

DECLARATION OF JUNE ANN MUNFORD

1. My name is June Ann Munford. I am over the age of 18, have personal knowledge of the facts set forth herein, and am competent to testify to the same.
2. I earned a Master of Library and Information Science (MLIS) from the University of Wisconsin-Milwaukee in 2009. I have over ten years of experience in the library/information science field. Beginning in 2004, I have served in various positions in the public library sector including Assistant Librarian, Youth Services Librarian and Library Director. I have attached my Curriculum Vitae as Appendix CV.
3. During my career in the library profession, I have been responsible for materials acquisition for multiple libraries. In that position, I have cataloged, purchased and processed incoming library works. That includes purchasing materials directly from vendors, recording publishing data from the material in question, creating detailed material records for library catalogs and physically preparing that material for circulation. In addition to my experience in acquisitions, I was also responsible for analyzing large collections of library materials, tailoring library records for optimal catalog

search performance and creating lending agreements between libraries during my time as a Library Director.

4. I am fully familiar with the catalog record creation process in the library sector. In preparing a material for public availability, a library catalog record describing that material would be created. These records are typically written in Machine Readable Catalog (herein referred to as “MARC”) code and contain information such as a physical description of the material, metadata from the material’s publisher, and date of library acquisition. In particular, the 008 field of the MARC record is reserved for denoting the date of creation of the library record itself. As this typically occurs during the process of preparing materials for public access, it is my experience that an item’s MARC record indicates the date of an item’s public availability.
5. Typically, in creating a MARC record, a librarian would gather various bits of metadata such as book title, publisher and subject headings among others and assign each value to a relevant numerical field. For example, a book’s physical description is tracked in field 300 while title/attribution is tracked in field 245. Fields 650 and 655 are frequently used to index library materials by subject. The 008 field of the MARC record is reserved for denoting the creation of the library record itself. As this is the only date reflecting the

inclusion of said materials within the library's collection, it is my experience that an item's 008 field accurately indicates the date of an item's public availability.

6. I have reviewed Exhibit APPLE-1011, "A Wearable Reflectance Pulse Oximeter for Remote Physiological Monitoring" by Y. Mendelson, R.J. Duckworth and G. Comtois as published in *Proceedings of the 28th IEEE EMBS Annual International Conference*, 2006.
7. I have reviewed Exhibit APPLE-1007, "A Sensor Network to iPhone Interface Separating Continuous and Sporadic Processes in Mobile Telemedicine" by Lorenzo T. D'Angelo, Michael Schneider, Paul Neugubauer and Tim C. Lueth as published in *Proceedings of the 33rd IEEE EMBS Annual International Conference*, 2011.
8. Attached hereto as Appendix OSU01 is a true and correct copy of the MARC record for *Proceedings of the IEEE EMBS Annual International Conference* as held by the Ohio State University library. I secured this record myself from the library's public catalog. The MARC record contained within Appendix OSU01 accurately describes the title, author, publisher, and ISSN number of *Proceedings of the IEEE EMBS Annual*

International Conference. Due to the record's inclusion in the library catalog, these proceedings have been indexed by subject and made searchable by keyword- and subject-level searching. I spoke with staff at the Ohio State University library who confirmed that their collection of *Proceedings of the IEEE EMBS Annual International Conference* contains the proceedings of the 28th conference containing "A Wearable Reflectance Pulse Oximeter for Remote Physiological Monitoring" (APPLE-1011) and the 33rd conference containing "A Sensor Network to iPhone Interface Separating Continuous and Sporadic Processes in Mobile Telemedicine" (APPLE-1007).

9. Attached hereto as Appendix SU01 is a true and correct copy of the MARC record for *Proceedings of the IEEE EMBS Annual International Conference* as held by the Syracuse University library. I secured this record myself from the library's public catalog. The MARC record contained within Appendix SU01 accurately describes the title, author, publisher, and ISSN number of *Proceedings of the IEEE EMBS Annual International Conference*. Due to the record's inclusion in the library catalog, these proceedings have been indexed by subject and made searchable by keyword- and subject-level searching. I spoke with staff at the Syracuse University library who confirmed that their collection of *Proceedings of the IEEE EMBS Annual*

International Conference contains the proceedings of the 28th conference containing “A Wearable Reflectance Pulse Oximeter for Remote Physiological Monitoring” (APPLE-1011) and the 33rd conference containing “A Sensor Network to iPhone Interface Separating Continuous and Sporadic Processes in Mobile Telemedicine” (APPLE-1007).

10. Attached hereto as Appendix UOFM01 is a true and correct copy of the MARC record for *Proceedings of the IEEE EMBS Annual International Conference* as held by the University of Michigan library. I secured this record myself from the library’s public catalog. The MARC record contained within Appendix UOFM01 accurately describes the title, author, publisher, and ISSN number of *Proceedings of the IEEE EMBS Annual International Conference*. Due to the record’s inclusion in the library catalog, these proceedings have been indexed by subject and made searchable by keyword- and subject-level searching. I spoke with staff at the University of Michigan library who confirmed that their collection of *Proceedings of the IEEE EMBS Annual International Conference* contains the proceedings of the 28th conference containing “A Wearable Reflectance Pulse Oximeter for Remote Physiological Monitoring” (APPLE-1011) and the 33rd conference containing “A Sensor Network to iPhone Interface

Separating Continuous and Sporadic Processes in Mobile Telemedicine”
(APPLE-1007).

11. Attached hereto as Appendix MENDELSON01 is a true and correct copy of
“A Wearable Reflectance Pulse Oximeter for Remote Physiological
Monitoring” as published in *Proceedings of the 28th IEEE EMBS Annual
International Conference* as held by the Ohio State University library. I
secured this file myself from the library’s collection. In comparing Exhibit
APPLE-1011 to Appendix MENDELSON01, it is my determination that
Exhibit APPLE-1011 is a true and correct copy of “A Wearable Reflectance
Pulse Oximeter for Remote Physiological Monitoring” as published in
Proceedings of the 28th IEEE EMBS Annual International Conference by Y.
Mendelson, R.J. Duckworth and G. Comtois.

12. Attached hereto as Appendix DANGELO01 is a true and correct copy of “A
Sensor Network to iPhone Interface Separating Continuous and Sporadic
Processes in Mobile Telemedicine” as published in *Proceedings of the 33rd
IEEE EMBS Annual International Conference* as held by the Ohio State
University library. I secured this file myself from the library’s collection. In
comparing Exhibit APPLE-1007 to Appendix DANGELO01, it is my
determination that Exhibit APPLE-1007 is a true and correct copy of “A

Sensor Network to iPhone Interface Separating Continuous and Sporadic Processes in Mobile Telemedicine” as published in *Proceedings of the 33rd IEEE EMBS Annual International Conference* by Lorenzo T. D'Angelo, Michael Schneider, Paul Neugubauer and Tim C. Lueth.

13. I am familiar with the Internet Archive, a digital library formally certified by the State of California as a public library. Among other services that the Internet Archive makes available to the general public is the Wayback Machine, an online archive. The Internet Archive’s Wayback Machine service archives webpages as of a certain capture date to track changes in the web over time. The Internet Archive has been in operation as a nonprofit library since 1996 and has hosted the Wayback Machine service since its inception in 2001. During my time as a librarian, I frequently used the Internet Archive’s Wayback Machine for research and instruction purposes. This includes teaching instructional classes on using the Wayback Machine to library patrons and using the Wayback Machine to research reference inquiries that require hard-to-find online resources. I consider the Internet Archive’s recordskeeping to be as rigorous and detailed as other formal library recordskeeping practices such as MARC records, OCLC records and Dublin Core.

