

UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE PATENT TRIAL AND APPEAL BOARD

Apple, Inc.
“Apple”
Petitioner

v.

Advanced Coding Technologies, LLC
“ACT”
Patent Owner

INTER PARTES REVIEW OF U.S. PATENT NO. 8,090,025

DECLARATION OF MR. DAVID B. LETT

I declare that all statements made in this declaration on 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.

Date: 5/12/2025

By: David B. Lett

David B. Lett

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I, David B. Lett., do hereby declare:

I. Introduction

A. Summary

1. My name is David Lett, and I have been retained by counsel for Apple Inc. (“Apple”) as an expert witness to assist in analyzing issues related to the patentability of certain claims of U.S. Patent No. 8,090,025, “the ’025 Patent.” I understand that Apple intends to submit this declaration in support of a petition for inter partes review (“IPR”) of the ’995 Patent before the Patent Trial and Appeal Board (“PTAB”) of the United States Patent and Trademark Office (“USPTO”).

2. I am being compensated for my work in this matter at my standard hourly rate for consulting services. My compensation in no way depends on the outcome of this proceeding or the content of my testimony.

3. I have been informed that an earlier inter partes review proceeding, IPR2024-00374, was instituted before the Patent Trial and Appeal Board concerning the ’025 Patent, in which Samsung Electronics Co., Ltd. and Samsung Electronics America, Inc. were the Petitioners (the “Samsung IPR”). I understand that Dr. Clifford Reader submitted a declaration in the Samsung IPR, which I have attached as Appendix B to the present declaration. I have reviewed Dr. Reader’s declaration in its entirety, including the analysis, claim constructions, and supporting technical opinions presented therein. Based on my independent analysis of the ’025 Patent and the

materials cited herein, I agree with the technical opinions and substance of Dr. Reader's declaration from the Samsung IPR, and I adopt them as my own unless otherwise noted. Dr. Reader's declaration is fully incorporated herein.

B. Qualifications

4. I am a technical consultant and product development industry veteran with expertise in electronics, software, hardware, video, audio, and data communications (including wireless cellular and Bluetooth), having led product development organizations in cable, satellite, consumer electronics, asset tracking, remote tank logistics, and alarm industries. My current *curriculum vitae* is attached as Appendix C and some highlights follow.

5. I earned my B.S. in Electrical Engineering (1982) with high honors from the University of Tennessee in Knoxville, Tennessee. I also attended the Georgia Institute of Technology from 1986 to 1987, completing 40% of the required degree hours for the M.S. Electrical Engineering program.

6. From 1982 to 1985, I worked at Scientific Atlanta as an Electrical Engineer designing video, audio, and data communications equipment for the cable television industry. I designed software and hardware including addressable data transmitters, video sync suppression scramblers, transaction format converters, and data channel monitors for addressable Cable Television systems and Set Top Boxes.

7. From 1983 to 1985, while working at Scientific Atlanta, I also worked as an Assistant Professor at DeVry Institute of Technology, teaching courses in electronics and microprocessor hardware/software.

8. From 1985 to 1990, I worked at Wegener Communications as a Senior Electrical engineer, designing satellite communications equipment including forward error correction (FEC) coding systems, PSK modems, and analog control systems for RF modulators and PSK demodulators. I was promoted to the Hardware Engineering Manager, where I managed product development of video, audio, and data satellite receivers, modulators, graphics display systems, DSP-based compandors, FSK and PSK satellite modems, multiplexers, forward error correction (FEC) codecs, RF upconverters and downconverters, and baseband analog and digital processing components.

