, or even months of footage before running out of space. That's not including the virtually unlimited storage available in the cloud. And hard drives can be easily erased and reused indefinitely.

The development of digital multiplexers in the mid-90s allowed a single digital video recorder (DVR) to capture and save footage from more than one camera. This led to the multi-camera security systems used now.

Cameras got smaller and more specific, too. For example, the first "Nanny Cam" arrived in 1992.

This digital migration saw the first IP (internet protocol) camera—the Axis NetEye 200—land in 1996. This removed the need for a closed-circuit system. The camera could transmit footage wirelessly over a computer network. The NetEye is the forefather of modern web and surveillance cameras.



Where Is the History of Surveillance Cameras Headed Today?

Modern security cameras are HD, wireless, and weatherproof. The best ones include crystal clear night vision, motion-only recording, two-way audio, and anywhere accessibility. Cutting-edge and effective, their mere presence can deter up to 67% of would-be thieves *before* they commit a crime.

How far we've come in just 80 years! And Deep Sentinel is leading the charge into the next wave of innovation. The history of surveillance cameras is starting a brand new chapter.

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Appendix LL

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Wireless Video Surveillance: A Survey

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ABSTRACT A wireless video surveillance system consists of three major components: 1) the video capture and preprocessing; 2) the video compression and transmission in wireless sensor networks; and 3) the video analysis at the receiving end. A myriad of research works have been dedicated to this field due to its increasing popularity in surveillance applications. This survey provides a comprehensive overview of existing state-of-the-art technologies developed for wireless video surveillance, based on the in-depth analysis of the requirements and challenges in current systems. Specifically, the physical network infrastructure for video transmission over wireless channel is analyzed. The representative technologies for video capture and preliminary vision tasks are summarized. For video compression and transmission over the wireless networks, the ultimate goal is to maximize the received video quality under the resource limitation. This is also the main focus of this survey. We classify different schemes into categories including unequal error protection, error resilience, scalable video coding, distributed video coding, and cross-layer control. Cross-layer control proves to be a desirable measure for system-level optimal resource allocation. At the receiver's end, the received video is further processed for higher-level vision tasks, and the security and privacy issues in surveillance applications are also discussed.

INDEX TERMS Video surveillance, wireless sensor networks, multimedia communications, cross-layer control, video analysis.

I. INTRODUCTION

Video Surveillance over wireless sensor networks (WSNs) has been widely adopted in various cyber-physical systems including traffic analysis, healthcare, public safety, wildlife tracking and environment/weather monitoring. The unwired node connection facility in WSNs comes with some typical problems for data transmission. Among them are line-of-sight obstruction, signal attenuation and interference, data security, and channel bandwidth or power constraint. A vast amount of research work has been presented to tackle these problems, and many have been successfully applied in practice and have become industrial standards. However, for video surveillance applications, especially those with real-time demands, the processing and transmission process at each wireless node for a large amount of video data is still challenging.

In current state-of-the-art wireless video surveillance systems, each source node is usually equipped with one or more cameras, a microprocessor, the storage unit, a transceiver, and a power supply. The basic functions of each node include video capture, video compression and data transmission. The process of video analysis for different surveillance purposes is implemented either by the sender or by the receiver, depending on their computational capability. The remote control unit at the receiver's end can also provide some useful information feedback to the sender in order to enhance the system performance. The major functional modules of a video surveillance system are illustrated in Figure 1.

The existing WSN technologies are utilized in all kinds of wireless video surveillance applications. One popular application is traffic analysis. For example, the traffic signal system deployed by the transportation department in the city of Irving, Texas (Irving, 2004) [1] implemented seventy pan-tilt-zoom (PTZ) CCTV (closed-circuit television) cameras to cover about two hundred intersections. One smart camera capable of video codec and video over IP functions was installed at each traffic site together with a radio/antenna unit. The on-site signal is transmitted to the base stations ringed in a 100 Mbps wireless backbone operating at the licensed frequencies of 18-23 GHz. The traffic monitoring system at the University of Minnesota (UMN, 2009) [2], and the system

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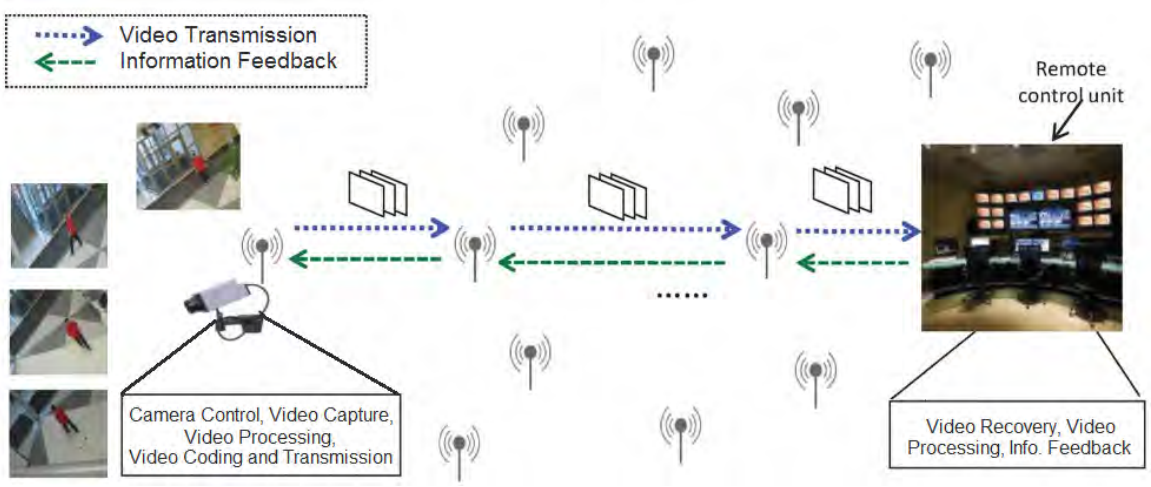


FIGURE 1. A wireless video surveillance system.

TABLE 1. Wireless video surveillance systems.

Surveillance system	Surveillance environment	MAC protocol	Carrier frequency	Maximum throughput	Network topology	Camera number	Camera control	Video delivery
Panoptes, 2003 [8]	indoor	802.11	2.4 GHz	12 Mbps	star	multiple	fixed	unicast
PRISMATICA, 2003 [7]	indoor/ outdoor	802.11	2.44 GHz	N. A.	star	multiple	fixed	unicast
Irving, 2004 [1]	highway	802.11a 802.16	5.8, 18, 24/23 GHz	20 - 60 Mbps for on-site, 100 Mbps for backbone	star, ring	multiple	PTZ	unicast
UMN, 2005 [2]	highway	802.16	5.4 GHz	3/30 Mbps	star	multiple	fixed	simulcast
FireWxNet, 2006 [4]	wildland	802.11	924Mhz	10 Mbps	tree	multiple	PTZ	unicast
MeshEye, 2007 [9]	indoor/ outdoor	802.15.4	2.4 GHz	11 Kbps	point-to-point	multiple	fixed	simulcast
Tsinghua, 2009 [10]	indoor	802.15.4	900 MHz	19.2 Kbps	star, tree, mesh	multiple	fixed	unicast
UML, 2010 [6]	indoor	802.11b/g	2.4 GHz	54 Mbps	tree	multiple	fixed	unicast
SCNS, 2011 [5]	railway	802.11g 802.11j	2.4, 5 GHz	20 Mbps	mesh	multiple	fixed, PTZ	unicast
UNT, 2011 [3]	campus	802.11 a/n	5.4, 5.8 GHz	20 Mbps	chain	multiple	PTZ	unicast

at the University of North Texas (UNT, 2011) [3] are among other examples of wireless traffic surveillance.

Video surveillance in other wireless communication applications is also intensively studied, such as the remote weather monitoring system (FireWxNet, 2006) initially developed for the fire fighting community in the Bitterroot National Forest in Idaho to monitor the lightning stricken forest fire [4], the smart camera network system (SCNS, 2011) used for security monitoring in a railway station [5], and the indoor surveillance system in a multi-floor department building at the University of Massachusetts-Lowell [6]. The common problems considered in these systems include the sensor deployment and the system configuration for video communications.

For surveillance in a wide social area like metropolis, the sensor deployment is more complex. An example is the multi-sensor distributed system developed at Kingston University, named proactive integrated systems for security management by technological institutional and communication assistance (PRISMATICA, 2003) [7]. Both wired and wireless video and audio subsystems were integrated in the centralized network structure. The data processing module at the operation center supported multiple real-time intelligent services, such as overshadowing and congestion detection upon received video.

The power efficiency problem is another major concern for some wireless video surveillance applications. In the system (Panoptes, 2003) described in [8], a central node received data from other client nodes and performed video aggregation to detect unusual events. The energy saving strategy employed by the client node included data filtering, buffering, and adaptive message discarding. In the work presented in [9], the hybrid-resolution smart camera mote (MeshEye, 2007) was designed to perform stereo vision at the sensor node with low energy cost. The location of the targeted object was

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first estimated from the image data by the two low resolution cameras. Then the high resolution camera marked the position in its image plane and transmitted only the video data inside the target region. The multiresolution strategy was also adopted in the multiview target surveillance system developed at Tsinghua University (Tsinghua, 2009) [10].

These surveillance systems are built upon the existing wireless video communication technologies, especially the WSN infrastructure and video codec. Compared to traditional systems adopting a wired connection, the advantage of network mobility greatly facilitates the system deployment and expansion. Some technical parameters of these systems are listed in Table 1.

While the well-established WSN infrastructure and video communication standards can be utilized in a surveillance system, many new technologies have been proposed to accommodate the special requirements of the surveillance applications, such as target object tracking, content-aware resource allocation, and delay or power constrained video coding and transmission. This paper presents a review of these proposals based on the analysis of the technical challenges in current systems, especially on the video delivery part in an unsteady wireless transmission environment, aiming to provide some beneficial insights for future development. The rest of the paper is organized as follows. Section II introduces the network infrastructure for a wireless video surveillance system, including the standard channel resource, and the network topology. Section III describes some examples of video capture and preliminary vision tasks that can be operated by the sensor node. Section IV summarizes a number of video coding and transmission techniques dedicated to unequal error protection, error resilience, and scalable and distributed data processing. The cross-layer control mechanism is introduced as an efficient way for optimal resource allocation. Section V briefly introduces several video analysis algorithms designed for wireless surveillance systems with single or multiple cameras. Section VI discusses the security and privacy issues, and conclusions are drawn in Section VII.

II. NETWORK INFRASTRUCTURE

Data transmission in a wireless video surveillance system is regulated by wireless communication standards. Before network deployment, comprehensive on-site investigation needs to be conducted to avoid signal interference and equipment incompatibility. This section discusses the channel resource and network topology for the configuration of a wireless video surveillance system. Detailed implementation of the sensor network deployment procedures can be found at [3].

A. CHANNEL RESOURCE

In the U.S.A., the Federal Communication Commission (FCC) is responsible for regulating radio spectrum usage [11]. The most commonly used license-exempt frequency bands in current wireless surveillance systems include 900MHz, 2.4GHz, and 5.8GHz. The 4.9GHz frequency band is reserved for Intelligent Transportation Systems (ITS) for public safety and other municipal services [12]. The specific communication parameters are defined in several groups of standards including IEEE 802.11/WiFi, IEEE 802.16/WiMax, IEEE 802.15.4/ZigBee, etc. The properties of operation with these frequency bands are summarized in Table 2. The higher frequency band demonstrates better range and interference performance, with lower penetration capability.

TABLE 2. Common radio frequency bands for wireless surveillance.

Frequency band	License	Line of sight	Advantage	Disadvantage
900 MHz	Unlicensed	Not required	Penetrates trees, dry wall	Lower throughput for video compared to other bands
2.4 GHz	Unlicensed	Required	Better penetration than 5 GHz	Interference from consumer devices
4.9 GHz	Licensed	Required	Reserved for public safety; less interference	Requires frequency coordination with other agencies
5 GHz	Unlicensed	Required	Better range and less interference than 2.4 GHz	Lower penetration than 2.4 GHz

B. NETWORK TOPOLOGY

As in WSNs, the network topology in a wireless video surveillance system could be a one hop or relayed point-to-point connection for single view video transmission, or a chain, star, tree or mesh structure for multiview surveillance. The network topology is application dependent. The resource constraints, cost efficiency, as well as the terrain and ecological condition of the surveillance environment are among the factors considered in adopting a suitable topology.

In the campus traffic monitoring system (UMN, 2005) [2], the surveillance environment was relatively small-scale, and the runtime video delivery was the primary concern. Therefore the point-to-point communication was realized by simulcasting multiple synchronized video sequences to the remote base station for real-time observation, as displayed in Figure 2(a). For surveillance in a large public area, different types of sensors might need to be installed at multiple distant locations, and hence a centralized star structure is preferred, such as the PRISMATICA system (PRISMATICA, 2003) [7] illustrated in Figure 2(b). The centralized network connection results in high throughput at the center node, which has to meet stringent standard for both the performance and stability requirements.