14. Attached hereto as Appendix MENDELSON02 is a screen capture of the Internet Archive Wayback Machine entry for <http://embs.gsbme.unsw.edu.au/confs.html>. I secured these screen captures myself from https://web.archive.org/web/20060515000000*/http://embs.gsbme.unsw.edu.au/confs.html. This particular record is dated as May 15, 2006.
15. Appendix MENDELSON02 is a screen capture of a webpage entitled “IEEE EMBSH Sponsorship of Conferences” hosted by the IEEE Engineering in Medicine and Biology Society. As visible on page 3 of this Appendix, the 2006 IEEE EMBC Conference where “A Wearable Reflectance Pulse Oximeter for Remote Physiological Monitoring” was presented is being advertised to take place from August 30 – September 3, 2006. As the capture date of this record is May 15, 2006, this web page also indicates that the IEEE EMBS was advertising this conference months before it took place.
16. Attached hereto as Appendix DANGELO02 is a screen capture of the Internet Archive Wayback Machine entry for <http://www.embs.org/conferences/index.html>. I secured these screen captures myself from

<https://web.archive.org/web/20110718005649/http://www.embs.org/conferences/index.html>. This particular record is dated as July 18, 2011.

17. Appendix DANGELO02 is a screen capture of a webpage entitled “IEEE EMBSH Sponsorship of Conferences” hosted by the IEEE Engineering in Medicine and Biology Society. As visible on page 2 of this Appendix, the 2011 IEEE EMBC Conference where “A Sensor Network to iPhone Interface Separating Continuous and Sporadic Processes in Mobile Telemedicine” was presented is being advertised to take place from August 30 – September 3, 2011. As the capture date of this record is July 18, this web page also indicates that the IEEE EMBS was advertising this conference a month before it took place.
18. The 008 field of the MARC record in Appendix OSU01 indicates the date of record creation. The 008 field of Appendix OSU01 indicates the Ohio State University library first acquired these proceedings as of March 11, 2005 and continued to acquire new editions in perpetuity.
19. The 008 field of the MARC record in Appendix SU01 indicates the date of record creation. The 008 field of Appendix SU01 indicates the Syracuse

University library first acquired these proceedings as of March 11, 2005 and continued to acquire new editions in perpetuity.

20. The 008 field of the MARC record in Appendix UOFM01 indicates the date of record creation. The 008 field of Appendix UOFM01 indicates the University of Michigan library first acquired these proceedings as of July 22, 2005 and continued to acquire new editions in perpetuity.

21. “A Wearable Reflectance Pulse Oximeter for Remote Physiological Monitoring” was published in the 28th edition of *Proceedings of the IEEE EMBS Annual International Conference*. This paper was presented at the 2006 edition of the IEEE EMBS Annual International Conference and Appendix MENDELSON02 indicates this conference held from August 30, 2006 – September 3 2006. As multiple universities were collecting new editions of *Proceedings of the IEEE EMBS Annual International Conference* as of September 2006, it is my determination that “A Wearable Reflectance Pulse Oximeter for Remote Physiological Monitoring” was first made available to the public at the 2006 IEEE EMBS Annual International Conference and was shortly after made available to the public from the Ohio State University, Syracuse University and University of Michigan among others.

22. “A Sensor Network to iPhone Interface Separating Continuous and Sporadic Processes in Mobile Telemedicine” was published in the 33rd edition of *Proceedings of the IEEE EMBS Annual International Conference*. This paper was presented at the 2011 edition of the IEEE EMBS Annual International Conference and Appendix DANGELO02 indicates this conference held from August 30, 2011 – September 3 2011. As multiple universities were collecting new editions of *Proceedings of the IEEE EMBS Annual International Conference* as of September 2011, it is my determination that “A Wearable Reflectance Pulse Oximeter for Remote Physiological Monitoring” was first made available to the public at the 2011 IEEE EMBS Annual International Conference and was shortly after made available to the public from the Ohio State University, Syracuse University and University of Michigan among others via the conference proceedings.

23. I have been retained on behalf of the Petitioner to provide assistance in the above-illustrated matter in establishing the authenticity and public availability of the documents discussed in this declaration. I am being compensated for my services in this matter at the rate of \$100.00 per hour plus reasonable expenses. My statements are objective, and my compensation does not depend on the outcome of this matter.

24. I declare under penalty of perjury that the foregoing is true and correct. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Dated: 8/1/2023

A handwritten signature in cursive script, appearing to read "June Ann Munford".

June Ann Munford

APPENDIX CV

June A. Munford
Curriculum Vitae

Education

University of Wisconsin-Milwaukee - MS, Library & Information Science, 2009
Milwaukee, WI

- Coursework included cataloging, metadata, data analysis, library systems, management strategies and collection development.
- Specialized in library advocacy, cataloging and public administration.

Grand Valley State University - BA, English Language & Literature, 2008
Allendale, MI

- Coursework included linguistics, documentation and literary analysis.
- Minor in political science with a focus in local-level economics and government.

Professional Experience

Researcher / Expert Witness, October 2017 – present
Freelance ● Pittsburgh, Pennsylvania & Grand Rapids, Michigan

- Material authentication and public accessibility determination. Declarations of authenticity and/or public accessibility provided upon research completion. Experienced with appeals and deposition process.
- Research provided on topics of public library operations, material publication history, digital database services and legacy web resources.
- Past clients include Alston & Bird, Arnold & Porter, Baker Botts, Fish & Richardson, Erise IP, Irell & Manella, O'Melveny & Myers, Perkins-Coie, Pillsbury Winthrop Shaw Pittman and Slayden Grubert Beard.

Library Director, February 2013 - March 2015
Dowagiac District Library ● Dowagiac, Michigan

- Executive administrator of the Dowagiac District Library. Located in

Southwest Michigan, this library has a service area of 13,000, an annual operating budget of over \$400,000 and total assets of approximately \$1,300,000.

- Developed careful budgeting guidelines to produce a 15% surplus during the 2013-2014 & 2014-2015 fiscal years while being audited.
- Using this budget surplus, oversaw significant library investments including the purchase of property for a future building site, demolition of existing buildings and building renovation projects on the current facility.
- Led the organization and digitization of the library's archival records.
- Served as the public representative for the library, developing business relationships with local school, museum and tribal government entities.
- Developed an objective-based analysis system for measuring library services - including a full collection analysis of the library's 50,000+ circulating items and their records.

November 2010 - January 2013

Librarian & Branch Manager, Anchorage Public Library ● Anchorage, Alaska

- Headed the 2013 Anchorage Reads community reading campaign including event planning, staging public performances and creating marketing materials for mass distribution.
- Co-led the social media department of the library's marketing team, drafting social media guidelines, creating original content and instituting long-term planning via content calendars.
- Developed business relationships with The Boys & Girls Club, Anchorage School District and the US Army to establish summer reading programs for children.

June 2004 - September 2005, September 2006 - October 2013

Library Assistant, Hart Area Public Library
Hart, MI

- Responsible for verifying imported MARC records and original MARC

cataloging for the local-level collection as well as the Michigan Electronic Library.

- Handled OCLC Worldcat interlibrary loan requests & fulfillment via ongoing communication with lending libraries.

Professional Involvement

Alaska Library Association - Anchorage Chapter

- Treasurer, 2012

Library Of Michigan

- Level VII Certification, 2008
- Level II Certification, 2013

Michigan Library Association Annual Conference 2014

- New Directors Conference Panel Member

Southwest Michigan Library Cooperative

- Represented the Dowagiac District Library, 2013-2015

Professional Development

Library Of Michigan Beginning Workshop, May 2008

Petoskey, MI

- Received training in cataloging, local history, collection management, children's literacy and reference service.

Public Library Association Intensive Library Management Training, October 2011

Nashville, TN

- Attended a five-day workshop focused on strategic planning, staff management, statistical analysis, collections and cataloging theory.