9. In 1990, I returned to Scientific Atlanta, which was acquired by Cisco in 2006. I worked as Engineering Manager running the set top box engineering group where I was promoted to Director and Vice President during my tenure until 2011. I led the design of many cable set top boxes and systems through the evolution of analog video, addressability, downloadable software, electronic program guides, digital video, software applications, high-definition TV, DVR, DOCSIS, full spectrum tuners, and multiroom DVR. These systems implemented various technologies including DOCSIS 1/2/3 and hybrid gateways, 802.11, IPTV, DVR, cable modems, ADSL,

VDSL, DVB-T/C/S, bootloaders, factory diagnostics, application frameworks, Nagra, DRMs, conditional access, secure microprocessors, device management, Android, Adobe Flash, Linux, DVD play/record, MPEG-4, MPEG-2, H.264, NTSC, PAL, DAVIC, MoCA, high-performance CPUs, cablecards, network processors, HDMI, multiple video/audio display interfaces, 2D/3D graphics, and multiple RF tuners.

10. From 2011 to 2016, I worked for EchoStar Technologies, which served as the product development organization for sister company DISH Network. I served as Vice President of Engineering and was the Head of the Atlanta research and development center. I led the development of satellite set top boxes, consumer electronic equipment, and a home automation and security system. Technologies used included video/audio, IoT, H.265, HEVC, 3D, Satellite, wireless Zigbee, Z-Wave, Wi-Fi, Bluetooth, MoCA, transcoding, embedded C Linux applications, mobile applications (IOS and Android), SaaS, web applications (Javascript, HTML), BSS/OSS, AWS cloud storage, 2-way video/audio streaming, authentication, and VoIP.

11. In 2016, I started an independent consulting business in technology and intellectual property projects. I have consulted in various technology areas and industries including consumer electronics, cable, satellite, television, security, camera image/AV capture and processing, online advertising, and Internet of Things (IoT).

12. From 2019 to 2022, I worked as Chief Technology Officer for Telular, an Ametek company. I was responsible for the development of Industrial IoT (IIoT) recurring revenue solutions, combining wireless technologies (cellular, Bluetooth, sub-GHz, GPS, and satellite), purpose-built hardware, and SaaS in the commercial telematics, security and home automation markets and sold under the SkyBitz and Telguard Brands.

13. My record of professional service includes awards on products I designed and developed from several organizations in my field of expertise, including Best of Show, Technology Emmy, and Best of Innovations.

14. I am a named inventor on at least 117 issued patents and published patent applications corresponding to the areas of my professional work. The patents and published applications involving data communications and multimedia technologies include:

- U.S. Patent No. 9,615,139 titled “Determining Device That Performs Processing of Output Pictures”
- U.S. Patent No. 9,495,860 titled “False Alarm Identification” Pictures”
- PCT Patent Publication No. WO 2022/231962 titled “Tractor-trailer id methods and system”
- U.S. Patent No. 9,882,736 titled “Remote Sound Generation for a Home Automation System”

- European Patent No. EP 1,552,698 titled “Video transmission systems and methods for a home network”
- U.S. Patent Nos. 8,120,924, 7,240,217, 6,785,817, 6,564,324, 6,212,278 and 5,440,632 titled “Reprogrammable subscriber terminal”
- U.S. Patent Application No. US2015/0160636 titled “Multi-Tiered Feedback-Controlled Home Automation Notifications”
- U.S. Patent Nos. 9,247,409 and 9,691,261 titled “Home Automation Communications”
- U.S. Patent No. 10,063,641 titled “Systems and methods for finding wireless signals sufficient for installation of wireless home automation devices”
- U.S. Patent No. 5,657,414 titled “Auxiliary device control for a subscriber terminal”
- PCT Patent Publication No. WO 2003/083606 titled “Exporting data from a digital home communication terminal to a client device”
- U.S. Patent No. 8,549,567 titled “Media Content Sharing Over a Home Network”
- U.S. Patent No. 8,161,388 titled “Interactive discovery of display device characteristics”
- U.S. Patent No. 7,908,625 titled “Networked Multimedia System”