When the energy conservation is the major consideration, the sensors need to be organized in a more efficient manner. The work presented in [10] tested the surveillance system under different WSN topologies and demonstrated that, when collaboration among different sensor nodes is required, a tree or mesh network could achieve higher system performance compared to a star structure, in terms of power efficiency and data throughput. Figure 2(c) shows the tree structure of SensEye [13], a multitier surveillance system with different data processing and power consumption patterns devised on

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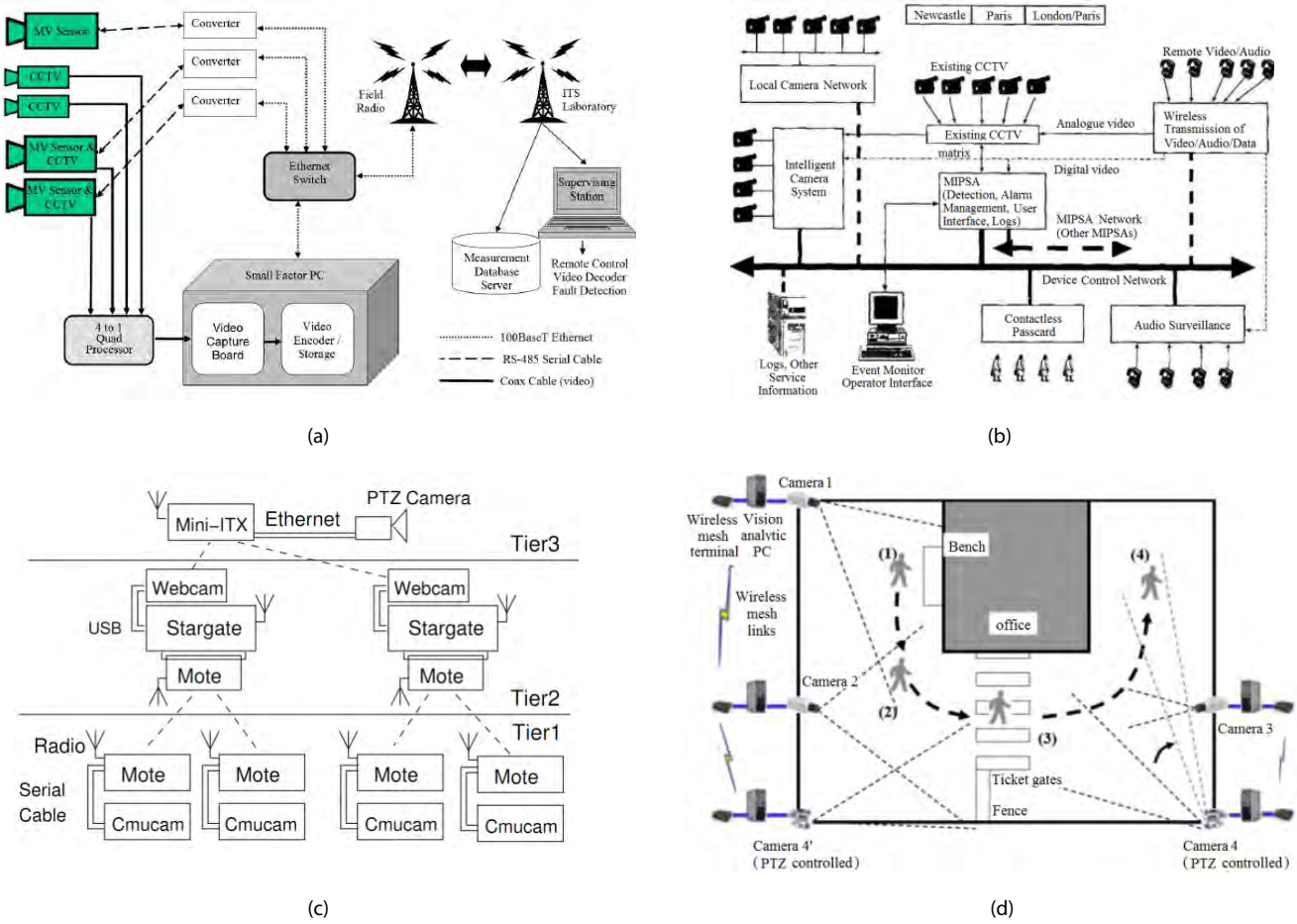


FIGURE 2. **Network topology. (a) Point-to-point (UMN, 2005). (b) Star (PRISMATICA, 2003). (c) Tree (SensEye, 2005). (d) Mesh (SCNS, 2011).**

each level of the tree. The sensor nodes at the lower tiers consisting of low power devices worked at a longer duty cycle than the nodes at the higher tiers which consumed more power and executed more complex functions only upon receiving the signals from its child nodes at the lower tier.

If the functionality and computational capability are equally distributed among the sensor nodes, a mesh network is more appropriate. The mesh structure of the multiview object tracking system SCNS [5] using the Ad-hoc On-Demand Distance Vector (AODV) routing protocol is demonstrated in Figure 2(d). In this system, each node was able to communicate with others to determine the target position and to select the nearest camera for object tracking.

Another interesting issue in designing an efficient network topology is how to choose a proper amount of surveillance nodes for full-view coverage of the moving target. The camera barrier coverage in an existing network deployment was analyzed in [14], [15]. An optimal subset of the camera sensors is selected for video capture, while the distance between the camera and the target is sufficiently close, and the angle between the camera view direction and the target 's face direction is within acceptable scope. The work presented in [16] studied the coverage problem with active cameras. The camera's pan and zoom parameters were configured to support full-view coverage with a smaller number of selected nodes. The coverage schedule leads to better utilization of the network resources. In a wireless surveillance system, the camera selection procedure also needs to consider other critical issues including how to effectively identify the target location and to coordinate the distributed sensors over the air, under limited resources.

III. VIDEO CAPTURE AND PRELIMINARY VISION TASKS

The surveillance video is recorded by the sensor node at the monitor site for further data processing and transmission. Some preliminary vision tasks can be performed by a smart camera or the integrated processing unit at the sensor node.

For the surveillance systems using fixed cameras, object detection and localization are among the most popular functions performed at the sensor node. Object detection with a fixed camera often takes advantage of the static background. A commonly used technique is background subtraction. The background image can be obtained through periodically updating the captured data [9], [17], or through adaptive background modeling based on the Gaussian Mixture Model (GMM) learning process [18], [19]. This temporal

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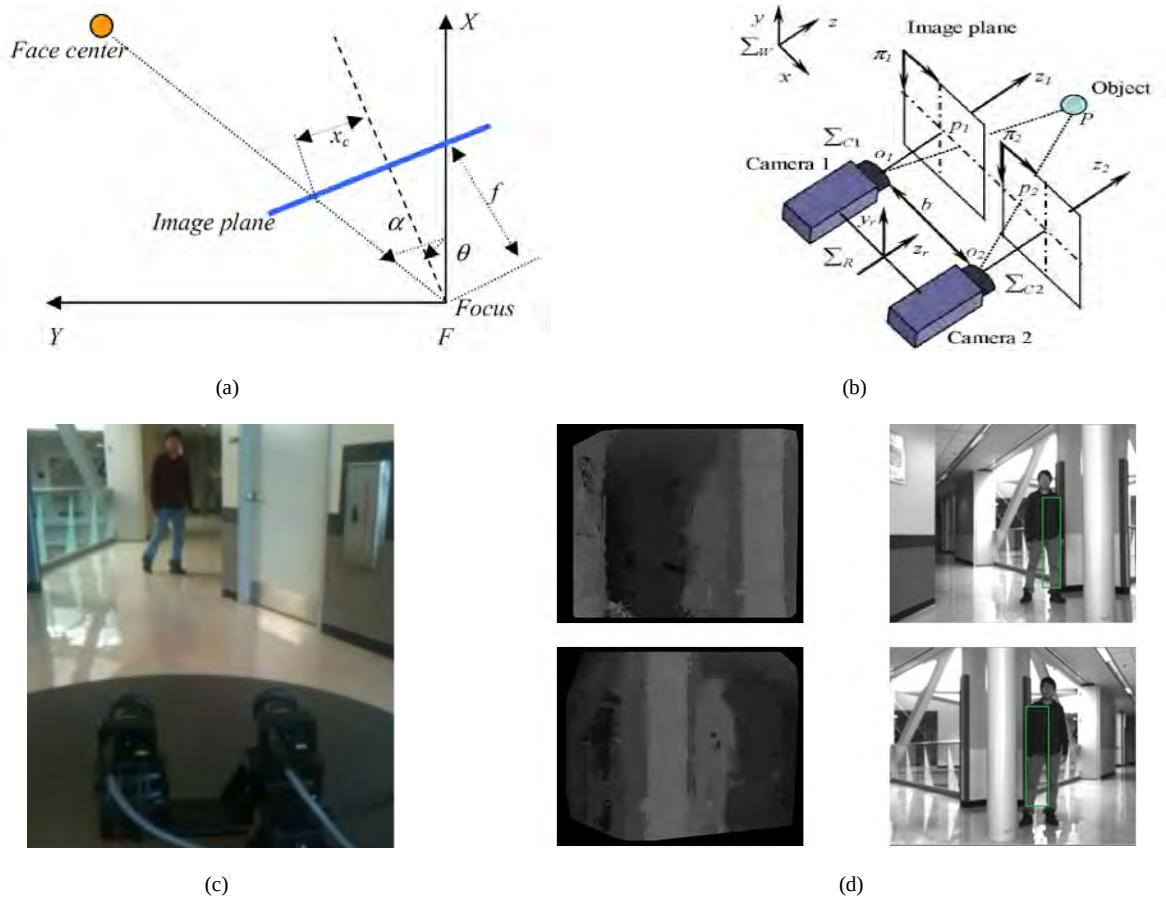


FIGURE 3. PTU camera for object tracking. (a) PTU camera control. (b) Binocular distance measure. (c) Binocular PTU cameras. (d) Disparity estimation and window size adjustment.

learning process models different conditions of a pixel at a certain position as a mixture of Gaussian distributions. The weight, mean, and variance values of each Gaussian model can be updated online, and pixels not conforming to any background model are quickly detected. The adaptive learning property makes this technique suitable for real-time applications, and a variety of detection methods are developed combining other spatiotemporal processing techniques [10], [20], [21]. With the object detection results provided by two or more cameras, the 3-D object position can be localized through vision analysis using the calibrated camera parameters and the object feature correlation [5], [9], [10], [17].

When the number of sensor nodes is restricted, a pan-tilt unit (PTU) or a PTZ camera provides more flexible view coverage than the stationary camera does. A PTU camera is capable of pan and tilt movements with a fixed focus position. The camera control can be manually performed by the remote receiver through information feedback [1], [3], [4], or automatically by the source node based on the vision analysis by the integrated processing unit [5], [22], [23]. The traffic surveillance system developed at the University of North Texas [3] had an Axis 213PTZ camera and a radio device installed at each of the three control center through a daisy chain network. The operator at the control center was able to adjust the PTZ camera motion and the focal length, and to estimate the vehicle speed on a roadway parallel to the image plane.

The automatic camera control is closely related to the vision task performed by the processing unit. For example, object detection is often integrated with the camera control process. Figure 3(a) displays the PTU camera control algorithm described in [22] for object tracking. The focus O denotes the projection center. The image plane is viewed down along its y axis, and is projected onto the $X - Y$ world coordinate plane. α is the angle between the detected object center and the X axis, θ is the camera angle between the image center and the X axis, f is the focal length, and x_c the distance between the projected object center and the image center along the x axis of the image plane. Only the pan control algorithm is displayed in the figure. It applies to the tilt control similarly.

In the camera control process, the camera angle θ is updated at each time instance, aiming to minimize x_c and the difference between the estimated object speed and the actual object speed measured by a local tracker using the Mean Shift algorithm [24]. The extended Kalman filter

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correlated to the pan and tilt movement (hand-eye calibration) were investigated in the binocular vision system introduced in [23]. In the tracking process, two PTU cameras were used to measure the distance campus sites. The traffic video was transmitted to the remote between the detected object and the image plane, as shown in Figure 3(b). The tracking region was scaled according to the estimated distance at the next detection process using the Continuously Adaptive Mean Shift Algorithm (CAMShift) algorithm [25]. To better obtain the distance information, in our binocular video surveillance system described in [26], the depth map for the entire frame is generated using a fast disparity estimation algorithm. Figure 3(c) and (d) demonstrate the binocular PTU cameras, and the tracking window adjustment using the generated depth information. The resulting 3D video data can be delivered to the receiver for further processing.

A PTU/PTZ camera is usually expensive and consumes much energy [13]. To reduce the cost and the technical complexity, some surveillance systems also used combined fixed and PTU/PTZ cameras for video capture and object tracking [5], [13], such as the systems illustrated in Figure 2 (c) and (d). Under some circumstances, special lenses can be adopted to further reduce the number of cameras. For example, the ultra wide-angle Fisheye and Panomorph lenses are used for panoramic or hemispherical viewing. The distorted images can be rectified using the camera parameters. The extra computation and communication resource consumption for processing the captured images can not be ignored in designing a wireless video surveillance system.

IV. VIDEO CODING AND TRANSMISSION

In a wireless video surveillance system, the captured video data are encoded and transmitted over the error prone wireless channel. Most of the current systems adopt a unicast or simulcast video delivery, as shown in Table 1. Each camera output is encoded independently using well-established image or video coding standards including JPEG, JPEG2000, motion JPEG (MJPEG), MPEG and H.26x. To better adapt to typical surveillance applications, a variety of techniques has been proposed for the video coding and transmission process in WSNs.

A. OBJECT BASED UNEQUAL ERROR PROTECTION

When the communication resources are limited, an alternative to heavier compression is to implement unequal error protection (UEP) for different parts of the video data. The idea of UEP is to allocate more resources to the parts of the video sequence that have a greater impact on video quality, while spending fewer resources on parts that are less significant [27]. In the surveillance video, the moving target object is of greater interest than the background. Hence the region of interest (ROI) based UEP mechanism is a natural way to optimize resource allocation.

An object based joint source-channel coding (JSCC) method over a differentiated service network was presented in [27]. The system scheduler considered the total energy consumption and the transmission delay as the channel resource constraints for the video coding and transmission process. Discriminative coding decisions were applied to the shape packets and the texture packets in the video object coding in MPEG-4, as illustrated in Figure 4(a). Packets were selectively transmitted over different classes of service channels such that the optimal cost-distortion state was achieved under the energy and delay constraint.

The ROI based wireless video streaming system introduced in [28] adopted multiple error resilience schemes for data protection. The ROI region was assigned more resources than other areas including higher degree of forward error correction (FEC) and automatic repeat request (ARQ). For example, in the interleaving process displayed in Figure 4(b), the chessboard interleaving was performed on the ROI region with increased code rate and better error concealment result compared to the error concealment scheme with slice interleaving on background area.