Alaska Library Association Annual Conference 2012 - Fairbanks, February 2012

Fairbanks, AK

- Attended seminars on EBSCO advanced search methods, budgeting, cataloging, database usage and marketing.

Depositions

2019 ● Fish & Richardson

Apple v. Qualcomm (IPR2018-001281, 39521-00421IP, IPR2018-01282 and 39521-00421IP2)

2019 ● Erise IP

Implicit, LLC v. Netscout Systems, Inc (Civil Action No. 2:18-cv-53-JRG)

2019 ● Perkins-Coie

Adobe Inc. v. RAH Color Technologies LLC (Cases IPR2019-00627, IPR2019-00628, IPR2019-00629 and IPR2019-00646)

2020 ● O'Melveny & Myers

Maxell, Ltd. v. Apple Inc. (Case No. 5:19-cv-00036-RWS)

2021 ● Pillsbury Winthrop Shaw Pittman LLP

Intel v. SRC (IPR2020-1449)

2022 ● Perkins-Coie

Realtek v. Future Link (IPR2021-01182)

2023 ● Fish & Richardson

Neuroderm Ltd. v. Abbvie, Inc (Case No. PGR2022-00040)

2023 ● Fish & Richardson

Nearmap US Inc. v. Pictometry International Corp. (IPR2022-00735)

Limited Case History & Potential Conflicts

Alston & Bird

- Ericsson
 - v. Collision Communications (IPR2022-01233)
- Nokia
 - v. Neptune Subsea, Xtera (Case No. 1:17-cv-01876)

Arnold & Porter

- Ivantis
 - v. Glaukos (Case No. 8:18-cv-00620)
- Samsung
 - v. Jawbone (Case No. 2:21-cv-00186)

Benesch Friedlander Coplan & Aronoff

- Voyis
 - v. Cathx (Case No. 5:21-cv-00077-RWS)

Erise I.P.

- Apple
 - v. Ericsson Inc. (IPR2022-00715)
 - v. Future Link Systems (IPRs 6317804, 6622108, 6807505, and 7917680)
 - v. INVT (Case No. 20-1881)
 - v. Navblazer LLC (IPR2020-01253)
 - v. Qualcomm (IPR2018-001281, 39521-00421IP, IPR2018-01282, 39521-00421IP2)
 - v. Quest Nettech Corp (Case No. 2:19-cv-00118-JRG)
 - v. Telefonaktiebolaget LM Ericsson (IPR2022-00275)

- Fanduel
 - v. CGT (Case No. 19-1393)
- Garmin
 - v. Phillips North America LLC (Case No. 2:19-cv-6301-AB-KS)
- Netscout
 - v. Longhorn HD LLC (Case No. 2:20-cv-00349)
 - v. Implicit, LLC (Civil Action No. 2:18-cv-53-JRG)
- Sony Interactive Entertainment LLC
 - v. Bot M8 LLC (IPR2020-01288)
 - v. Infernal Technology LLC (Case No. 2:19-CV-00248-JRG)
- Unified Patents
 - v. GE Video Compression (Civil Action No. 2:19-cv-248)

Fish & Richardson

- Apple
 - v. AliveCor (3:21-cv-03958)
 - v. LBS Innovations (Case No. 2:19-cv-00119-JRG-RSP)
 - v. Koss Corporation (IPR2021-00305)
 - v. Masimo (IPR 50095-0012IP1, 50095-0012IP2, 50095-0013IP1, 50095-0013IP2, 50095-0006IP1)
 - v. Neonode (Case No. 21-cv-08872-EMC)
 - v. Qualcomm (IPR2018-001281, 39521-00421IP, IPR2018-01282, 39521-00421IP2)
- Dell
 - v. Neo Wireless (IPR2022-00616)

- Dish Network
 - v. Realtime Adaptive Streaming (Case No. 1:17-CV-02097-RBJ)
 - v. TQ Delta LLC (Case No. 18-1798)
- Evapco Dry Cooling
 - v. SPG Dry Cooling (IPR2021-00688)
- Genetec
 - v. Sensormatic Electronics (Case No. 1:20-CV-00760)
- Huawei
 - v. Bell Northern Research LLC (IPR2019-01174)
- Kianxis
 - v. Blue Yonder (Case No. 3:20-cv-03636)
- LG Electronics
 - v. Bell Northern Research LLC (Case No. 3:18-cv-2864-CAB-BLM)
- Metaswitch
 - v. Sonus Networks (IPR2018-01719)
- Microsoft
 - v. Throughputer Inc (IPR2022-00757)
- MLC Intellectual Property
 - v. MicronTech (Case No. 3:14-cv-03657-SI)
- Nearmap Inc
 - v. EagleView Technologies (IPR2022-01009)
- Neuroderm Ltd.
 - v. Abbvie, Inc (Case No. PGR2022-00040)
- Realtek Semiconductor
 - v. Future Link (IPR2021-01182)

- Quectel
 - v. Koninklijke Philips (Case No. 1:20-cv-01710)
- Samsung
 - v. Aire Technology (IPR2022-00877)
 - v. Bell Northern Research (Case No. 2:19-cv-00286-JRG)
 - v. Communication Technologies Inc (IPR2022-01221)
 - v. Jawbone Innovations (IPR2022-00865)
 - v. MemoryWeb LLC (IPR2022-00885)
 - v. Telefonaktiebolaget LM Ericsson (IPR2021-00615)
- Texas Instruments
 - v. Vantage Micro LLC (IPR2020-01261)
- Xilinx
 - v. Sentient Sensors LCC (Case No. 1:22-cv-00173)

Irell & Manella

- Curium

O'Melveny & Myers

- Apple
 - v. Maxell (Case No. 5:19-cv-00036-RWS)

Perkins-Coie

- Heru Industries
 - v. The UAB Research Foundation (IPR2022-01148)
- Realtek Semiconductor
 - v. Future Link (IPR2021-01182)

- Twitter Inc
 - v. VOIP-Pal.com (Case No. 3:20-cv-02397-JD)
- TCL Industries
 - v. Koninklijke Philips NV (IPR2021-00495, IPR2021-00496 and IPR2021-00497)

Pillsbury Winthrop Shaw Pittman

- Intel
 - v. FG SRC LLC (Case No. 6:20-cv-00315)
- Gravel Rating Systems
 - v. Costco (Case No. 4:21-cv-149)
 - v. Lowe's Home Centers (Case No. 4:21-cv-150)
 - v. T-Mobile USA (Case No. 4:21-cv-152)
 - v. Kohl's Inc. (Case No. 4:21-cv-258)
 - v. Under Armor (Case No. 4:21-cv-356)

APPENDIX OSU01

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246 13 IEEE Engineering in Medicine and Biology ... Annual Conference

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246 17 Proceedings of the ... Annual International Conference of the IEEE EMBS

264 1 Piscataway, NJ :|bIEEE Service Center,|c[2004-]

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300 1 online resource (volumes :|billustrations

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362 0 26th (2004)-

515 Volumes for 2004- issued in multiple parts. volumes for 2004-2005 numbered as 26th and 27th. Beginning with 2006, issued as vol. 1 each year

650 12 Biomedical Engineering.|0(DNLM)D001698.|0https://id.nlm.nih.gov/mesh/D001698

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Publ History26th (2004)-

NoteVolumes for 2004- issued in multiple parts. volumes for 2004-2005 numbered as 26th and 27th. Beginning with 2006, issued as vol. 1 each year

ISSN1557-170X

OCLC/Control #973040125

Other SubjectBiomedical Engineering.