- U.S. Patent Nos. 7,861,272 and 7,849,486 titled “Networked subscriber television distribution”
- U.S. Patent Nos. 7,774,820 and 7,069,578 titled “Settop cable television control device and method including bootloader software and code version table for maintaining and updating settop receiver operating system software”
- U.S. Patent No. 5,715,515 titled “Method and apparatus for downloading on-screen graphics and captions to a television terminal”
- U.S. Patent No. 5,592,551 titled “Method and apparatus for providing interactive electronic programming guide”
- U.S. Patent No. 5,539,822 titled “System and Method for Subscriber Interactivity in a Television System”
- U.S. Patent Application Publication Nos. 2004/0068753 and 2008/0072272 titled “Video Transmission Systems and Methods for a Home Network”
- U.S. Patent No. 5,771,064 titled “Home communications terminal having an applications module”
- U.S. Patent Application Publication No. 2004/0133911 titled “Subscriber Network in a Satellite System”

- U.S. Patent No. 5,367,571 titled “Subscriber terminal with plug in expansion card”
- U.S. Patent No. 5,357,276 titled “Method of Providing Video On Demand with VCR Like Functions”
- U.S. Patent No. 4,817,148 titled “Signal scrambling transmission system”

C. Materials Considered

15. In preparing this Declaration, I considered the following materials:

- (a) U.S. Patent No. 8,090,025 (“the ’025 Patent”) (Exhibit APPLE-1001)
- (b) The Prosecution History of the ’025 Patent (Exhibit APPLE-1002)
- (c) Al-Mualla, et al., “Video Coding for Mobile Communications: Efficiency, Complexity and Resilience,” Elsevier, 2002 (Exhibit APPLE-1005)
- (d) S. Shirani, et al., “A Concealment Method for Video Communications in an Error-Prone Environment,” in IEEE Journal on Selected Areas in Communications, vol. 18, no. 6, pp. 1122-1128, June 2000 (Exhibit APPLE-1006)
- (e) N. Saito, et al., “The Polyharmonic Local Sine Transform: A New Tool for Local Image Analysis and Synthesis without Edge Effect,” Applied and Computational Harmonic Analysis, vol. 20, pp. 41-73, 2006 (Exhibit APPLE-1007)

- (f) B. Girod, et al., “Feedback-Based Error Control for Mobile Video Transmission,” in Proceedings of the IEEE, vol. 87, no. 10, pp. 1707-1723, Oct. 1999 (Exhibit APPLE-1008)
- (g) T. Stockhammer, et al., “H.264/AVC in Wireless Environments,” in IEEE Trans. on Circuits and Systems for Video Tech., vol. 13, no. 7, July 2003 (Exhibit APPLE-1009)
- (h) Perez, et al., “Poisson Image Editing,” ACM, ACM Transactions on Graphics (TOG), vol. 22, Issue 3, Jul. 2003, pp. 313-318 (Exhibit APPLE-1010)
- (i) Wexler, et al., “Space-Time Video Completion,” In Proc. IEEE Comput. Soc. Conf. Computer Vision and Pattern Recognition, 2004, pp. 120 –127 (Exhibit APPLE-1011)
- (j) Raskar, et al., “Image Fusion for Context Enhancement and Video Surrealism,” Proceedings of the 3rd Symposium on Non-Photorealistic Animation and Rendering, 2004, pp. 85-152 (Exhibit APPLE-1012)
- (k) Sun, et al., “Poisson Matting,” ACM Transactions on Graphics (Tog), Special Issue: Proceedings of the 2004 Siggraph Conference Session: Interacting With Images, vol. 23, Issue 3, 2004, pp. 315-321 (Exhibit APPLE-1013)
- (l) U.S. Patent No. 7,636,128 B2 to Sun, et al. (Sun-128) (Exhibit APPLE-1014)
- (m) Fattal, et al., “Gradient Domain High Dynamic Range Compression,” In Proceedings of ACM SIGGRAPH, 2002, 249–256 (Exhibit APPLE-1015)