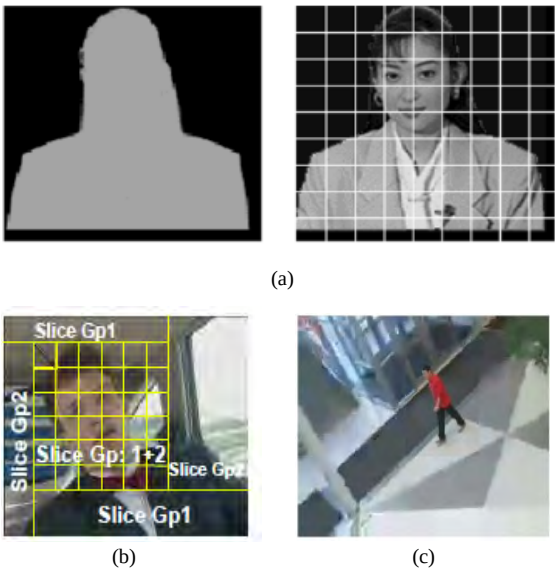


FIGURE 4. Unequal error protection. (a) Shape (left) and texture (right). (b) Interleaving. (c) Target region.

The system designed for surveillance video delivery over wireless sensor and actuator networks (WSANs) proposed in [29] extended the UEP mechanism from source data processing to network management. Each intermediate sensor node in the selected transmission path put the target packets ahead of all the background packets in the queue. Thus the target packet had a lower packet loss rate (PLR) than the background packet when the sensor node started dropping packets with a higher expected waiting time than the packet delay limit. The visual result of a received reconstructed frame can be observed from Figure 4(c).

Current video coding standards provide different interfaces for ROI data processing. For example, the object based video representation is supported in the MPEG-4 standard, and is more efficient when it is incorporated with the rate-distortion

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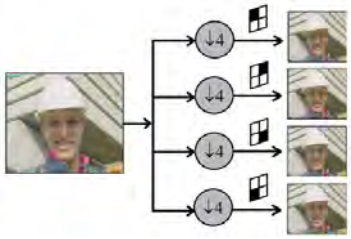
estimation technique [30]. A contour free object shape coding method compatible with the SPIHT (Set Partition In Hierarchical Trees) codec [31] was introduced in [32]. In the latest H.264/AVC standard, several tools intended for error resilience like Flexible Macroblock Ordering (FMO) and Arbitrary Slice Ordering (ASO) can be used to define the ROI [33]. These interfaces enable convenient incorporation of the object based UEP mechanism into the coding process.

B. ERROR RESILIENCE

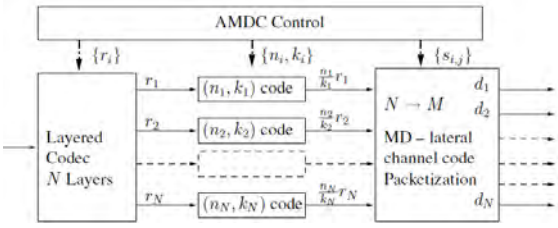
To cope with the signal distortion over the wireless channel, error resilience has been extensively studied to protect data transmission over WSNs. Some popular techniques include FEC, ARQ, adaptive modulation and coding (AMC), and channel aware resource allocation [34]–[39]. While traditional methods mainly focus on channel distortion, and are independent of the video coding process, more advanced error resilience techniques consider the end-to-end data distortion as the auxiliary information for making coding and/or transmission decisions, such as the JSCC method, the cross-layer control, and the multiple description coding. Multiple error resilience technologies have been adopted in the video codec standards H.263 and MPEG-4, as described in [39].

The JSCC method determines the coding parameters by estimating the end-to-end video distortion. In packetized video transmission over wireless networks, video compression and packet loss are two major causes for the data distortion observed by the receiver. Incorporating the packet loss information in the end-to-end distortion estimation process has been shown to be an efficient measure to improve the coding efficiency. In [34], a recursive optimal per-pixel estimate (ROPE) method was presented for the coding mode decision in block based coding process. This statistical model demonstrated a new way to adjust coding decisions according to both source coding and channel distortion. Another JSCC method introduced in [35] adopted random intra refreshing for error resilience. The source coding distortion was modeled as a function of the intra macro block (MB) refreshing rate, while the channel distortion was calculated in a similar recursive fashion as was done in [34]. This method also took into account the channel coding rate and FEC in the rate-distortion (RD) model. A further evolved type of channel aware WSN techniques that are considered efficient to deal with the packet loss is through the cross-layer control [36], [38], [40]. Both the source coding parameters and the transmission parameters are coordinated by the cross-layer controller to achieve the optimal end-to-end performance. More details about the cross-layer control mechanism will be introduced in Section IV-E. These techniques can be built upon current network protocols supporting video streaming, including TCP (Transmission Control Protocol), UDP (User Datagram Protocol), RTP (Real-time Transport Protocol)/RTCP (RTP control protocol), and RSVP (Resource ReSerVation Protocol) [41]–[43].

Another class of error resilience technique closely related to the video coding process is the multiple description coding (MDC). The main concept of MDC is to create several independent descriptions that contribute to one or more characteristics of the original signal: spatial or temporal resolution, signal-to-noise ratio (SNR), or frequency content [43]–[46]. For video coding, the subdivision is usually performed in the spatial domain or in the temporal domain, such as separating the odd and even numbered frames [47], the spatial chessboard MB decomposition [28], and the spatiotemporal slice interleaving [48]. The descriptions can be generated in a way that each description is equally important to the reconstructed content. An example of constructing four balanced descriptions using spatial down-sampling to separate odd/even numbered rows and columns is displayed in Figure 5(a) [49]. The descriptions can also be constructed with unequal importance or with UEP. The asymmetric MDC (AMDC) scheme designed in [50] used layered coding to create unbalanced descriptions for several available channels with different bandwidths and loss characteristics in a heterogeneous network. The optimal description data length and FEC code rate for each channel were determined by an AMDC controller, as shown in Figure 5(b).



(a)

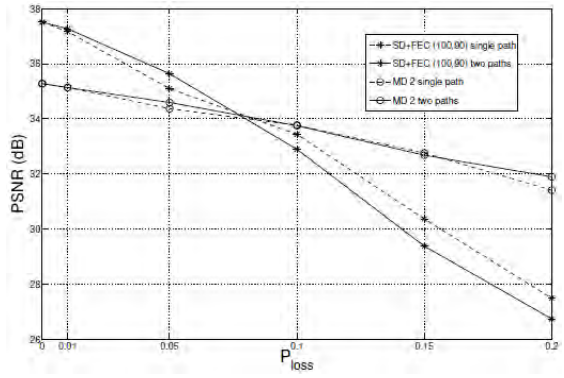


(b)

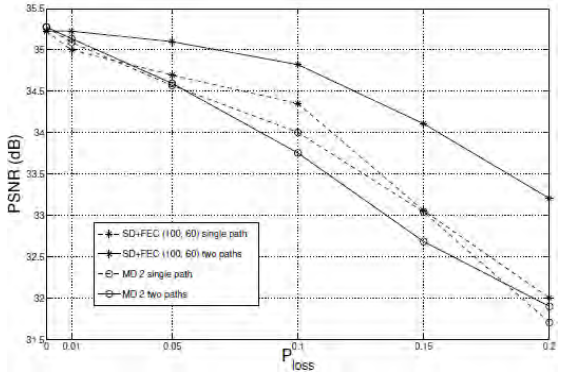
FIGURE 5. Balanced and unbalanced MDC. (a) Spatial downsampling. (b) Unbalanced descriptions.

MDC is considered to be an efficient measure to counteract bursty packet losses. Its robustness lies in the fact that it is unlikely the portions of the whole set of descriptions corresponding to the same part of the picture all corrupt during transmission. Each description can be independently decoded and the visual quality is improved when more descriptions are received. The compression efficiency of MDC is affected due to reduced redundancy in each description. The extra overhead is largely ignored when otherwise the complex channel coding schemes or the complex communication protocols have to be applied in the presence of high PLR. A comparison on the performance of the two description MDC coding (MD2) and the single description coding with Reed-Solomon code (SD+FEC) under the same

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(a)



(b)

FIGURE 6. Comparison of MDC and SD+FEC. (a) Mean burst length = 10 packets. (b) Mean burst length = 20 packets.

data rate (*Foreman*, CIF, 30 fps, 850 kbps) is demonstrated in Figure 6 [51]. When the mean burst length is small, and the PLR is high, the MDC schemes outperform the FEC schemes.

Due to many advantages, MDC is favorably adopted in advanced coding paradigms including scalable video coding (SVC) and distributed video coding (DVC), as will be discussed in the following subsections. These coding techniques could enhance the adaptability of the wireless surveillance systems, especially when multiple cameras are recording simultaneously and the channel resource is strictly constrained.

C. SCALABLE VIDEO CODING

The development of SVC is intended for adaptive video delivery over heterogeneous networks. The basic idea is to encode the video into a scalable bitstream such that videos of lower qualities, spatial resolutions and/or temporal resolutions can be generated by simply truncating the scalable bitstream to meet the bandwidth conditions, terminal capabilities and quality of service (QoS) requirements in streaming video applications such as video transcoding and random access [52]. An SVC bit-stream consists of a base layer and one or more enhancement layers. The SVC feature is supported in several video coding standards including MPEG-2, MPEG-4, MJPEG 2000 and H.264/AVC [53]–[56].

The quality scalability of SVC is based on the progressive refinement data, such as the higher bit planes of the transform coefficients [52], and the prediction data with coarser quantization parameters (QPs) [57], added to the base layer. The spatial scalability is achieved by generating enhancement layers using video sequences of different resolutions. The data on higher layers are predicted from a scaled version of the reconstructed data on a lower layer [58]. The temporal scalability uses hierarchical B pictures for temporal decomposition. The pictures of the coarsest temporal resolution are encoded as the base layer, and B pictures are inserted at the next finer temporal resolution level in a hierarchical manner to construct the enhancement layers [56]. To improve the coding efficiency and granularity, a combination of SNR and spatiotemporal scalabilities is often adopted [59]–[63].

Compression efficiency and computation complexity are two major concerns in SVC applications. An influential concept to achieve efficient scalable coding is Motion Compensated Temporal Filtering (MCTF) based on the wavelet lifting scheme [64]. Figure 7(a) illustrates a two-channel analysis filter bank structure of MCTF consisting of the polyphase operation, prediction and update steps [65]. The output signals H_k and L_k can be viewed as high-pass and low-pass bands with motion compensation (MC) that spatially aligns separated input signals S_{2k} and S_{2k+1} towards each other. A three-band MCTF scheme was proposed in [60] to enhance the rate adaptation to the bandwidth variations in heterogeneous networks. The MCTF scheme proposed in [62] incorporated spatial scalability to further reduce inter-layer redundancy. A frame at a certain high-resolution layer was predicted both from the up-sampled frame at the next lower resolution layer, and the temporal neighboring frames within the same resolution layer through MC. For mobile devices with constrained computational resources, the SVC coding complexity scalability was considered in the work presented in [66]. Closed-form expressions were developed to predict the complexity measured in terms of the number of motion estimation (ME) computations, such that optimized rate-distortion-complexity tradeoffs can be achieved.

The dependency between nested layers is another hindrance for the application of SVC in wireless communications. The data on an enhancement layer are decodable only when the data on depended lower resolution layers are correctly recovered. To reduce the dependency, the work introduced by Crave et al. [67] applied MDC and Wyner-Ziv (WZ) coding [68], [69] in MCTF. The coding structure is displayed in Figure 7(b). Each description contained one normally encoded subsequence and another WZ encoded subsequence. The system achieved both enhanced error resilience ability and distributed data processing.

SVC has been applied in many video streaming systems [37], [70], [71]. The rate-distortion model related to the enhancement layer truncation, drift/error propagation, and error concealment in the scalable H.264/AVC video is discussed in details in [71]. A possible application in video surveillance is the interactive view selection. The user could

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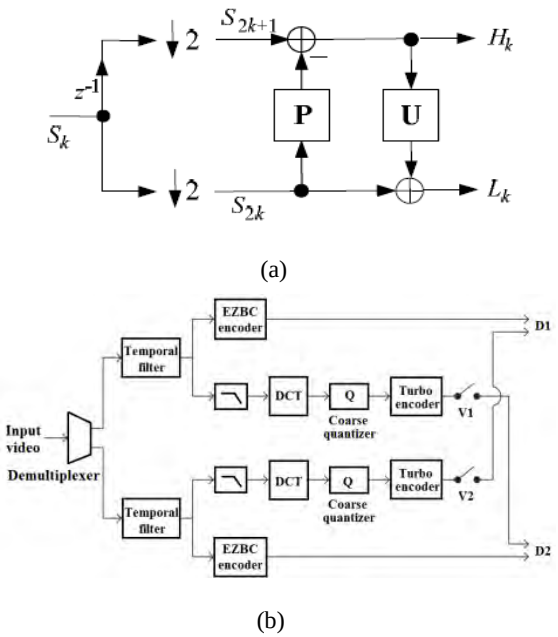


FIGURE 7. SVC coding structure. (a) MCTF. (b) MCTF with MDC.

randomly access the video data at any region, resolution, and/or view direction. To enable this function in the real-time video play, random access points are devised in the coding structure to realize smooth switching between different video streams. In H.264/AVC standard, the SP/SI slices are defined to achieve identical reconstruction of temporally co-located frames in different bitstreams coded at different bit-rates without causing drift [72]. This feature is especially useful for free-viewpoint applications [70], [73], [74].

D. DISTRIBUTED VIDEO CODING

DVC refers to the video coding paradigm applying the Distributed Source Coding (DSC) technology. DSC is based on the Slepian-Wolf (SW) [75] and WZ [68] theorems. In DSC, correlated signals are captured and compressed independently by different sensors, and are jointly decoded by the receiver [83]. Due to the many advantages of distributed data processing and the inherent spatiotemporal correlation in video data, DSC is applied in video coding in order to reduce encoder complexity and to maintain desirable error resilience ability [76].