Add'l AuthorIEEE Service Center., publisher
IEEE Engineering in Medicine and Biology Society Conference

Other TitleConf Proc Annu Int Conf IEEE Eng Med Biol Soc
Conf Proc IEEE Eng Med Biol Soc
IEEE Engineering in Medicine and Biology ... Annual Conference
IEEE Engineering in Medicine and Biology Society Conference proceedings
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APPENDIX SU01



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APPENDIX MENDELSON01

A Wearable Reflectance Pulse Oximeter for Remote Physiological Monitoring

Y. Mendelson*, *Member, IEEE*, R. J. Duckworth, *Member, IEEE*, and G. Comtois, *Student Member, IEEE*

Abstract—To save life, casualty care requires that trauma injuries are accurately and expeditiously assessed in the field. This paper describes the initial bench testing of a wireless wearable pulse oximeter developed based on a small forehead mounted sensor. The battery operated device employs a lightweight optical reflectance sensor and incorporates an annular photodetector to reduce power consumption. The system also has short range wireless communication capabilities to transfer arterial oxygen saturation (SpO_2), heart rate (HR), body acceleration, and posture information to a PDA. It has the potential for use in combat casualty care, such as for remote triage, and by first responders, such as firefighters.

I. INTRODUCTION

STEADY advances in noninvasive physiological sensing, hardware miniaturization, and wireless communication are leading to the development of new wearable technologies that have broad and important implications for civilian and military applications [1]-[2]. For example, the emerging development of compact, low-power, small-size, light-weight, and unobtrusive wearable devices may facilitate remote noninvasive monitoring of vital signs from soldiers during training exercises and combat. Telemetry of physiological information via a short-range wirelessly-linked personal area network can also be useful for firefighters, hazardous material workers, mountain climbers, or emergency first-responders operating in harsh and hazardous environments. The primary goals of such a wireless mobile platform would be to keep track of an injured person's vital signs, thus readily allowing the telemetry of physiological information to medical providers, and support emergency responders in making critical and often life saving decisions in order to expedite rescue operations. Having wearable physiological monitoring could offer far-forward medics numerous advantages, including the ability to determine a casualty's condition remotely without exposing the first

responders to increased risks, quickly identifying the severity of injuries especially when the injured are greatly dispersed over large geographical terrains and often out-of-site, and continuously tracking the injured condition until they arrive safely at a medical care facility.

Several technical challenges must be overcome to address the unmet demand for long-term continuous physiological monitoring in the field. In order to design more compact sensors and improved wearable instrumentation, perhaps the most critical challenges are to develop more power efficient and low-weight devices. To become effective, these technologies must also be robust, comfortable to wear, and cost-effective. Additionally, before wearable devices can be used effectively in the field, they must become unobtrusive and should not hinder a person's mobility. Employing commercial off-the-shelf (COTS) solutions, for example finger pulse oximeters to monitor blood oxygenation and heart rate, or standard adhesive-type disposable electrodes for ECG monitoring, is not practical for many field applications because they limit mobility and can interfere with normal tasks.

A potentially attractive approach to aid emergency medical teams in remote triage operations is the use of a wearable pulse oximeter to wirelessly transmit heart rate (HR) and arterial oxygen saturation (SpO_2) to a remote location. Pulse oximetry is a widely accepted method that is used for noninvasive monitoring of SpO_2 and HR. The method is based on spectrophotometric measurements of changes in the optical absorption of deoxyhemoglobin (Hb) and oxyhemoglobin (HbO_2). Noninvasive spectrophotometric measurements of SpO_2 are performed in the visible (600-700nm) and near-infrared (700-1000nm) spectral regions. Pulse oximetry also relies on the detection of photoplethysmographic (PPG) signals produced by variations in the quantity of arterial blood that is associated with periodic contractions and relaxations of the heart. Measurements can be performed in either transmission or reflection modes. In transmission pulse oximetry, the sensor can be attached across a fingertip, foot, or earlobe. In this configuration, the light emitting diodes (LEDs) and photodetector (PD) in the sensor are placed on opposite sides of a peripheral pulsating vascular bed. Alternatively, in reflection pulse oximetry, the LEDs and PD are both mounted side-by-side on the same planar substrate to enable readings from multiple body locations where transillumination measurements are not feasible. Clinically, forehead reflection pulse oximetry has been used as an alternative approach to conventional transmission-based

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oximetry when peripheral circulation to the extremities is compromised.

Pulse oximetry was initially intended for in-hospital use on patients undergoing or recovering from surgery. During the past few years, several companies have developed smaller pulse oximeters, some including data transmission via telemetry, to further expand the applications of pulse oximetry. For example, battery-operated pulse oximeters are now attached to patients during emergency transport as they are being moved from a remote location to a hospital, or between hospital wards. Some companies are also offering smaller units with improved electronic filtering of noisy PPG signals.

Several reports described the development of a wireless pulse oximeter that may be suitable for remote physiological monitoring [3]-[4]. Despite the steady progress in miniaturization of pulse oximeters over the years, to date, the most significant limitation is battery longevity and lack of telemetric communication. In this paper, we describe a prototype forehead-based reflectance pulse oximeter suitable for remote triage applications.

II. SYSTEM ARCHITECTURE

The prototype system, depicted in Fig. 1, consists of a body-worn pulse oximeter that receives and processes the PPG signals measured by a small ($\phi = 22\text{mm}$) and lightweight (4.5g) optical reflectance transducer. The system

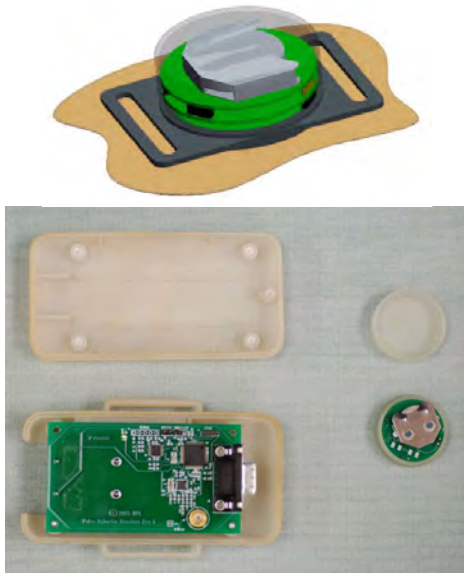


Fig. 1. (Top) Attachment of Sensor Module to the skin; (Bottom) photograph of the Receiver Module (left) and Sensor Module (right).

consists of three units: A Sensor Module, consisting of the optical transducer, a stack of round PCBs, and a coin-cell battery. The information acquired by the Sensor Module is transmitted wirelessly via an RF link over a short range to a body-worn Receiver Module. The data processed by the Receiver Module can be transmitted wirelessly to a PDA. The PDA can monitor multiple wearable pulse oximeters simultaneously and allows medics to collect vital physiological information to enhance their ability to extend more effective care to those with the most urgent needs. The

system can be programmed to alert on alarm conditions, such as sudden trauma, or physiological values out of their normal range. It also has the potential for use in combat casualty care, such as for remote triage, and for use by first responders, such as firefighters.

Key features of this system are small-size, robustness, and low-power consumption, which are essential attributes of wearable physiological devices, especially for military applications. The system block diagram (Fig. 2), is described in more detail below.