- (n) ITU-T Rec. H.263 (01/2005) (“the H.263 standard”) (Exhibit APPLE-1016)
- (o) M. Wada, “Selective Recovery of Video Packet Loss Using Error Concealment,” IEEE Journal on Selected Areas of Communication, vol. 7, pp. 807–814, June 1989 (Exhibit APPLE-1017)
- (p) ITU-T Rec. H.263 (02/1998) (Exhibit APPLE-1021, SAMSUNG-1020 in Appendix B)
- (q) List, et al., “Adaptive Deblocking Filter,” IEEE Journal on Circuits and Systems for Video Technology, vol. 13, pp. 614-619, July 2003 (Exhibit APPLE-1022)
- (r) ISO/IEC 11172-2: 1993 (E) (Exhibit APPLE-1023, SAMSUNG-1016 in Appendix B)
- (s) U.S. Patent Pub. No. 2003/0174776 A1 to Shimizu et al. (“Shimizu”) (Exhibit APPLE-1024)
- (t) P. Salama, et al., “Error Concealment for Shape Coding,” Proceedings, 2002 International Conference on Image Processing, Rochester, NY, USA, Vol. 2, pp. 701-704, Sep. 2002 (“Salama”) (Exhibit APPLE-1025)
- (u) L.D. Soares, et al., “Motion-based shape error concealment for object-based video,” Proceedings, 2004 International Conference on Image Processing, Singapore, Vol. 2, pp. 797-800, 2004 (“Soares”) (Exhibit APPLE-1026)

- (v) Petition (Paper 2), IPR2024-00374, *Samsung Electronics. Co., Ltd. v. Advanced Coding Techs., LLC* (Jan. 8, 2024) (Exhibit APPLE-1027)
- (w) Decision Instituting *Inter Partes* Review (Paper 11), IPR2024-00374, *Samsung Electronics. Co., Ltd. v. Advanced Coding Techs., LLC* (July 22, 2024) (Exhibit APPLE-1028)
- (x) ISO/IEC 13818-2: 2000 (E) (MPEG2/H.262 Video) (Exhibit APPLE-1030, SAMSUNG-1028 in Appendix B)
- (y) ISO/IEC 14496-10 AVC (2004) (Exhibit APPLE-1032, SAMSUNG-1027 in Appendix B)

II. Legal Standards

16. I have been asked to provide my opinions as to whether claims 1-10 of the '025 Patent would have been obvious to a person of ordinary skill in the art as of the earliest claimed priority date of the '025 patent (April 17, 2006) ("Critical Date").

17. I am an engineer by training and profession. The opinions I express in this declaration involve the application of my technical knowledge and experience to the evaluation of certain prior art with respect to the '025 Patent. In addition, I understand that the following legal principles apply.

18. It is my understanding that, in determining whether claims of the '025 patent are obvious in this proceeding, the claim terms are generally given their ordinary and customary meaning as understood by a person of ordinary skill in the relevant art. A person of ordinary skill in the art would read the claim terms in the context of the entire patent specification in which they appear, as well as the prosecution history of the patent.

19. It is my understanding that a claim is unpatentable under 35 U.S.C. § 103 if the claimed subject matter as a whole would have been obvious to a person of ordinary skill in the art at the time of the alleged invention. I also understand that an obviousness analysis takes into account the scope and content of the prior art, the differences between the claimed subject matter and the prior art, and the level of ordinary skill in the art at the time of the invention.

20. In determining the scope and content of the prior art, it is my understanding that a reference is considered relevant prior art if it falls within the field of the inventor's endeavor. In addition, a reference is prior art if it is reasonably pertinent to the particular problem with which the inventor was involved. A reference is reasonably pertinent if it logically would have commended itself to an inventor's attention in considering his problem. If a reference relates to the same problem as the claimed invention, that supports use of the reference as prior art in an obviousness analysis.

21. To assess the differences between prior art and the claimed subject matter, it is my understanding that 35 U.S.C. § 103 requires the claimed invention to be considered as a whole. This "as a whole" assessment involves showing that one of ordinary skill in the art at the time of invention, confronted by the same problems as the inventor and with no knowledge of the claimed invention, would have selected the elements from the prior art and combined them in the claimed manner.