Two representative architectures of DVC for single view video coding are the PRISM (Power-efficient, Robust, hIgh-compression, Syndrome-based Multimedia coding) [77] and the WZ coding structure [78]. In both schemes, part of the video data was compressed using the conventional intra coding method, and was prone to channel distortion. The rest was WZ encoded with coarser quantization and the error detection/correction code. At the decoder, the WZ data were restored using the correctly received intra coded data as side information. In [78], a feedback channel was adopted to request the error control information. The DISCOVER (DIStributed COding for Video sERvices) project presented in [79] improved this coding structure with multiple enhancements including rate estimation and applying motion compensated temporal interpolation (MCTI) to obtain the side information. The work in [80] studied the effect of Group of Picture (GOP) size on the performance of DISCOVER with Low-Density Parity-Check (LDPC) codes for single view video coding. Based on the statistical analysis for the encoder time complexity and the RD performance, the DISCOVER encoder attained similar visual quality to the H.264/AVC encoder while the processing time was reduced by thirty percent on average. This feature makes the WZ coding scheme a competitive option for real-time video communication applications.

For multiview video coding, the inter-view correlation is also utilized by the decoder to restore the WZ data [76], [81]–[85]. The multiview DVC developed within the DISCOVER project applied both MCTI and homography compensated inter-view interpolation (HCII) in decoding [81], [76]. Similar coding structures for data processing in wavelet transform domain were reported [82]. The PRISM based multiview DVC presented in [85] incorporated disparity search (PRISM-DS) and view synthesis search in the decoding process. From the performance comparison with several simulcast coding schemes and the DISCOVER DVC scheme on visual quality under different PLR, the proposed coding scheme achieved better visual quality than the DISCOVER DVC scheme under low PLR, an average 2dB gain in PSNR when PLR $< 5\%$. The experimental results also revealed that under low level packet loss, the conventional MPEG/H.26x codec is still superior to the DVC schemes, and the additionally introduced complexity for reducing inter-view redundancy needs to be balanced with the coding efficiency.

E. CROSS-LAYER CONTROL

In the wireless video communication system, the limited channel resources are managed through configuring the options at different layers in the network architecture, such as the coding and error control at the application layer, the congestion control and reliability protocol at the transport layer, the routing at the network layer, the contention scheme at the MAC (medium access control) layer, and the MCS at the physical layer [86]. To jointly implement the configuration procedure, the cross-layer control methodology is developed to optimize the system-level resource allocation [87]. Given the channel state information (CSI), the controller is able to coordinate decision making at different layers in order to maximize the visual quality of the received video. The general optimization framework is formulated as a distortion minimization problem under certain resource constraints, typically the delivery delay constraint [29], [36], [38], [40], [88], and the transmission power constraint [27], [89]–[91]. The video coding scheme described in [40] considered the physical layer MCS in estimating the dynamic PLR in a Rayleigh fading channel. For video streaming over multi-hop WSNs, the systems demonstrated in [36] and [38] enabled adaptive configuration for both the physical layer MCS and the link layer path selection. A priority based packet

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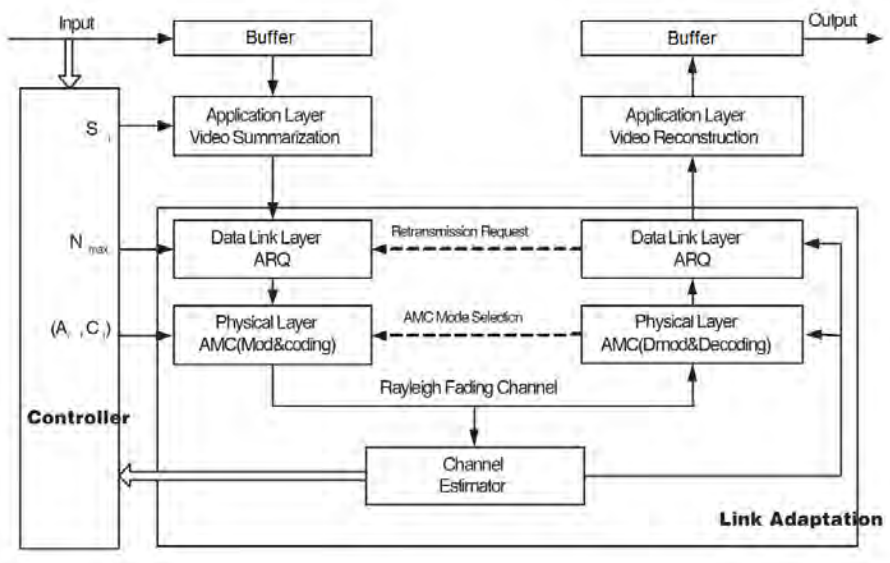


FIGURE 8. Cross-layer control model for wireless video streaming.

TABLE 3. Video technologies for wireless surveillance.

Video technology	Implementation	Advantage	Disadvantage
Object based UEP	Shape coding, priority queuing	Discriminative resource allocation	Extra computation for ROI detection and processing
Error resilience	FEC, ARQ, MDC, JSCC, cross-layer control	Better error control with CSI	Increased complexity for CSI collection and distortion estimation
Scalable video coding	Quality/spatial/temporal scalability	Rate adaptivity	Coding efficiency and complexity, dependence between layers
Distributed video coding	Single view/multiview DVC	Low encoding complexity	Deteriorated video quality

queuing mechanism at each sensor node is adopted in the video surveillance system designed in [29] to implement UEP for the target packets and the background packets at the transport layer. The work introduced in [88] incorporates congestion control with link adaptation for real-time video streaming over ad hoc networks. Power constraint is another consideration for energy efficient mobile devices. In [89], node cooperation is applied to optimally schedule the routing in order to minimize the energy consumption and delay. The cross-layer design presented in [90] jointly configured the physical, MAC, and routing layers to maximize the lifetime of energy-constrained WSNs. The object based video coding and transmission scheme developed in [27] performed UEP for the shape data and the texture data in the rate and energy allocation procedure. The optimal rate allocation policies introduced in [91] are developed to maximize aggregate throughput or to minimize queuing delays.

A standard formulation for the cross-layer optimization procedure can be expressed as

$$\begin{aligned} &\min \sum E\{D(\psi_1, \psi_2, \ldots, \psi_n, p)\} \\ &s.t. \qquad \boldsymbol{C}(\psi_1, \psi_2, \ldots, \psi_n) \le \boldsymbol{C}^{\max} \end{aligned} \tag{1}$$

where $E\{D\}$ is the expected video data distortion under the system configuration set $\psi_1, \psi_2, \ldots, \psi_n$, p is the expected data loss over the WSN given the same configuration, $\boldsymbol{C}(\psi_1, \psi_2, \ldots, \psi_n)$ is the vector of corresponding consumed resources, and $\boldsymbol{C}^{\max}$ represents the resource constraints. The most challenging part in the procedure is to accurately predict the data loss information based on the system configuration set and the collected CSI from the time varying wireless network, in order to estimate the received data distortion. In online video communication application, the computational complexity of the solution procedure is also a primary concern. Figure 8 shows a paradigm of the cross-layer optimized video streaming scheme described in [38]. A summary of above potential technologies for a wireless video surveillance system is provided in Table 3.

V. VIDEO ANALYSIS

After transmission over the lossy channel, the video data is recovered by the receiver for observation and further analysis. In advanced video surveillance systems, two commonly studied applications are object detection and object tracking. A variety of techniques have been developed for related vision

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tasks. For example, with fixed cameras, object detection takes advantage of static background. A popular technique is the background subtraction based on a Gaussian Mixture Model [18]. This temporal learning process models different conditions of a pixel at certain positions as a mixture of Gaussian distributions. The weight, mean, and variance values of each Gaussian model can be updated online, and pixels not conforming to any background model are quickly detected. The adaptive learning property makes this technique suitable for real-time applications [20], [21], [92]. Other detection methods include the region segmentation based graph cut [93], edge detection based variational level set [94], and compressive sensing [95].

With active cameras such as PTZ cameras, the detection method needs to consider the changing background in the recorded video. The feature point matching algorithm has been widely studied for the purpose of robust object detection and tracking, including the scale invariant feature transform [96], and the kernel filtering algorithm [97]. These point matching methods are costly to implement and hence are not suitable for real-time applications. The RANSAC (RANdom SAmple Consensus) algorithm is often adopted for fast implementation of the point matching process [98], [99]. In the video object detection scheme presented in [99], the moving target is detected through subtracting the background image synthesized by the homography-RANSAC algorithm, which is based on the special property of the PTU camera movement. The object detection procedure is illustrated in Figure 9.

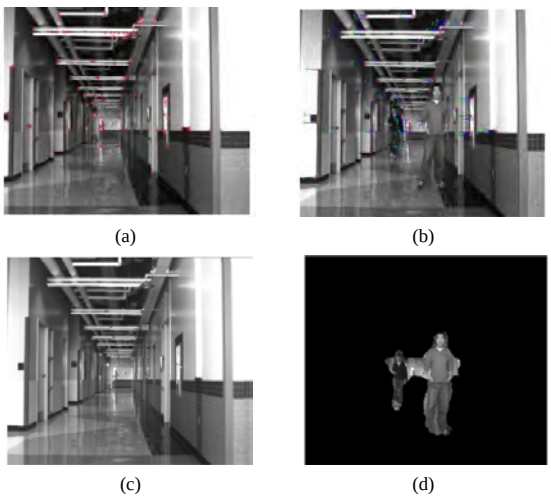


FIGURE 9. Object detection procedure: (a) feature point detection on precaptured background image; (b) feature point correspondence on the recorded image with homography-RANSAC; (c) background synthesis using the estimated homography; (d) object segmentation with background subtraction and level-set contour.

Another well known motion detection technique under dynamic scene is the optical flow [100]. The affine transformation between consecutive frames is estimated such that the motion area not conforming to the transformation stands out. Real-time computation of optical flow was presented in [101]. In [102], the disparity information was combined with optical flow for binocular view object tracking. Other popular methods for dynamic object tracking include Lucas-Kanade-Tomasi tracker [103], Mean Shift [24], level set contour [104], and the techniques fusing multiple properties of the video data [105], [106]. In multiview object detection/tracking, the problem of object correspondence in different view was discussed in [17], [107]. The camera control algorithm based on the object detection result was also rigorously studied for tracking with active cameras [22], [70].

Other vision technologies, such as super resolution [108], view synthesis [109], and 3D model reconstruction [110], can be possibly applied to a video surveillance system. However, most of these technologies are either based on undistorted video data, or are independent of the error control procedure at the transmitter. The impact of video compression on RD performance was considered in several vision applications for optimal source coding decisions at the transmitter, including view synthesis [111], [112], object tracking [113], and super resolution [114]. Some JSCC schemes were embedded in the coding structure for optimal resource allocation based on the end-to-end distortion estimation [27], [35], [115]–[117]. The channel distortion model for more complex vision applications remains a challenging research topic.

VI. OTHER ISSUES

Data security is an important issue in secret communications in sensor networks [118]. For video data, the encryption can be performed on the compressed bitstream using well established cryptographic algorithms, such as the built-in authentication and AES (Advanced Encryption Standard) encryption defined in the IEEE 802.16/WiMax standard [119]. For a large amount of video data, the resource allocated for security protection has to be balanced with the error control effort supported by the wireless communication system, in order to achieve the optimal end-to-end secrecy.

The encryption can also be performed within the coding process using the video scrambling technique [120], without adverse impact on error resilience. Moreover, video watermarking has been proved to be an efficient measure for data protection and authentication in WSNs [121], [122]. These security measures often come with the reduced coding efficiency, and the requirement of more advanced error concealment techniques for recovering the corrupted video.

Privacy is another issue gaining increasing attention in video surveillance systems [123]. A major concern regarding this issue is that some contents of the surveillance video, such as those involving personal identity, are inappropriate or illegal to be displayed directly in front of the audience. Current methods applied to address this issue are based on object detection techniques [124], especially the facial recognition techniques. The content-aware coding method proposed in [125] utilized the spatial scalability features of the JPEG XR (JPEG extended range) codec for face masking. The face regions were detected and scrambled in the transform domain. In another shape coding scheme [126], the object region was

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encrypted independently in the SPIHT based coding process, with enhanced coding efficiency compared to the contour based block coding in MPEG-4. The implementation of privacy measures in a real-time surveillance application could be very difficult, as the prerequisite to identify the sensitive content or to detect the unusual event is a challenging task itself.

VII. CONCLUSION

Wireless video surveillance is popular in various visual communication applications. IMS Research has predicted that the global market for wireless infrastructure gear used for video surveillance applications will double up from 2011 to 2016 [127]. This paper presents a survey on the technologies dedicated to different functional modules of a video surveillance system. A comprehensive system design would require interdisciplinary study to seamlessly incorporate different modules into an optimal system-level resource allocation framework. While the advanced WSN infrastructure provides a strong support for surveillance video communications, new challenges are emerging in the process of compressing and transmitting large amounts of video data, and in the presence of run time and energy conservation requirements for mobile devices. Another trend in this field is the 3D signal processing technology in more advanced multiview video surveillance. The wireless communication environment posts greater difficulty for this kind of applications. How to efficiently estimate the distortion for the dedicated vision task at the receiving end using the compressed and concealed video data is essential to the system performance.

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Appendix MM

Cost-Efficient Mining Techniques for Data Streams

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Abstract

A data stream is a continuous and high-speed flow of data items. High speed refers to the phenomenon that the data rate is high relative to the computational power. The increasing focus of applications that generate and receive data streams stimulates the need for online data stream analysis tools. Mining data streams is a real time process of extracting interesting patterns from high-speed data streams. Mining data streams raises new problems for the data mining community in terms of how to mine continuous high-speed data items that you can only have one look at. In this paper, we propose algorithm output granularity as a solution for mining data streams. Algorithm output granularity is the amount of mining results that fits in main memory before any incremental integration. We show the application of the proposed strategy to build efficient clustering, frequent items and classification techniques. The empirical results for our clustering algorithm are presented and discussed which demonstrate acceptable accuracy coupled with efficiency in running time.