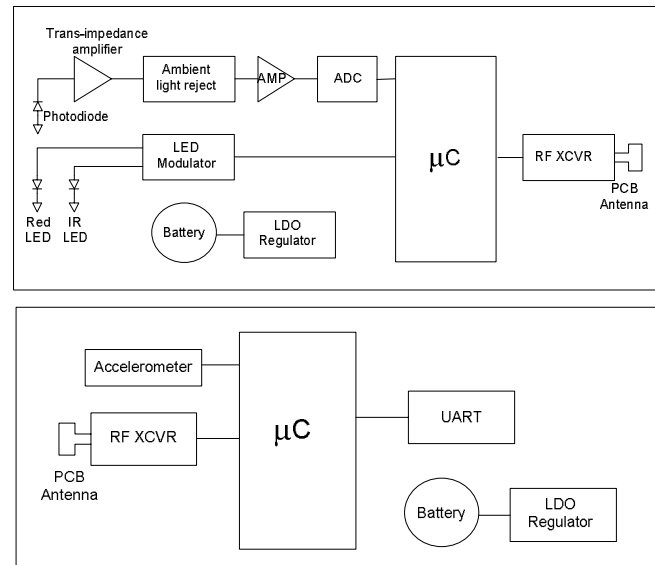


Fig. 2. System block diagram of the wearable, wireless, pulse oximeter. Sensor Module (top), Receiver Module (bottom).

Sensor Module: The Sensor Module contains analog signal processing circuitry, ADC, an embedded microcontroller, and a RF transceiver. The unit is small enough so the entire module can be integrated into a headband or a helmet. The unit is powered by a CR2032 type coin cell battery with 220mAh capacity, providing at least 5 days of operation.

Receiver Module: The Receiver Module contains an embedded microcontroller, RF transceiver for communicating with the Sensor Module, and a Universal Asynchronous Receive Transmit (UART) for connection to a PC. Signals acquired by the Sensor Module are received by the embedded microcontroller which synchronously converts the corresponding PD output to R and IR PPG signals. Dedicated software is used to filter the signals and compute SpO_2 and HR based on the relative amplitude and frequency content of the reflected PPG signals. A tri-axis MEMS accelerometer detects changes in body activity, and the information obtained through the tilt sensing property of the accelerometer is used to determine the orientation of the person wearing the device.

To facilitate bi-directional wireless communications between the Receiver Module and a PDA, we used the DPAC Airborne™ LAN node module (DPAC Technologies, Garden Grove, CA). The DPAC module operates at a frequency of 2.4GHz, is 802.11b wireless compliant, and has a relatively small ($1.6 \times 1.17 \times 0.46$ inches) footprint. The wireless module runs off a 3.7VDC and includes a built-in

TCP/IP stack, a radio, a base-band processor, an application processor, and software for a “drop-in” WiFi application. It has the advantage of being a plug-and-play device that does not require any programming and can connect with other devices through a standard UART.

PDA: The PDA was selected based on size, weight, and power consumption. Furthermore, the ability to carry the user interface with the medic also allows for greater flexibility during deployment. We chose the HP iPAQ h4150 PDA because it can support both 802.11b and Bluetooth™ wireless communication. It contains a modest amount of storage and has sufficient computational resources for the intended application. The use of a PDA as a local terminal also provides a low-cost touch screen interface. The user-friendly touch screen of the PDA offers additional flexibility. It enables multiple controls to occupy the same physical space and the controls appear only when needed. Additionally, a touch screen reduces development cost and time, because no external hardware is required. The data from the wireless-enabled PDA can also be downloaded or streamed to a remote base station via Bluetooth or other wireless communication protocols. The PDA can also serve to temporarily store vital medical information received from the wearable unit.

A dedicated National Instruments LabVIEW program was developed to control all interactions between the PDA and the wearable unit via a graphical user interface (GUI). One part of the LabVIEW software is used to control the flow of information through the 802.11b radio system on the PDA. A number of LabVIEW VIs programs are used to establish a connection, exchange data, and close the connection between the wearable pulse oximeter and the PDA. The LabVIEW program interacts with the Windows CE™ drivers of the PDA’s wireless system. The PDA has special drivers provided by the manufacturer that are used by Windows CE™ to interface with the 802.11b radio hardware. The LabVIEW program interacts with Windows CE™ on a higher level and allows Windows CE™ to handle the drivers and the direct control of the radio hardware.

The user interacts with the wearable system using a simple GUI, as depicted in Fig. 3.



Fig. 3. Sample PDA Graphical User Interface (GUI).

The GUI was configured to present the input and output information to the user and allows easy activation of various

functions. In cases of multiple wearable devices, it also allows the user to select which individual to monitor prior to initiating the wireless connection. Once a specific wearable unit is selected, the user connects to the remote device via the System Control panel that manages the connection and sensor control buttons. The GUI also displays the subject’s vital signs, activity level, body orientation, and a scrollable PPG waveform that is transmitted by the wearable device.

The stream of data received from the wearable unit is distributed to various locations on the PDA’s graphical display. The most prominent portion of the GUI display is the scrolling PPG waveform, shown in Fig. 3. Numerical SpO₂ and HR values are displayed in separate indicator windows. A separate tri-color indicator is used to annotate the subject’s activity level measured by the wearable accelerometer. This activity level was color coded using green, yellow, or red to indicate low or no activity, moderate activity, or high activity, respectively. In addition, the subject’s orientation is represented by a blue indicator that changes orientation according to body posture. Alarm limits could be set to give off a warning sign if the physiological information exceeds preset safety limits.

One of the unique features of this PDA-based wireless system architecture is the flexibility to operate in a free roaming mode. In this ad-hoc configuration, the system’s integrity depends only on the distance between each node. This allows the PDA to communicate with a remote unit that is beyond the PDA’s wireless range. The ad-hoc network would therefore allow medical personnel to quickly distribute sensors to multiple casualties and begin immediate triage, thereby substantially simplifying and reducing deployment time.

Power Management: Several features were incorporated into the design in order to minimize the power consumption of the wearable system. The most stringent consideration was the total operating power required by the Sensor Module, which has to drive the R and IR LEDs, process the data, and transmit this information wirelessly to the Receive Module. To keep the overall size of the Sensor Module as small as, it was designed to run on a watch style coin-cell battery.

It should be noted that low power management without compromising signal quality is an essential requirement in optimizing the design of wearable pulse oximeter. Commercially available transducers used with transmission and reflection pulse oximeters employ high brightness LEDs and a small PD element, typically with an active area ranging between 12 to 15mm². One approach to lowering the power consumption of a wireless pulse oximeter, which is dominated by the current required to drive the LEDs, is to reduce the LED duty cycle. Alternatively, minimizing the drive currents supplied to the R and IR LEDs can also achieve a significant reduction in power consumption. However, with reduced current drive, there can be a direct impact on the quality of the detected PPGs. Furthermore, since most of the light emitted from the LEDs is diffused by the skin and subcutaneous tissues, in a predominantly forward-scattering direction, only a small fraction of the incident light is normally backscattered from the skin. In

addition, the backscattered light intensity is distributed over a region that is concentric with respect to the LEDs. Consequently, the performance of reflectance pulse oximetry using a small PD area is significantly degraded. To overcome this limitation, we showed that a concentric array of either discrete PDs, or an annularly-shaped PD ring, could be used to increase the amount of backscattered light detected by a reflectance type pulse oximeter sensor [5]-[7].

Besides a low-power consuming sensor, afforded by lowering the driving currents of the LEDs, a low duty cycle was employed to achieve a balance between low power consumption and adequate performance. In the event that continuous monitoring is not required, more power can be conserved by placing the device in an ultra low-power standby mode. In this mode, the radio is normally turned off and is only enabled for a periodic beacon to maintain network association. Moreover, a decision to activate the wearable pulse oximeter can be made automatically in the event of a patient alarm, or based on the activity level and posture information derived from the on-board accelerometer. The wireless pulse oximeter can also be activated or deactivated remotely by a medic as needed, thereby further minimizing power consumption.

III. IN VIVO EVALUATIONS

Initial laboratory evaluations of the wearable pulse oximeter included simultaneous HR and SpO₂ measurements. The Sensor Module was positioned on the forehead using an elastic headband. Baseline recordings were made while the subject was resting comfortably and breathing at a normal tidal rate. Two intermittent recordings were also acquired while the subject held his breath for about 30 seconds. Fig. 4 displays about 4 minutes of SpO₂ and HR recordings acquired simultaneously by the sensor.