22. It is my further understanding that several rationales may be applied for combining references or modifying a reference to show obviousness of claimed subject matter. These rationales include: combining prior art elements according to known methods to yield predictable results; simple substitution of one known element for another to obtain predictable results; a predictable use of prior art elements according to their established functions; applying a known technique to a known device (method

or product) ready for improvement to yield predictable results; choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success; and some teaching, suggestion, or motivation in the prior art that would have led one of ordinary skill to modify a prior art reference or to combine prior art teachings to arrive at the claimed invention.

III. Person of Ordinary Skill in the Art

23. It is my understanding that when interpreting the claims of the '025 patent I must do so based on the perspective of one of ordinary skill in the art at the time of the alleged invention ("POSITA"). For purposes of my analysis in this declaration, I have taken the earliest claimed priority date of the '025 patent (April 17, 2006) as the date of the alleged invention ("Critical Date"). I understand that the factors considered in determining the ordinary level of skill in a field of art include the level of education and experience of persons working in the field; the types of problems encountered in the field; the teachings of the prior art, and the sophistication of the technology at the time of the alleged invention. I understand that a POSITA is not a specific real individual, but rather is a hypothetical individual having the qualities reflected by the factors above. I understand that a POSITA would also have knowledge from the teachings of the prior art, including the art cited below.

24. Taking these factors into consideration, it is my opinion that one of ordinary skill in the art in the field of digital video coding as of the Critical Date, would

have had at least a bachelor's degree in computer science, computer engineering, electrical engineering, or a related field, and at least two years of industry experience in digital video processing, or a related field. Additional graduate education could substitute for professional experience, or additional professional experience could substitute for formal education.

25. I have possessed the qualifications of a POSITA since the Critical Date of the '025 patent, and long before.

IV. Overview of the Subject Patent US8090025

A. Overview

26. The '025 Patent is directed to “a moving-picture coding apparatus, method and program, and a moving-picture decoding apparatus, method and program that, without a smoothing procedure, can produce a predictive picture maintaining continuity of a video signal.” APPLE-1001, 2:30-38. In addition to known video coding and decoding techniques, the '025 Patent discloses a “controller” (117a and 313a) and a “switch” (102/103 and 701) for selecting between “ordinary” motion estimation/compensation and “zone-border” motion estimation/compensation.” APPLE-1001, 25:21-42, 26:24-48, 28:21-39, FIGS. 5 (showing an encoder) and 7 (showing a decoder). The '025 Patent discloses that these two modes of motion compensation are “adaptively switched based on the data amount, thus producing high-quality decoded videos with a fewer code amount overall.” APPLE-1001, 28:21-39.

27. The “ordinary” motion estimation/compensation is performed by a “motion estimator” (502) and a “motion compensator” (503 and 702) which the ’025 Patent describes in detail in its FIG. 13 description (produced below). APPLE-1001, 10:4-39, 21:63-22:14, 28:21-39, FIGS. 5, 7, 13.