Keywords: Mining data streams, clustering, frequent items, classification and algorithm output granularity.

1 Introduction

A data stream is a sequence of unbounded, real time data items with a very high data rate that can only read once by an application. (Muthukrishnan 2003, Henzinger, Raghavan, and Rajagopalan 1998, Golab and Ozsu 2003, Babcock, Babu, Datar, Motwani, and Widom 2002). For example in NASA Earth Observation System (EOS), a pair of Landsat 7 and Terra spacecraft generates 350 GB of data per day as mentioned by Park and Kargupta (2002). Another example by Muthukrishnan (2003), an oil drill can transmit its current drilling conditions at 1 Mb/Second.
Two recent advancements result in the need for data stream processing systems as discussed in (Muthukrishnan 2003, Golab and Ozsu 2003):

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- The automatic generation of a highly detailed, high data rate sequence of data items in different scientific and business applications.
- The need for complex analyses of these high-speed data streams.

The main constraints for querying data streams are the unbounded memory requirement and the high data rate. Thus, the computation time per data element should be less than the data rate. Also, it is very hard due to unbounded memory requirements to have an exact result. Research studies have been done to approximate the query result. Sliding window, batch processing, sampling, and synopsis data structures have been discussed by (Babcock, Babu, Datar, Motwani, and Widom 2002, Garofalakis, Gehrke, Rastogi 2002) for query result approximation.

Recently, load shedding and rate based query optimization have been proposed by (Babcock, Datar, and Motwani 2003, Tatbul, Cetintemel, Zdonik, Cherniack and Stonebraker 2003) as an approach for querying data streams. Load shedding refers to the process of dropping data elements from data stream randomly or semantically.

Analogous to load shedding for query processing, we propose data rate adaptation as a solution approach for mining data streams. Data rate adaptation could be used from the input side using sampling, filtering and aggregation. We propose the use of data rate adaptation from the output side using algorithm output granularity. Algorithm output granularity is the amount of mining results that fits in main memory before any incremental integration. The application of the proposed technique for different data mining techniques is presented in this paper accompanied with empirical studies for the clustering technique.

The paper is organized as follows. Section 2 presents related works in mining data streams. Section 3 reviews the problem of the high-data rate feature, discusses data rate adaptation techniques and introduces algorithm output granularity as an approach for data stream mining. The application of the algorithm output granularity for clustering, classification and frequent items is presented in terms of new techniques for these data mining strategies in Section 4. Section 5 shows the experimental results of the clustering algorithm. Finally we conclude the paper and present our future work in Section 6.

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2 Related Works

Clustering data streams has been studied in (Guha, Mishra, Motwani, and O'Callaghan 2000, Domingos and Hulten 2001, O'Callaghan, Mishra, Meyerson, Guha , and Motwani 2002, Aggarwal, Han, Wang, Yu 2003, Ordonez 2003, Keogh, Lin, and Truppel 2003, Babcock, Datar, and Motwani 2003, Charikar, O'Callaghan, and Panigrahy 2003, Datar, Gionis, Indyk, and Motwani 2002). Data stream classification has been studied in (Domingos and Hulten 2000, Hulten, Spencer, and Domingos 2001, Ganti, Gehrke, Ramakrishnan 2002, Papadimitriou, Faloutsos, and Brockwell 2003, Wang, Fan, Yu and Han 2003). Extracting frequent items and frequent itemsets have been studied in (Cormode, Muthukrishnan 2003, Giannella, Han, Pei, Yan, and Yu 2003, Manku and Motwani 2002).

The main focus of the above algorithms is how to reduce the number of passes and the number of data elements being tested in order to have an efficient approximate algorithm compared to the traditional techniques. The fact that the main problem in data stream mining is the high data rate and how to develop light-weight data mining techniques that adapt to the incoming data rate according to the available resources is our approach. Our proposed solution for data rate adaptation has the advantage of the generality to any algorithm as well as the simplicity of implementation. The next section presents our algorithm output granularity approach and discusses the issues that result from the adoption of data rate adaptation approach in mining data streams.

3 Data Rate Adaptation

In this section, a formalization of mining data streams problem is given followed by an approach for solving this problem.

High-speed data stream: data rate > processing rate given the processing environment, this requires the development of an algorithm that can result in an approximate solution for the given problem.

The above is the general definition of the data stream processing problem. Thus, our research problem can be formalized as follows:

Given data rate > mining rate (given the processing environment), it is required to design, develop and test resource-aware mining algorithms that can result in an acceptable output accuracy.

Data rate adaptation techniques represented by sampling, aggregation and our proposed technique *algorithm granularity* (AG) try to reduce the data rate in order to give the algorithm the capability to catch up with data in a resource constrained environment. These adaptation techniques can limit the algorithm accuracy. The ultimate goal is to find a solution using one or more of the adaptation techniques in order to maximize the algorithm output accuracy given the available resources (memory, CPU utilization, battery consumption for mobile devices, effective bandwidth). We define algorithm granularity as the amount of generated results kept in main memory before doing any incremental integration in order to catch up with the high data rate. The algorithm granularity is based on the following:

a) The algorithm rate (AR) is function in a data rate (DR), i.e., $AR = f(DR)$. The number of generated cluster centers per unit time for example depends on the data rate.

b) The time needed to fill the available memory by the algorithm results (TM) is function in (AR), i.e., $TM = f(AR)$. The time needed for example to fill the available memory by cluster centers depends on the algorithm rate.

c) The algorithm accuracy (AC) is function in (TM), i.e., $AC = f(TM)$. That is if the time needed to fill the available memory is enough to the algorithm at the highest data rate without sampling, aggregation or algorithm granularity, this would be the best solution

The higher the algorithm granularity, the more accurate the algorithm output will be.

The above discussion raises a number of issues:

1) What is the optimum combination of data rate adaptation techniques that might be used to catch up with the high-speed data stream?
2) How to measure the effect of one strategy on the available resources? For example how to measure the effect of the algorithm granularity on the available memory or CPU utilization.
3) How to measure the algorithm accuracy for any combination of data adaptation techniques?
4) How to dynamically change this combination according to the variability of the available resources in order to achieve the required accuracy?
5) Which data rate techniques are more appropriate to a specific mining algorithm?
6) How to deal with unbounded memory requirements due to the continuous flow of data streams?
7) How to achieve the required accuracy?

Our light-weight algorithms address the issues of unbounded memory requirements and the required accuracy. The next section presents our light-weight mining algorithms using the algorithm output granularity approach.

4 Algorithm Granularity based Mining Techniques

In the following subsections, we show the application of the algorithm output granularity to clustering, classification and frequent items. Since all these algorithms perform only one pass over the data stream, we term them light-weight mining algorithms: LWC, LWClass, and LWF for the above techniques respectively.

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4.1 LWC

In this section, our one-look clustering algorithm (LWC) is explained and discussed. The algorithm has two main components. The first one is the resource-aware RA component that uses the data adaptation techniques to catch up with the high-speed data stream and at the same time to achieve the optimum accuracy according to the available resources. It starts by checking the minimum data rate that could be achieved using data adaptation techniques with an acceptable accuracy. If the algorithm can catch up with the minimum data rate, the RA component tries to find a solution that maximizes the accuracy by increasing the data rate. Otherwise the algorithm should send a data mining request to a data mining server that can achieve the minimum acceptable accuracy.
The other component is the LWC algorithm. The algorithm follows the following steps:

1- Data items arrive in sequence with a data rate.
2- The algorithm starts by considering the first point as a center.
3- Compare any new data item with the centers to find the distance.
4- If the distance for all the centers is greater than a threshold, the new item is considered as a new center; else increase the weight for the center that has the shortest distance between the data item and the center by 1 and let the new center equals the weighted average.
5- Repeat 3 and 4.
6- If the number of centers = k (according to the available memory) then create a new centers vector.
7- Repeat 3, 4, 5, and 6.
8- If memory is full then re-cluster (incrementally integrate the clusters)

The algorithm output granularity (k) is represented here by the number of cluster centers' kept in memory before doing any incremental clustering integaration. The higher the algorithm granularity the higher is the algorithm accuracy. The threshold value here represents the minimum distance between any point and the cluster center. The lower the threshold the more the clusters is created.

The algorithm according to the given threshold and the data set domain generates the maximum number of subsequent data items, each of which represents a center; that will be given using the following formula:
Maximum number of subsequent data points that could be centers = [(Maximum item value in the data set - Minimum item value in the data set) / threshold]

Since these points in the worst case might be the first points in the data stream in order for them to be centers, the following formula gives the number of data elements that would do the comparison over the generated centers:

Cluster Members = Data Set Size - [(Maximum item value in the data set - Minimum item value in the data set) / threshold].

Thus the algorithm complexity is *O(nm)*, where "n" is the data set size, and "m" is maximum number of subsequent data points that could be centers.

4.2 LWClass

In this section, we present the application of the algorithm output granularity to light weight K-Nearest-Neighbors classification LWClass. The algorithm starts with determining the number of instances according to the available space in the main memory. When a new classified data element arrives, the algorithm searches for the nearest instance already in the main memory according to a pre-specified distance threshold. The threshold here represents the similarity measure acceptable by the algorithm to consider two or more elements as one element according to the element attributes' values. If the algorithm finds this element, it checks the class label. If the class label is the same, it increases the weight for this instance by one, otherwise it decrements the weight by one. If the weight becomes zero, this element will be released from the memory. The algorithm granularity here could be controlled by the distance threshold value and could be changing over time to cope with the high speed of the incoming data elements. The algorithm procedure could be described as follows:

1) Data streams arrive item by item. Each item contains attribute values for a_1, a_2, …,a_n attributes and the class category.
2) According to the data rate and the available memory, we apply the algorithm output granularity as follows:
    a) Measure the distance between the new item and the stored ones.
    b) If the distance is less than a threshold, store the average of these two items and increase the weight for this average as an item by 1. (The threshold value determines the algorithm accuracy and should be chosen according to the available memory and data rate that determines the algorithm rate).
    This is in case that both items have the same class category. If they have different class categories, decrement the weight by 1 till the weight equals to zero, then delete the item from the memory.
    c) After a time interval threshold for the training, we come up with the classification results.
3) Using the above classification results, we have some items that we need to classify them. According to the available time for the

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classification process, we choose nearest K-items and these items will be variable according to the time needed by the process.

4) Find the majority class category taking into account the calculated weights from the K items and this will be the answer for this classification task.

4.3 LWF

In this section, we present our light-weight frequent items LWF algorithm. The algorithm starts by setting the number of frequent items that will be calculated according to the available memory. This number changes over time to cope with the high data rate. The AG is represented here by the number of frequent items that the algorithm can calculate as well as the number of counters that will be re-set after some time threshold to be able to cope with the continuous nature of the data stream. The algorithm receives the data elements one by one and tries to find a counter for any new item and increase the item for the registered items. If all the counters are occupied, any new item will be ignored and the counters will be decreased by one till the algorithm reaches some time threshold a number of the least frequent items will be ignored and their counters will be re-set to zero. If the new item is similar to one of the items in memory according to a similarity threshold, the average of both items will be allocated and the counter will be increased by one. The main parameters that can affect the algorithm accuracy are time threshold, number of calculated frequent items and number of items that will be ignored and their counter will be re-set after some time threshold.

We presented our light weight mining techniques. The empirical studies for the clustering technique will be discussed in the following section.

5 Empirical studies for LWC

The experiments were conducted using Matlab 6.0 in which the LWC is developed and the k-means algorithm included in the Matlab package is used as a guide to measure the algorithm accuracy. The experiments were conducted using a machine with Pentium 4 CPU 2.41 GHz, 480 MB of RAM, and running Windows XP Professional operation system. Data sets are synthesized data generated using random number generators in Matalab. We have conducted a number of experiments to evaluate the algorithm.

Experiment 1: (Figure 1)

Aim: Measure the algorithm running time with different threshold values.

Experiment Setup: Running LWC several times using different threshold values with a synthesized data set.

Results: The higher the threshold the lower the running time.

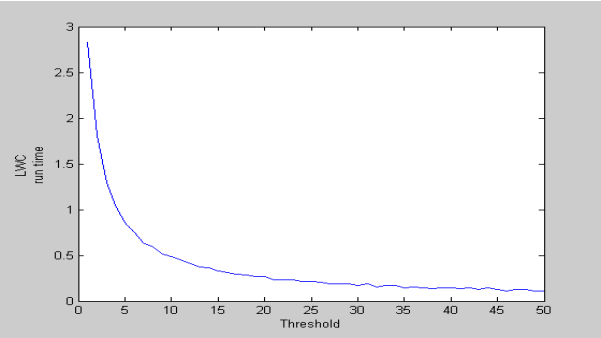


Figure 1: LWC Running Time.

Analysis: We have to minimize the threshold according to the available resources of memory and CPU utilization. We can use the threshold as an output adaptation technique which could be used together with the data rate adaptation techniques discussed earlier. That is because the threshold value controls the algorithm rate (The higher the threshold the lower the algorithm rate). On the other hand, we can use the threshold as an application-oriented parameter that does not affect the accuracy; however it might increase it according to some domain knowledge about the clustering problem that might be known in advance.

Experiment 2: (Figure 2)

Aim: Measuring the algorithm accuracy with different threshold values.

Experiment Setup: Running LWC and K-means several times with different threshold values for LWC. The experiment is repeated three times with different data set sizes.