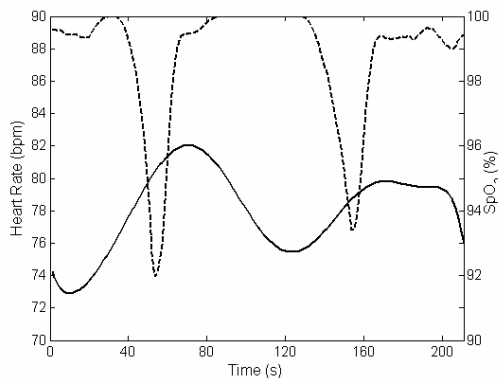


Fig. 4. Typical HR (solid line) and SpO₂ (dashed line) recording of two voluntary hypoxic episodes.

The pronounced drops in SpO₂ and corresponding increases in HR values coincide with the hypoxic events associated with the two breath holding episodes.

IV. DISCUSSION

The emerging development of compact, low power, small size, light weight, and unobtrusive wearable devices can facilitate remote noninvasive monitoring of vital

physiological signs. Wireless physiological information can be useful to monitor soldiers during training exercises and combat missions, and help emergency first-responders operating in harsh and hazardous environments. Similarly, wearable physiological devices could become critical in helping to save lives following a civilian mass casualty. The primary goal of such a wireless mobile platform would be to keep track of an injured person's vital signs via a short-range wirelessly-linked personal area network, thus readily allowing RF telemetry of vital physiological information to command units and remote off-site base stations for continuous real-time monitoring by medical experts.

The preliminary bench testing plotted in Fig. 4 showed that the SpO₂ and HR readings are within an acceptable clinical range. Similarly, the transient changes measured during the two breath holding maneuvers confirmed that the response time of the custom pulse oximeter is adequate for detecting hypoxic episodes.

V. CONCLUSION

A wireless, wearable, reflectance pulse oximeter has been developed based on a small forehead-mounted sensor. The battery-operated device employs a lightweight optical reflectance sensor and incorporates an annular photodetector to reduce power consumption. The system has short range wireless communication capabilities to transfer SpO₂, HR, body acceleration, and posture information to a PDA carried by medics or first responders. The information could enhance the ability of first responders to extend more effective medical care, thereby saving the lives of critically injured persons.

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APPENDIX DANGELO01

A Sensor Network to iPhone Interface separating Continuous and Sporadic Processes in Mobile Telemedicine

Lorenzo T. D'Angelo, Michael Schneider, Paul Neugebauer and Tim C. Lueth, *Member, IEEE*

Abstract – In this contribution, a new concept for interfacing sensor network nodes (motest) and smartphones is presented for the first time. In the last years, a variety of telemedicine applications on smartphones for data reception, display and transmission have been developed. However, it is not always practical or possible to have a smartphone application running continuously to accomplish these tasks. The presented system allows receiving and storing data continuously using a mote and visualizing or sending it on the go using the smartphone as user interface only when desired. Thus, the processes of data reception and storage run on a safe system consuming less energy and the smartphone's potential along with its battery are not demanded continuously. Both, system concept and realization with an Apple iPhone are presented.

I. INTRODUCTION

INDUSTRIALIZED countries are facing a demographic change which will push the social security systems to their limits. In Germany, the ratio between people older than 65 and between 15 and 64 is expected to surpass 50% until 2030 [1]. The number of older people living alone and cannot be taken care of and assisted by their families will also increase. This will lead to a significant increase in health care need and in a loss of quality of life for people dependent of care. For these reasons a great effort is done worldwide to develop systems able to keep people in good health through prevention, early diagnosis and short hospital stays. Assuring that elderly people with cognitive or physical impairments keep self-sufficient is also often issued. Many of these systems use sensor networks to collect health information about the individual in their home or outside and to process it in order to detect deviations and give help based on the findings or alarm relatives or clinicians. As smartphones and small handheld electronic devices are spreading, it makes sense to use their processing power and their user interfaces without needing to embed them redundantly in assistant devices, increasing their mass, volume and price [2]. In this contribution, we present a new concept for interfacing assistant devices and smartphones aiming at increasing the combined system's energy

efficiency and security.

After a state of the art overview about mobile systems for telemedicine and a task description, the concept will be described and a prototypical implementation will be shown.

A. State of the art in mobile systems for telemedicine.

Within the fitness and monitoring of chronic illnesses domains there are many commercial products able to monitor specific vital parameters over the day, e.g. chest straps and sport watches for heart rate, long term electrocardiogram (ECG) or blood pressure monitoring as well as glucose monitoring. Most of these products do not interface smartphones and do not enable mobile uploading of recorded data to a server.

In research, many project focus on mobile acquisition, processing and transmission of vital parameters through personal health management systems (PHMS) enabling telemedicine and e-health solutions. Among those are AMON, MOBIHEART, WEALTHY and MYHEART, to name a few [3]. In WEALTHY, various vital parameter sensors are embedded into garments. Data acquisition, processing and transmission takes place in specifically designed electronics. There is no direct visual feedback for the user [4]. The device has been improved in the Healthwear project [5]. In MYHEART, a mobile system able to send an ECG using a PDA phone over the internet is presented [6]. In [7], a mobile phone based system with direct user feedback is presented. The system also allows data transmission on a server using the scalable Healthcare Integrated Platform (SHIP). A wearable body sensor network interfacing a PDA phone for data upload is presented in [8]. A Smart Personal Health Manager interfacing a Body Area Network with a PDA phone in order to instantly show acquired data is presented in [9]. A similar system using a WLAN infrastructure inside a hospital instead of Bluetooth is presented in [10].

Several groups also work on acquiring behavioral information rather than vital parameters. Activity Recorders and Transceivers are sensor nodes capable of detecting and storing information about interaction [11]. One example is the Eventlogger presented in [12] which uses radio modules to detect interactions with objects. In [13], a platform for acquisition and display of vital parameters measured by body-worn or car-embedded sensor is presented.

An overview of the presented systems and their main characteristics is given in Table I.

Summing up, most presented systems can be distinguished between systems transmitting acquired data

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TABLE I
COMPARISON OF STATE OF THE ART IN MOBILE SYSTEMS FOR
TELEMEDICINE

DEVICE	SENSORS	CENTRAL DEVICE	VISUAL USER INTERFACE	DATA UPLOAD
[4]	ECG, Resp, Movement	DD	No	MPN
[5]	"	DD	No	MPN
[6]	ECG	PDA	Yes	MPN
[7]	ECG, Movement, Temp, Imp	Mobile phone	Yes	MPN
[8]	ECG, SpO ₂	PDA	Yes	MPN
[9]	Env, Sound, SpO ₂	PDA	Yes	MPN
[10]	ECG, SpO ₂ , Temp	PDA board	Yes	WLAN
[11-13]	SpO ₂ , SC, BP, Movement, Int	DD	Yes	-

Resp=Respiratory frequency. Temp=Temperature. Imp=Impedance.
Env=Environmental Sensors. Sound=Heart and respiratory sounds.
SC=Skin conductivity. BP=Blood pressure. Int=Interactions.
DD=Dedicated device. MPN=Mobile Phone Network.

directly to a server or using a mobile phone or handheld consumer electronic device for both data transmission and direct user feedback. Systems transmitting data directly could be expanded in order to offer user interfaces. However, this would increase system price, mass and volume as well, in most cases, be redundant, as the user carries a mobile phone anyway. However, using a mobile phone for reception, processing and transmission of private medical data and for time-critical or safety-critical processes can be very risky, especially considering that modern mobile phones are getting more and more complex. Regardless of whether they use an open or a proprietary operating system; proprietary operating systems strongly constrain developers and may abruptly disable third party applications while open operating systems may get unstable or allow running applications which may interfere or stop the telemedicine application.