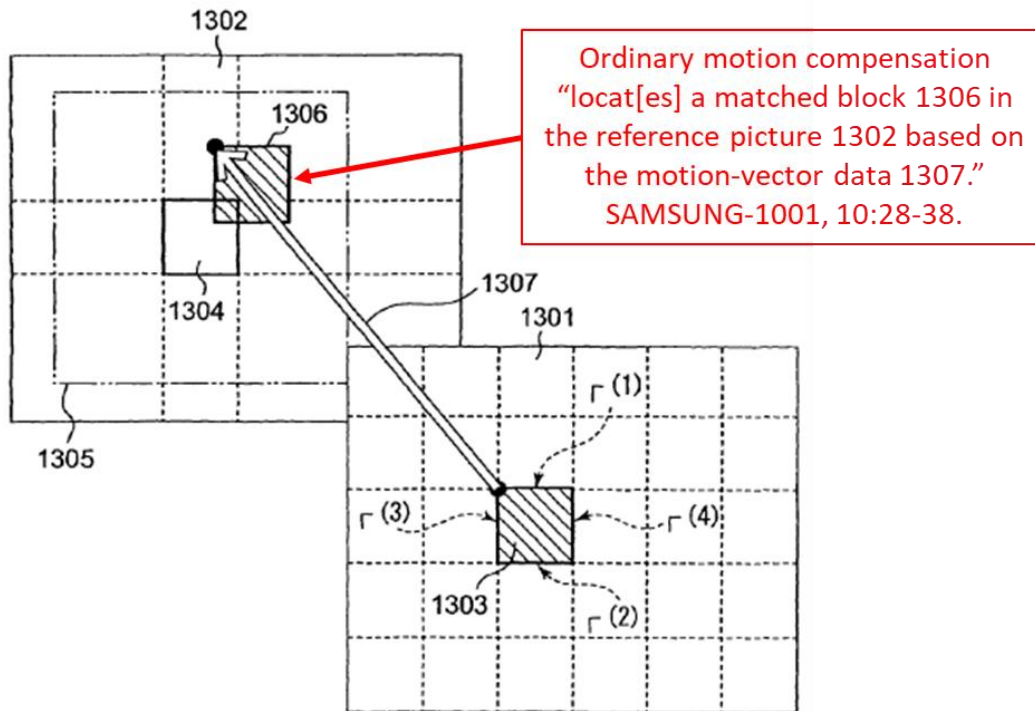


FIG. 13

APPLE-1001, FIG. 13 (annotated).

28. The “zone-border” motion estimation/compensation includes two steps, described in FIGS. 14-17. APPLE-1001, 10:39-12:20. In the first step, as shown in FIGS. 14 and 15, “motion-vector search is performed on block borders.” APPLE-1001, 10:39-45. Block borders are associated with a “boundary condition” which is “a

gradient of a video signal on a block border.” APPLE-1001, 10:46-56. The zone-border motion estimator then “obtains border gradient data that is a boundary condition of a block border in a picture to be coded” and then selects the “closest gradient to the gradient of an original signal on the block border.” APPLE-1001, 10:57-65, FIGS. 14-15. This process is shown below in FIGS. 14-15. Next, in the second step as shown in FIGS. 16 and 17, “Poisson's Equation is then applied based on the gradient data of the video signal thus defined to generate a predictive signal in block which is then applied to a predictive block 1606a.” APPLE-1001, 11:20-34.

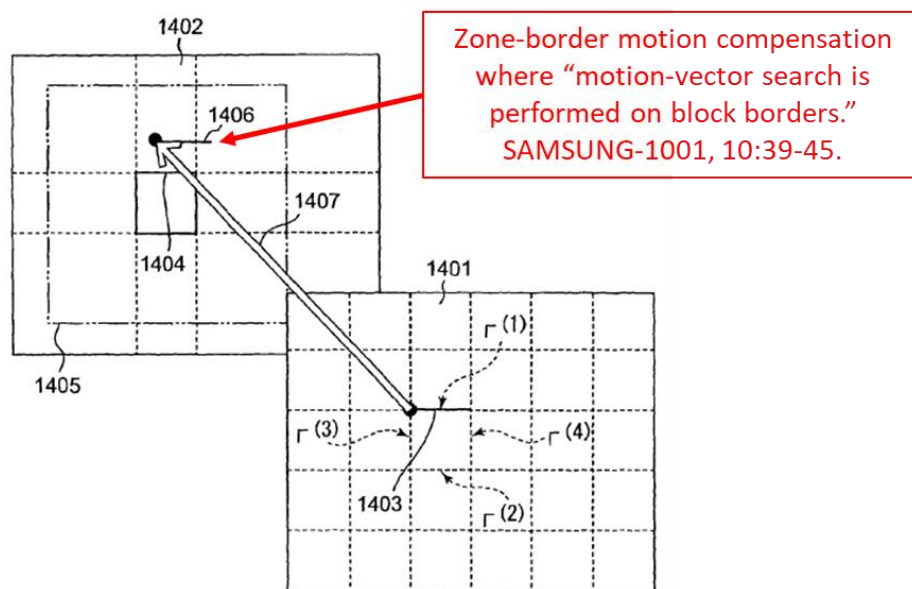


FIG. 14

APPLE-1001, FIG. 14 (annotated).