Results: The lower the threshold the higher the accuracy of the algorithm which is measured as follows: *Accuracy (LWC) = average (|sorted LWC centers – sorted K-means centers|). The lower this measure will be, the higher the accuracy.*

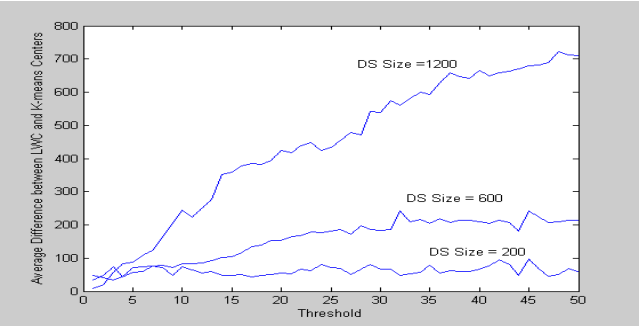


Figure 2: LWC Accuracy (DS Size measured in number of data items).

Analysis: Choosing the threshold value is an important issue to achieve the required accuracy. It should be noted that from this experiment and the previous one the higher the accuracy the higher the running time. And that both factors are affected by the threshold value.

Experiment 3: (Figure 3)

Aim: Measure the LWC algorithm running time against the data set sizes.

Experiment setup: Running the LWC algorithm with different large data sets.

Results: The algorithm has a linear relation with the data set size.

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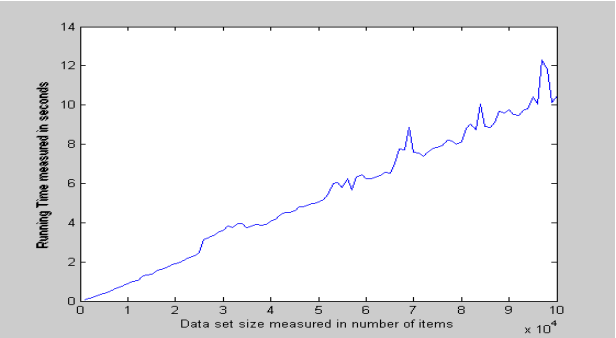


Figure 3: LWC running time with different data set sizes

Analysis: the LWC algorithm is efficient for large data sets due to the linearity of the running time against data set size

Experiment 4: (Figure 4)

Aim: Measuring the effect of the threshold on the above experiment.

Experiment setup: Running LWC algorithm with the same data set sizes as the above experiment, but with decreasing threshold value with each run.

Results: The threshold value affects the running time of the algorithm since the maximum running time in the above experiment is approximately 12 seconds. The maximum running time in this experiment is about 47 seconds.

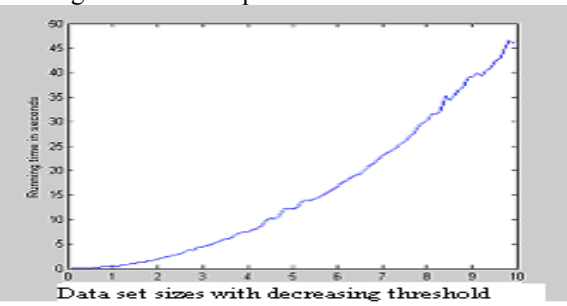


Figure 4: LWC running time with different data set sizes and threshold values

Analysis: According to the application and/or the required accuracy, we have to maximize the threshold value to have more efficient algorithm in terms of running time.

Experiment 5: (Figure 5)

Aim: Comparison between K-means and LWC efficiency.

Experiment setup: Running LWC (with a small threshold value which results in a high accuracy) and K-means several times on the same data sets with different sizes and measuring the running time.

Results: The running time of LWC is low compared to K-means with small data set sizes.

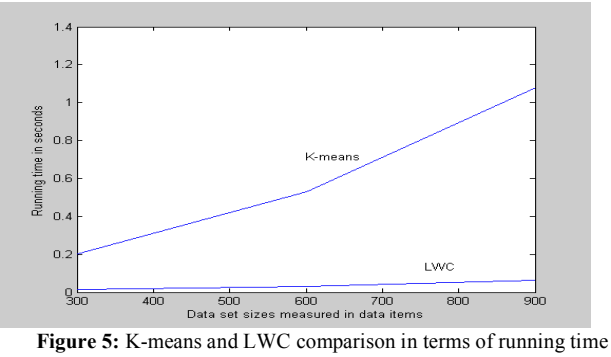


Figure 5: K-means and LWC comparison in terms of running time

Analysis: LWC is efficient compared to K-means for small data sets, when we try to run both on large data sets, we found that LWC over performs the K-means.

The above experiments show an efficient one-look clustering algorithm that is adaptable to the available resources using data adaptation techniques and the control of the threshold value as an algorithm rate adaptation technique.

6 Conclusions and Future Work

In this paper, we show algorithm output granularity as a data rate adaptation technique for mining data streams. The application of this technique to clustering, classification and frequent items is proposed and discussed. The empirical studies of the clustering algorithm are discussed. They show an acceptable accuracy accompanied with efficiency in running time.

The development of frequent items and classification techniques as well as the empirical studies are our future work in testing the efficiency of algorithm output granularity approach in mining data streams. The combination among different data rate adaptation techniques to achieve the required accuracy will be investigated experimentally. Automating the threshold adaptation using linear regression to cope with the change in the data rate, and the deployment of the developed algorithms for potential applications in sensor networks and ubiquitous data analysis business applications such as stock markets are planned for our future work.

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Appendix NN

Lecture notes on Image Compression and Video Compression

7. Video Compression

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Topics

- Introduction to Image Compression
- Transform Coding
- Subband Coding, Filter Banks
- Introduction to Wavelet Transform
- Wavelet Image Compression
- Perceptual Audio Coding
- Video Compression

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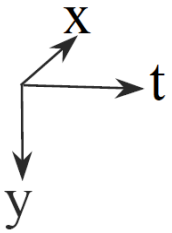
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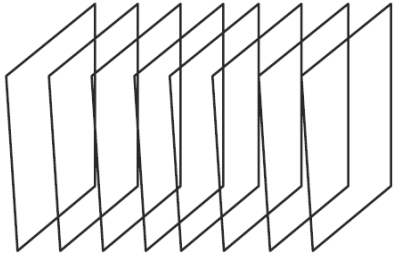
- Introduction to Video Compression
- MPEG 1 Video Compression
- Motion Compensation
- Video Compression Standards

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Digital Video

- A series of frames (i.e. digital images)
- Can be sampled
  - From raster analog scan
  - Directly with a CCD camera

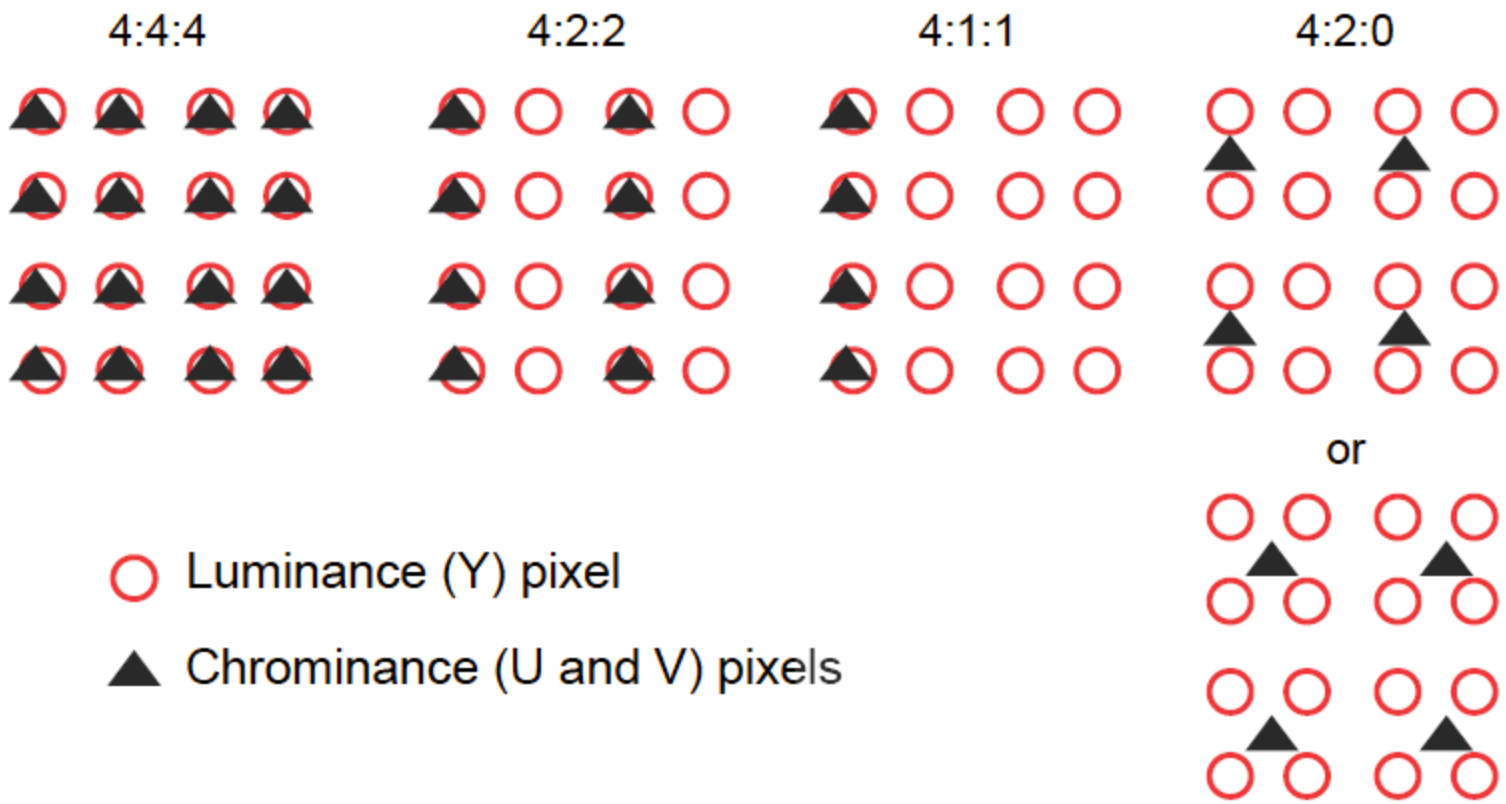




- 3 color components
- Usually, color components down-sampled

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Color Down-sampling



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The Need for Compression

- Image sequences must be significantly compressed for efficient storage and transmission as well as for efficient data transfer among various components of a video system.
- Examples (Motion Picture)
  - One frame of a Super 35 format motion picture may be digitized (via Telecine equipment) to a 3112 lines by 4096 pixels/color, 10 bits/color image.
  - As a result, 1 sec. of the movie takes ~1 Gbytes !

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The Need for Compression - Examples

- HDTV
  - A typical progressive scan (non-interlaced) HDTV sequence may have 720 lines and 1280 pixels with 8 bits per luminance and chroma channels.
  - The data rate corresponding to a frame rate of 60 frames/sec is 720 x 1280 x 3 x 60 = 165 Mbytes/sec!

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Applications of Digital Video Compression

- Teleconference or video phone
  - Very low delay (1/10 second is a standard)
- Live Broadcast Video
  - Modest delay is tolerable (seconds is normal)
  - Error tolerance is needed.
- Video-in-a-can (DVD, Video-on-Demand)
  - Random access to compressed data is desired
  - Encoding can take a lot of time
- Decoding must always be at least the frame rate.

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Approaches to Video Compression

- Intraframe compression treats each frame of an image sequence as a still image.
  - Intraframe compression, when applied to image sequences, reduces only the spatial redundancies present in an image sequence.
- Interframe compression employs temporal predictions and thus aims to reduce temporal as well as spatial redundancies, increasing the efficiency of data compression.
  - Example: Temporal motion-compensated predictive compression.

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Why can Images be Compressed?

- Image compression can be achieved primarily because image data are highly redundant.
- The degree of redundancy determines how much compression can be achieved.
- Four types of redundancy can be identified:
  - Spatial Redundancy
    - Correlation between adjacent data points
  - Temporal Redundancy
    - Correlation between different frames in an image
  - Spectral Redundancy
    - Correlation between different color planes or sensors
    - Limitation of Low-level Human Vision System
  - Psycho-visual Redundancy
    - Limitation of high-level Human Vision System

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Human Perception of Video

- 30 frames per second seems to allow the visual system to integrate the discrete frames into continuous perception.
- If distorted, nearby frames in the same scene should have only small details wrong.
  - A difference in average intensity is noticeable
- Compression choice when reducing bit rate
  - skipped frames cause stop action
  - lower fidelity frames may be better

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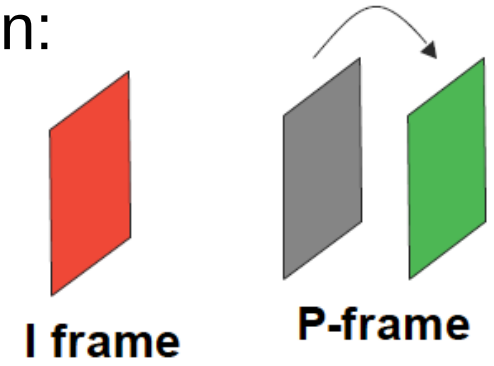
High Compression Ratios Possible

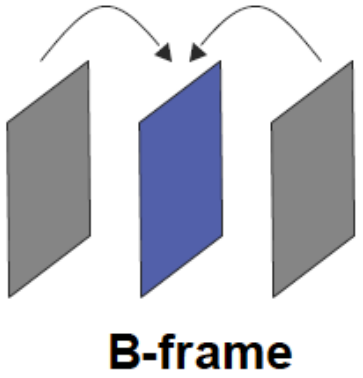
- Nearby frames are highly correlated. Use the previous frame to predict the current one.
- Need to take advantage of the fact that usually objects move very little in 1/30th of a second.
  - Video coders use motion compensation as part of prediction.