B. Task description

The goal of the presented concept is to offer a telemedicine platform distinguishing between continuously running time-critical or safety-critical processes and sporadic processes like complex user interaction or user-operated uploads of big data amounts. It should be possible to run the continuous and the sporadic processes on two different devices, in order to optimize the system's safety and energy expenditure.

II. SYSTEM CONCEPT

A. Static system concept description

The presented concept employs a dedicated device, called management device, which is part of the sensor network

used to acquire health information and a smartphone. The management device can receive data from a variety of sensors, e.g. the Eventlogger presented in [12] for behavior recognition, the sensor unit described in [13] for car-embedded vital parameter acquisition or the garment described in [14] for fall detection.

B. Dynamic system concept description

The continuous processes, e.g. data acquisition, processing and time-stamped storage, run on the management device. Should a safety-critical function like alarming also be needed, the management device must also contain a module for this function, e.g. a GSM module. For sporadic processes like user interaction or data visualization, the management device is connected to a mobile phone or smartphone, and data is exchanged between the management device and the smartphone.

In Fig. 1, the proposed concept's components and processes are displayed and compared with a conventional telemedicine system with mobile-phone based user interaction.

III. SYSTEM PROTOTYPE

A. Materials and methods

In the following, only the management device and one exemplary smartphone application developed to demonstrate the concept will be presented.

The management device is very similar to the Eventlogger presented in [12], as it already includes modules for data reception, processing and storage. The first addition is transistor-transistor logic (TTL) level converter for the serial interface of the management device's microcontroller, allowing communication between the smartphone and the

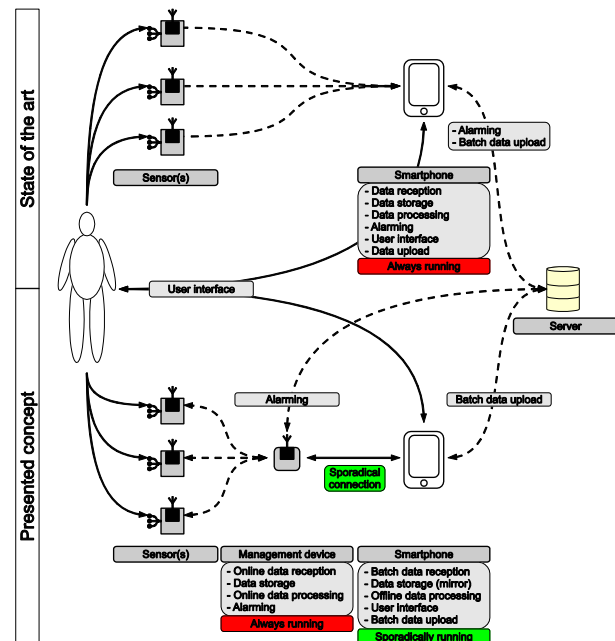


Fig. 1 Comparison between presented concept (bottom) and state of the art (top) in mobile telemedicine systems with smartphone-based visual user interface.

management device. The second addition is a connection between the smartphone's power output pin and the management device's charging pin, allowing to read out the management device with the smartphone even when its battery is empty. A system overview is given in Fig. 2. A third addition, namely a GSM module, is needed to cover all functions according to the presented concept. However, the presented prototype focuses on demonstrating the interface between the management device and the smartphone.

As a smartphone, we used the Apple iPhone 3G. When we chose the smartphone platform, this was the only phone offering a user interface consisting almost exclusively of a touch display, a very good software development kit and thus the ability to easily design intuitive and adaptive user interfaces. The downside of this platform is the very restrictive proprietary operating system, in which both processes of application authorization and becoming a licensed developer are far from transparent. The latter is especially needed when developing applications requiring access to the serial interface, which is the case here. Thus, the presented application can only run on a jailbroken device. However, this is not the case for other smartphones, on which this concept is also applicable.

The management device has a built-in connector which is compatible with the Apple Dock Connector. In addition to this, some pins can be used to program and debug the management device's microcontroller using the Joint Test Action Group (JTAG) interface. The pin assignment is illustrated in Fig. 3.

The management device has been built in two variants; the first one enables continuous connection between iPhone and management device. The second one is an adapter transforming the Eventlogger presented in [12] into a management device just during the connection with the iPhone, i.e. containing the additional components needed to use the Eventlogger as a management device. Prototypes of both devices are shown in Fig. 4.

B. Smartphone application

The realized iPhone application enables transferring the data stored on the microSD card inside the management device to the iPhone via the serial interface. It is stored into an SQLite database and visualized (data being acquired as

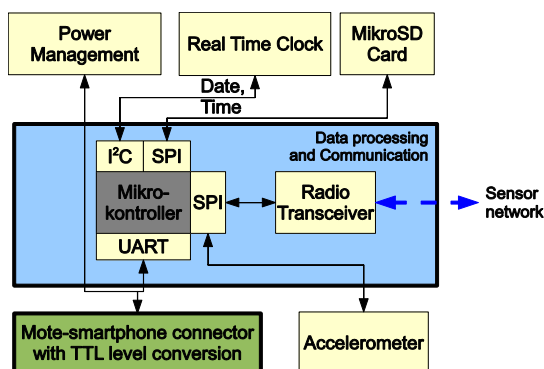


Fig. 2 Parts and interfaces of the management device prototype.

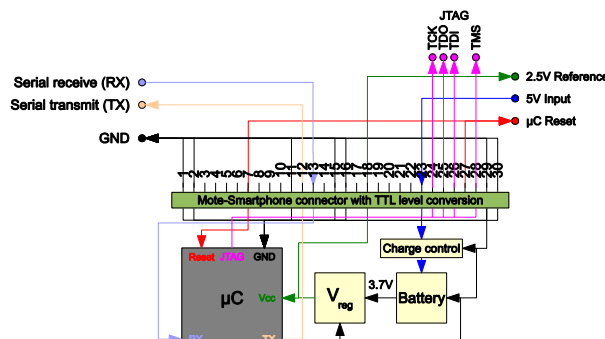


Fig. 3 Pin assignment of the mote-smartphone connector.

well as data stored previously) on the iPhone's display.

Upon starting the application, if the management device is connected to the iPhone, the iPhone-internal SQLite database is synchronized with the data on the management device. To do this, a request is sent to the management device to transmit all the data recorded since the last synchronization (batch data reception, see Fig. 1). Subsequently, a message to synchronize the real time clock inside the management device with the iPhone's time information is sent out from the iPhone application. While the application is running, a request for current data is sent out regularly. Hence data can also be displayed promptly on the iPhone upon acquisition.

The graphical user interface is divided in three views (see Fig. 5):

- 1) Main view
- 2) Graph view
- 3) Options view

In the main view, all the measured variables supported by the database are shown in a table. For each variable, normal upper and lower limits can be set. If a measured value is out of these limits, it is displayed in a distinctive color. The upper and lower limits can be set in the options view (see below).

The graph view is also structured as a table in which each row is associated to a variable. In contrast to the main view, here only rows corresponding to variables for which values are available are being shown. This is done to optimize the display space usage. Values are displayed in a graph on the



Fig. 4 Prototypes of management devices in two variants: integrated into a smartphone cover (left) and as Eventlogger with adapter for smartphone connection (right). On the left, the application for vital parameter visualization is running.

left side of the screen. New values are added scrolling the graph automatically. On the right side, the value is shown as a number along with the corresponding unit and current maximum and minimal value measured. The graph height adapts to these values. Tapping and wiping on the left side, the automatic scrolling can be stopped and the user can scroll through current and older values. Older data sets can also be loaded and displayed. With a double tap, the graph scrolls back to show current values on the right end and the automatic scrolling is reactivated.