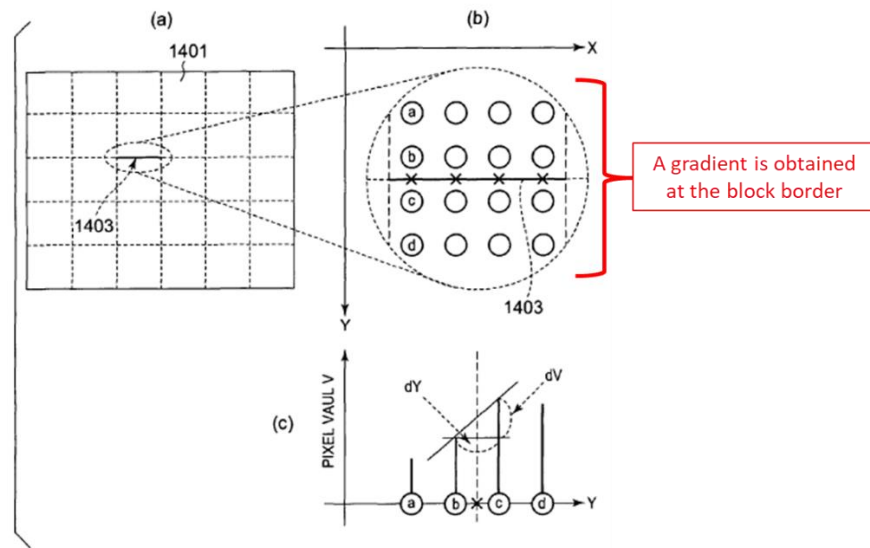


FIG. 15

APPLE-1001, FIG. 15 (annotated).