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Video Compression

- Main addition over image compression:
  - Exploit the temporal redundancy
- *Predict current frame* based on previously coded frames
- Three types of coded frames:
  - ***I-frame:*** Intra-coded frame, coded independently of all other frames
  - ***P-frame:*** Predictively coded frame, coded based on previously coded frame
  - ***B-frame:*** Bi-directionally predicted frame, coded based on both previous and future coded frames

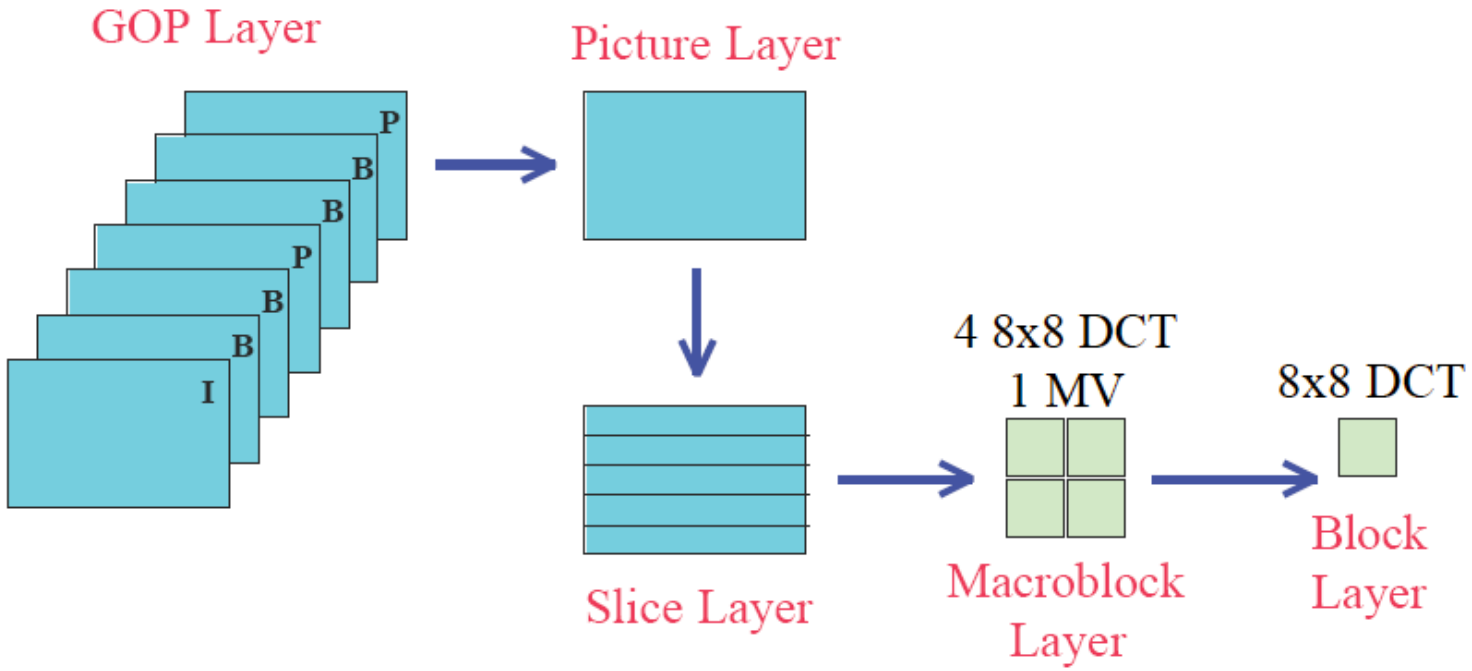




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MPEG 1 Structure

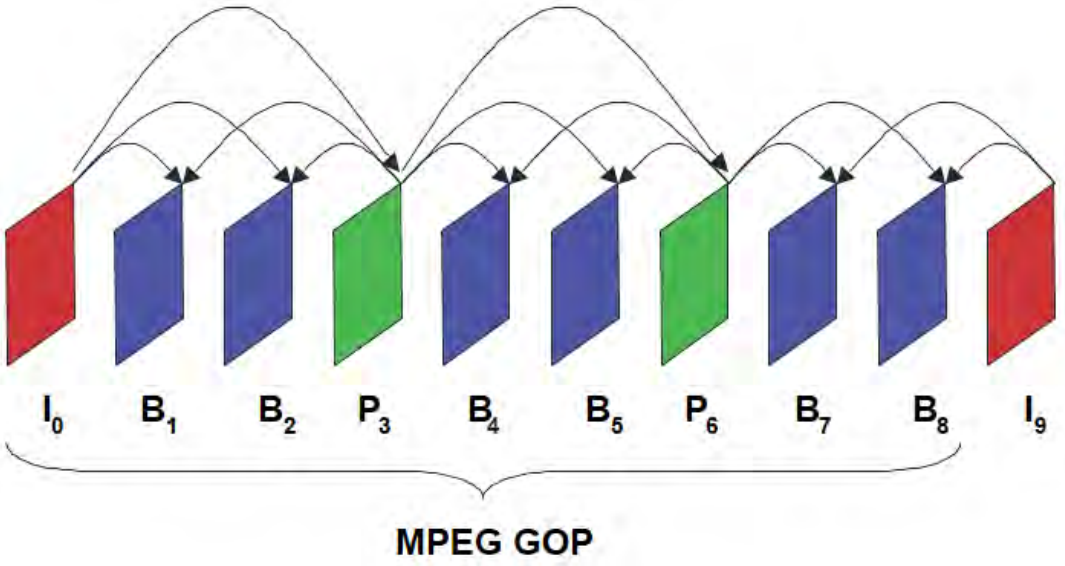
- MPEG codes video in a hierarchy of layers.



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MPEG 1 Group of Pictures (GOP) Structure

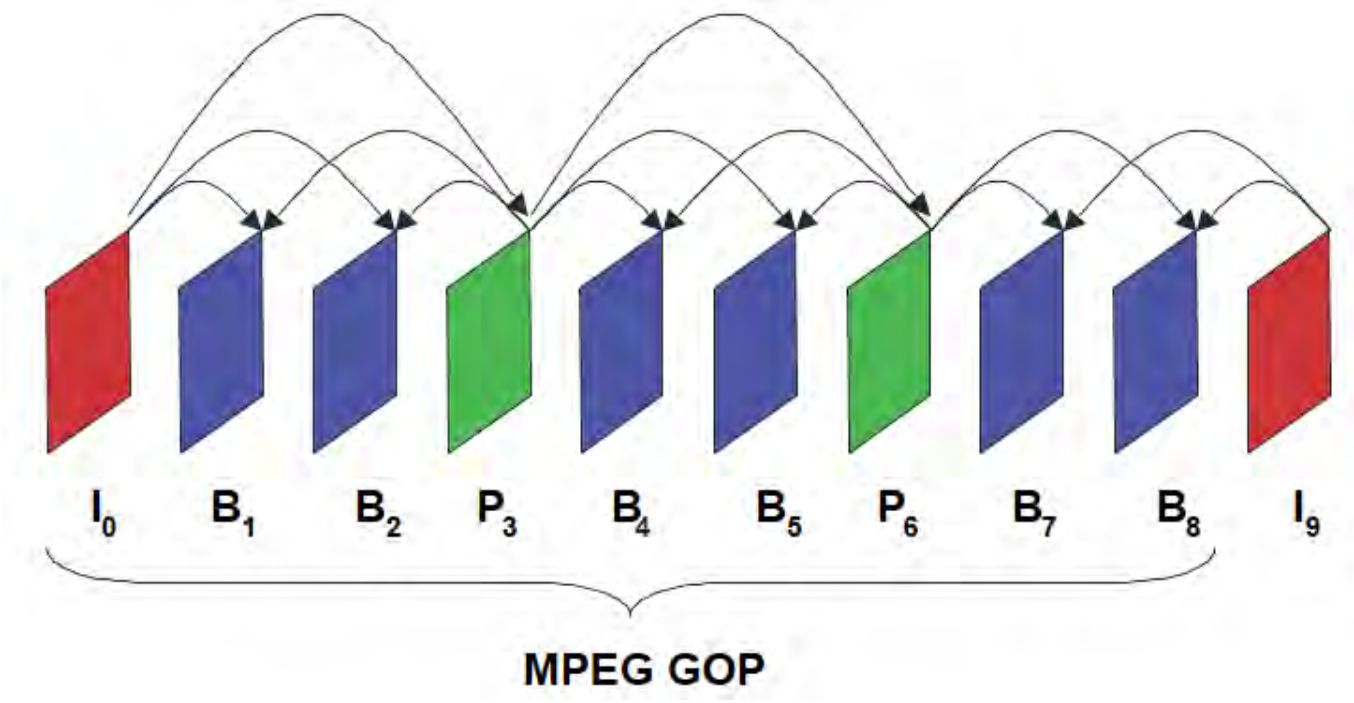
- Composed of I, P, and B frames
- Periodic I-frames enable random access into the coded bit stream.
- Parameters: (1) Spacing between I frames (2) number of B frames between I and P frames



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Example Use of I-,P-,B-frames: MPEG 1 Group of Pictures (GOP)

- Arrows show prediction dependencies between frames



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Definition of P Frames

- P Pictures are composed of macroblocks that are either
  - forward predictive (non-intra) coded . Or
  - intra coded (using the same quantization and VLC as macroblocks of the I pictures).
- The encoder is allowed to make an Intra/Non-Intra decision depending on the accuracy of the prediction.
- This decision can be made in many different ways and the choice is up to the encoder.

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P Frames

- A possible simple decision mechanism compares the variance of the luminance component of the original macroblock with that of the prediction error macroblock.
- If the variance of the prediction error macroblock is higher, then the macroblock is intra coded.

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Definition of B Pictures

- B Pictures are composed of macroblocks that are
  - bi-directional predictive coded, or
  - backward predictive coded, or
  - forward predictive coded, or
  - intra coded
- A possible decision mechanism is picking the mode that results in the least macroblock (luminance component) variance.
- The macroblocks in the B pictures are not used as references.

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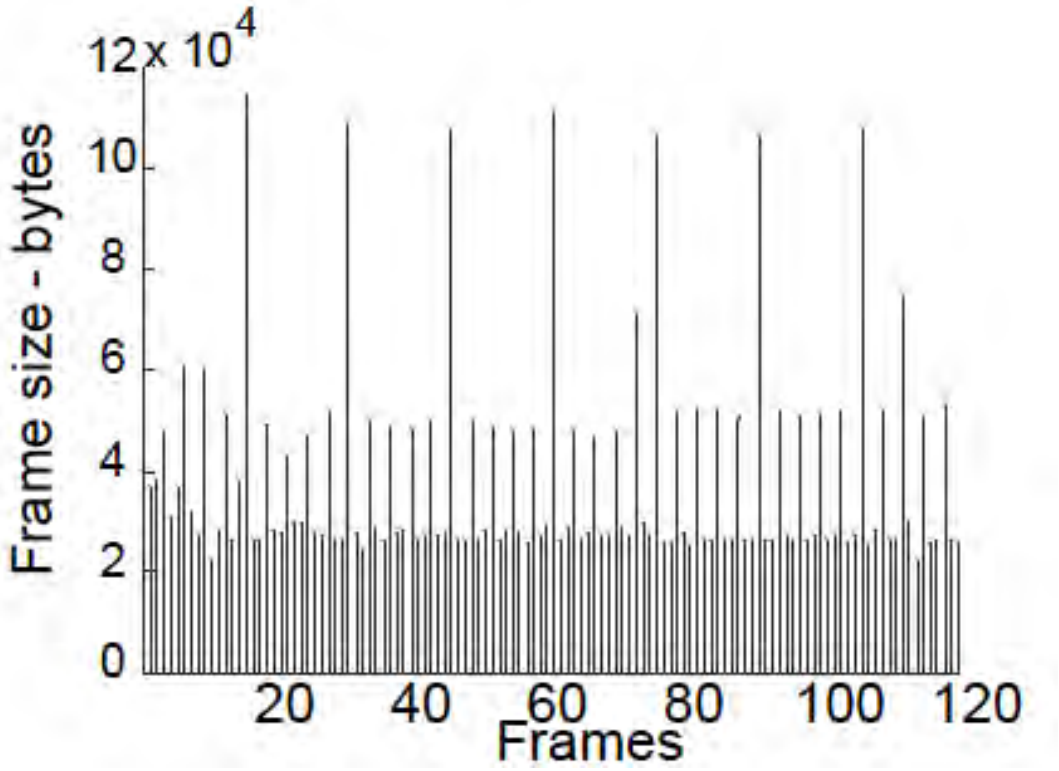
MPEG 1

- Relative number of (I), (P), and (B) pictures can be arbitrary.
  - It depends on the nature of the application.
  - For instance it depends on fast access and compression ratio requirements; relatively smaller amount of compression is expected to be achieved at (I) pictures compared to (P) and (B) pictures.
- The (B) pictures are expected to provide relatively the largest amount of compression under favorable predictability conditions.

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MPEG 1 Frame Size

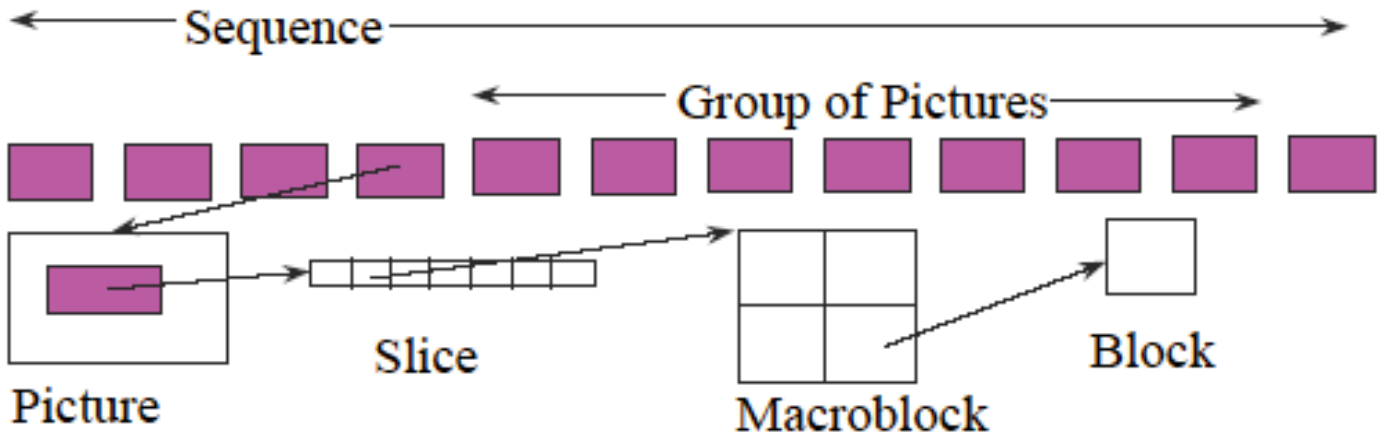
- Size of I, P, B frames



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MPEG-1- Bit Stream Hierarchy

- MPEG-1- Bit Stream Hierarchy



The Bit Stream

Sequence 1 Level	GOP Level	Picture Level	Slice Level	MB Level	Block Level	Sequence 2 Level	

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Temporal Redundancy

- Adjacent frames are highly correlated.