In the options view, the user can set the upper and lower limits for each variable using a picker wheel. A screenshot of all three views is shown in Fig. 5.

IV. CONCLUSION

In this contribution, a new concept separating continuous critical processes and sporadic processes in sensor networks for telemedicine applications executing them on separate platforms is presented. Running continuous processes like detection of critical situations and alarming on a stable, reliable platform known to the developer avoid the stability and security risks of using a complex platform like a modern smartphone. Running sporadic processes like user interaction on a complex platform like a mobile phone or smartphone offer their advantages, i.e. an intuitive visual user interface, without the need of integrating big, expensive and energy consuming components like touch displays or keeping them active all the time.

A prototype has been presented connecting a mote and an iPhone in order to show how the concept can be realized with the first smartphone offering a touch-based user interface, although the access to its external interfaces is far from developer-friendly.

As future work, it is planned to extend the application and the system interoperability in order to also show interaction data and to find a method of implementing the presented concept without the need of jailbreaking a smartphone.

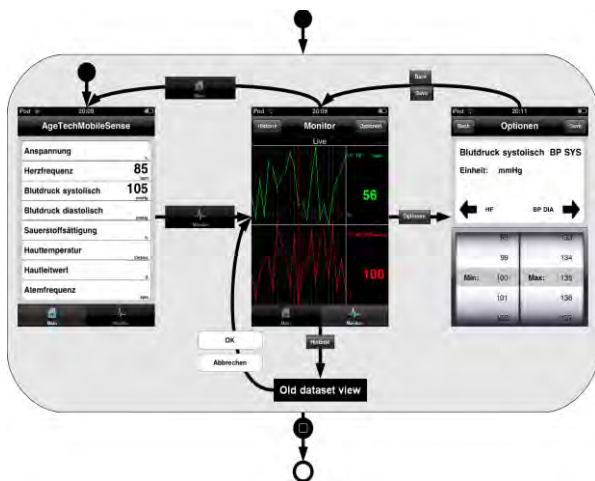


Fig. 5 Screenshots of the iPhone application visualizing acquired vital parameters live and previously recorded datasets.

ACKNOWLEDGMENT

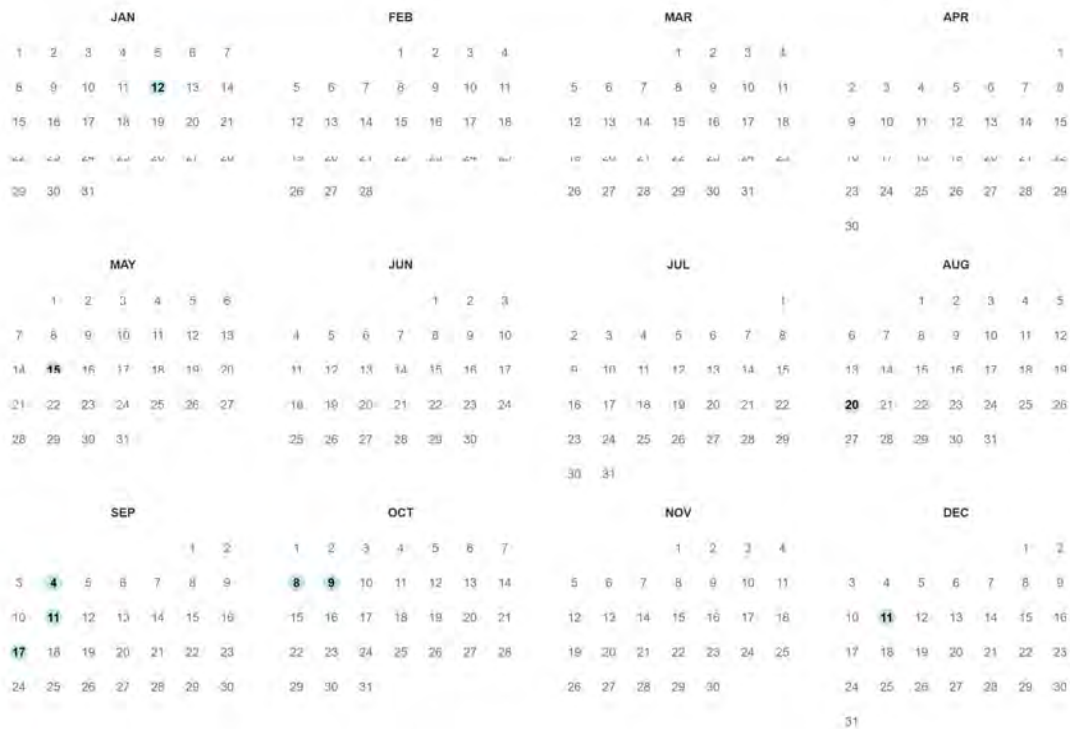
Within the research consortium of the Bavarian Research Foundation (BFS) „FitForAge“ a team of scientists and engineers affiliated to 13 departments of the Bavarian universities Erlangen-Nürnberg, München, Regensburg and Würzburg works together with 25 industrial partners on the development of products and services for the aging society.

The scope of the research consortium is to develop technology based solutions which will help elderly people but eventually also other social groups at home, at their workplace and in their mobility.

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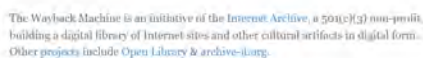
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The 28th Annual International Conference of the IEEE Engineering in Medicine and Biology Society will be held in New York, USA from the 30th August to the 3rd of September, 2006.

Details of the conference are at <http://embs2006.njit.edu/>

27th IEEE EMBS Annual International Conference in 2005 in Shanghai



The 27th Annual International Conference of the IEEE Engineering in Medicine and Biology Society was held in Shanghai, China from the 1st to the 4th of September, 2005 with a record attendance! Details of the conference are at <http://www.ee.cuhk.edu.hk/EMBC05shanghai>

26th IEEE EMBS Annual International Conference in 2004 in San Francisco



The 26th Annual International Conference of the IEEE Engineering in Medicine and Biology Society was held in





San Francisco, USA from the 1st to the 4th of September.

Details of the conference are at <http://www.fresno.ucsf.edu/embs2004>

Pictures from the conference can be found [here](#).



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25th IEEE EMBS Annual International Conference in 2003



The 25th Annual International Conference of the IEEE Engineering in Medicine and Biology Society was held in Cancun, Mexico from the 17th to the 21st of September. The science was solid and the location was exceptional!

Details are at <http://itzamna.uam.mx/cancun>

Pictures from the conference can be found [here](#).

24th IEEE EMBS Annual International Conference in 2002



The 2nd Joint Conference of the IEEE Engineering in Medicine and Biology Society and the Biomedical Engineering Society was held on the 23-26 October, 2002 Westin Galleria Hotel Houston, TX.

Full details at <http://embs-bmes2002.org/>

Pictures from the conference can be found [here](#).

23rd IEEE EMBS Annual International Conference in 2001

The 23rd Annual International Conference of the IEEE-EMBS was held in Istanbul, Turkey, 25th-28th, October, 2001. Despite the recent tragic events throughout the world that limited attendance, set in the backdrop of the beautiful city of Istanbul, the conference was a scientific success and a most exciting social event.



5th

INTERNATIONAL SUMMER SCHOOL on Biocomplexity from System to Gene



In the continuing vein of successful summer schools, this event organized by Metin Akay, was held from June 26 to July 2, 2005 at Dartmouth College, Hanover, NH USA. Two reports (in PDF format) on the summer school can be found [here](#) and [here](#).

More details can be found at <http://www.dartmouth.edu/~bioc2005/>

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