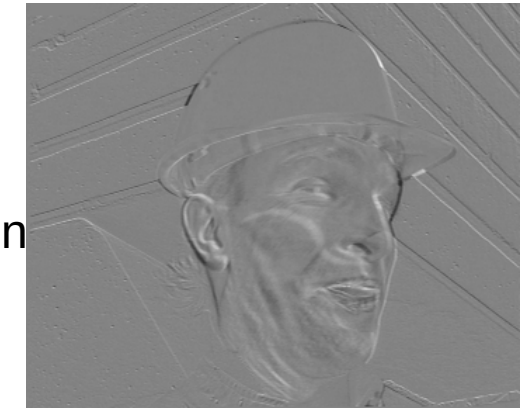
Frame 7



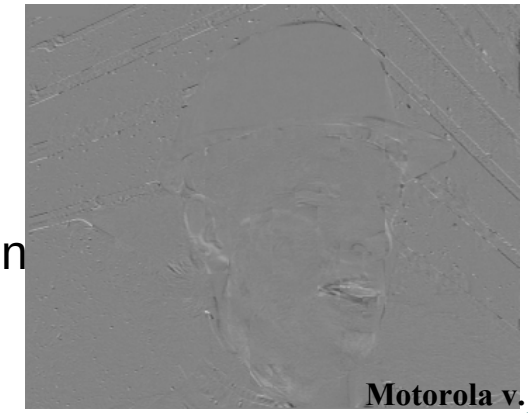
Frame 8



No motion compensation



With motion compensation



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Motion Compensation

- In general, we speak of motion of objects in 3-D real world.
  - Here, we are concerned with the "projected motion" of 3-D objects onto the 2-D plane of an imaging sensor.
  - By motion estimation, we mean the estimation of the displacement (or velocity) of image structures from one frame to another in a time sequence of 2-D images.
- In the literature, this projected motion is referred to as "apparent motion", "2-D image motion", or "optical flow".
- The detail algorithms on "optical flow“ is beyond the content of this course.

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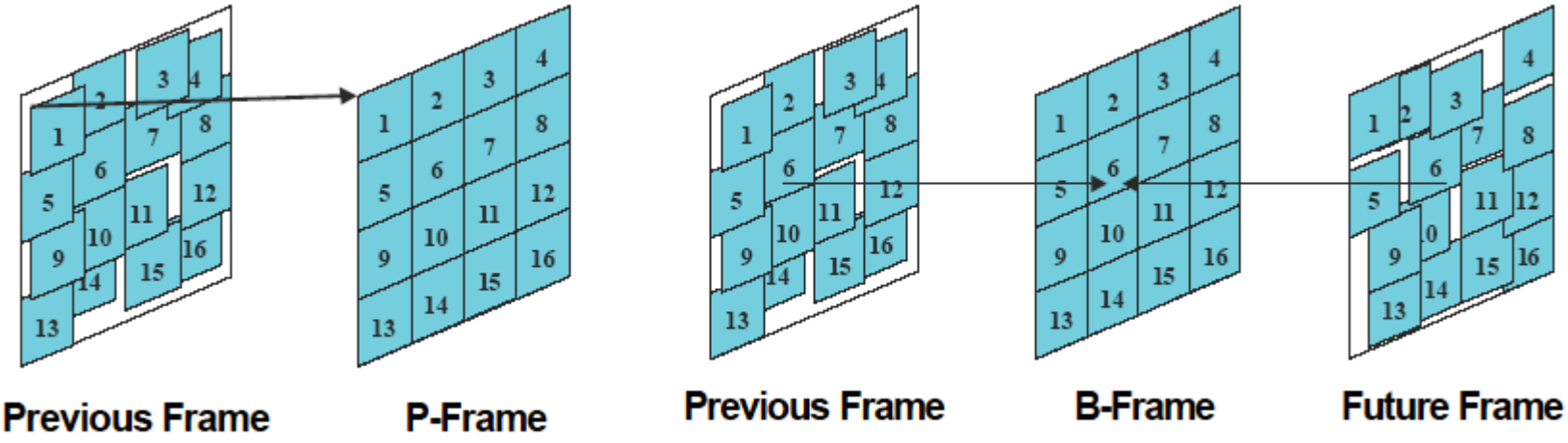
Motion Compensation

- Predict the current frame based on reference frames while compensating for the motion.
- For each motion compensation block
  - Find the block in the reference decoded frame that gives the least distortion.
  - If the distortion is too high then code the block independently. (intra block)
  - Otherwise code the difference (inter block)

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MC-Prediction and Bi-Directional MC-Prediction (P- and B-frames)

- Examples of block-based motion-compensated prediction (*P-frame*) and bi-directional prediction (*B-frame*)



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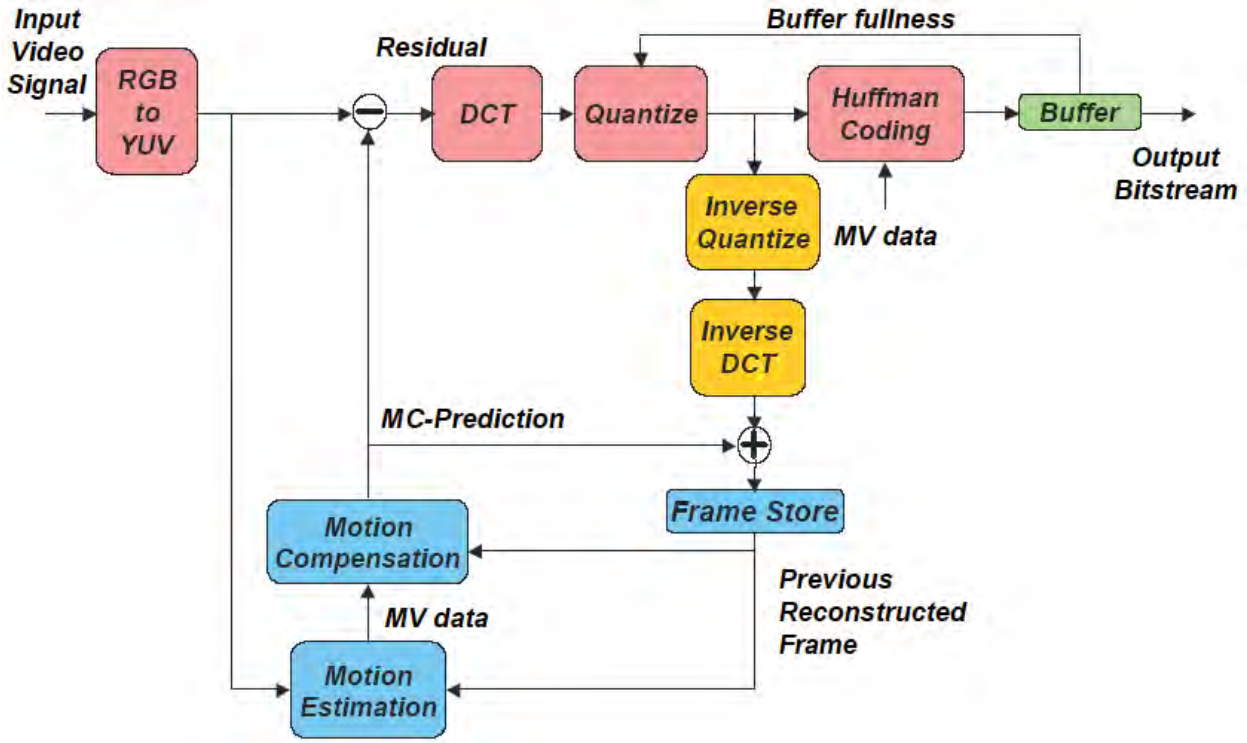
Summary of Temporal Processing

- Use MC-prediction (P and B frames) to reduce temporal redundancy.
- MC-prediction usually performs well; In compression have a second chance to recover when it performs badly.
- MC-prediction yields:
  - Motion vectors
  - MC-prediction error or residual
    -> Code error with conventional image coder.
- Sometimes MC-prediction may perform badly
  - Examples: Complex motion, new imagery (occlusions)
  - Approach:
    - 1. Identify frames or individual blocks where prediction fails
    - 2. Code them without prediction

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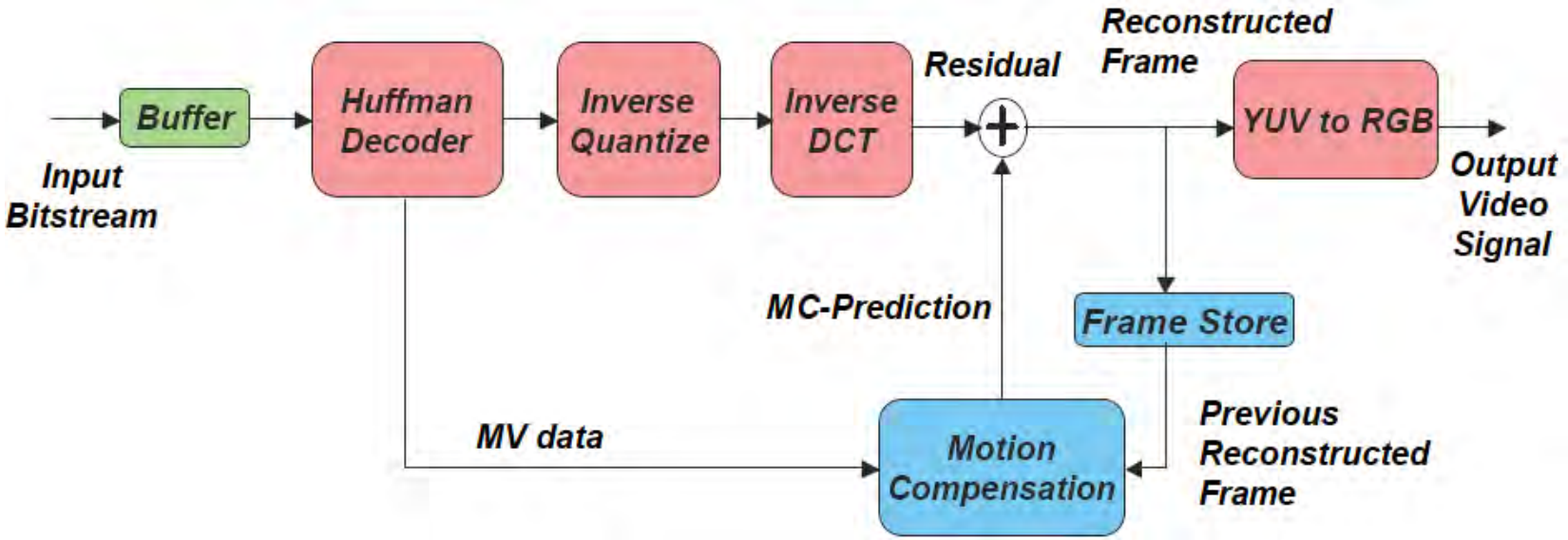
Example Video Encoder

- Theoretically, MPEG = JPEG + ME.



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Example Video Decoder



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Video Standard

- ITU-T Standards for Audio-Visual Communications
  - H.261
  - H.263
  - H.263+, H.263++
- ISO Standards for
  - MPEG-1
  - MPEG-2
  - MPEG-4
  - MPEG-7

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Multimedia Communications Standards and Applications

Standards	Application	Video Format	Raw Data Rate	Compressed Data Rate
H.320 (H.261)	Video conferencing over ISDN CIF	CIF/ QCIF	37 Mbps 9.1 Mbps	>=384 Kbps >=64 Kbps
H.323 (H.263)	Video conferencing over Internet	4CIF/ CIF/ QCIF		>=64 Kbps
H.324 (H.263)	Video over phone lines/ wireless	QCIF	9.1 Mbps	>=18 Kbps
MPEG-1	Video distribution on CD/ WWW	CIF	30 Mbps	1.5 Mbps
MPEG-2	Video distribution on DVD / digital TV	CCIR601 4:2:0	128 Mbps	3-10 Mbps
MPEG-4	Multimedia distribution over Inter/Intra net	CIF/ QCIF		28-1024 Kbps
GA-HDTV	HDTV broadcasting	SMPTE 296/295	<=700 Mbps	18-45 Mbps
MPEG-7	Multimedia databases (content description and retrieval)			

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Comparing Current Video Compression Standards

- Based on the same fundamental building blocks
  - Motion-compensated prediction (I, P, and B frames)
  - 2-D Discrete Cosine Transform (DCT)
  - Color space conversion
  - Scalar quantization, runlengths, Huffman coding
- Additional tools added for different applications:
  - Progressive or interlaced video
  - Improved compression, error resilience, scalability, etc.
- MPEG-1/2/4, H.261/3/L: Frame-based coding
- MPEG-4: Object-based coding and Synthetic video

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Newest Trends

- H.264
  - Just out in 2003, many new features
  - Quarter pixel motion compensation
  - Variable size motion blocks
- 3-D Wavelet Coding
  - Third dimension is time
  - 3-D SPIHT has been implemented
  - Delay is large because GOP is large
- GTV
  - Group testing for video
  - Bits per frame can be controlled enabling off-line rate control to succeed.

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