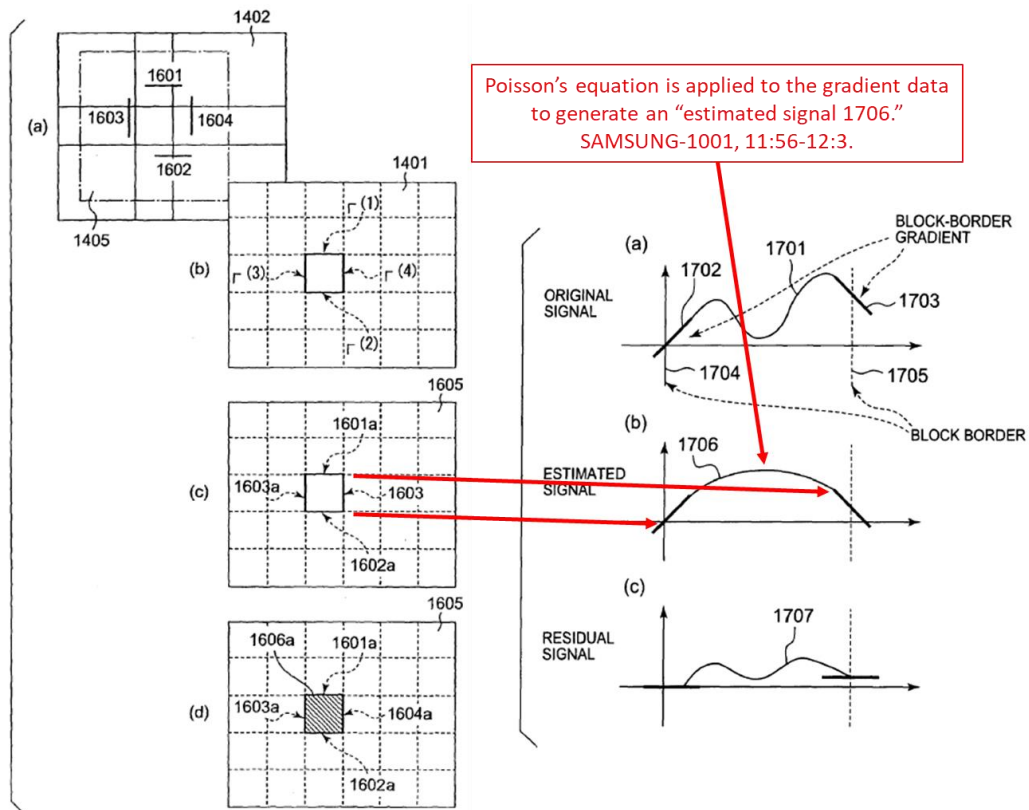


FIG. 16

FIG. 17

APPLE 1001, FIGS. 16-17 (annotated).

B. Prosecution History of the '025 Patent

29. Application Serial No. 11/787,623 (“the ’025 application”) that issued as the ’025 Patent was filed on April 17, 2007, claiming priority to Japanese Application Nos. 2007-093162 and 2006-112995 filed on March 30, 2007, and April 17, 2006, respectively. APPLE-1001, Cover. On September 28, 2011, without issuing any previous prior art rejections, the Examiner issued a notice of allowability and an Examiner’s amendment. APPLE-1002, 34-52. The Applicant paid the issue fee on November 30, 2011. APPLE-1002, 23-27. The ’025 application issued as the ’025 Patent on January 3, 2012. APPLE-1001, Cover. In sum, the examiner allowed the application over prior art references that are substantially different from those relied upon in this petition. Indeed, during prosecution, there is no indication that the examiner considered Mualla, Shirani, Saito, Stockhammer, or Shimizu which render the challenged claims obvious, as discussed below. *See generally*, APPLE-1002.

V. Summary of '025 Prior Art

30. The following pieces of prior art render obvious the alleged invention of the ’025 patent in the combinations addressed further below (Grounds 1A/1B).

31. Below, I present three distinct grounds of unpatentability. Grounds 1A/1B of the petition describe switching between conventional Motion Estimation/Motion Compensation (ME/MC) and error-concealment to correct coding and decoding errors, whereas Ground 2 describes both error-prone and error-free

scenarios, and how switching between conventional ME/MC and the hybrid 2-stage motion compensated prediction of Ground 1A/1B (in view of the additional disclosure of Shimizu) would have provided benefits in both scenarios.

A. Overview of Mualla (and Mualla and Stockhammer in Ground 1B)

32. Mualla is a book on “fundamentals and standards of video source coding” and addresses “areas of coding efficiency, computational complexity, and error resilience in a single volume.” APPLE-1005, 9-10. Structurally, Chapters 1 and 2 of Mualla provide “an introduction to video coding” by describing “some of the fundamentals of video source coding.” APPLE-1005, 10, 31-64. Chapter 3 of Mualla provides a “brief introduction to video coding standards” such as “H.263 (and its extensions H.263+ and H.263++).” APPLE-1005, 10, 65-111. Chapters 4 and 7 of Mualla provide details of “motion estimation (ME)” and “motion compensation (MC).” APPLE-1005, 10-11, 115-146, 181-195. Chapters 9 and 10 of Mualla describe techniques for “error resilience” in video coding systems. APPLE-1005, 11, 225-279.

33. Given its comprehensive nature, Mualla presents different details of encoders/decoders in different figures, depending on what is being explained, but these figures are substantively cumulative to an overall teaching of video coding systems. To facilitate understanding, aggregated views of the relation between different figures of Mualla are shown in Diagrams A and B, below.

34. Diagram A (below) illustrates the relation between Figures 9.1 and 2.3 of Mualla. In Figure 9.1 (annotated in yellow, below) Mualla provides an illustration of a “typical video communication system.” APPLE-1005, Figure 2.3, 18, Figure 9.1, 227-228. The system includes a “source encoder” designed to “compress the input video” (annotated in blue, below). APPLE-1005, Figure 9.1, 228. The source encoder of Figure 9.1 “consists of a *waveform encoder* and an *entropy encoder*” (annotated in orange and red, respectively, in Figure 9.1, below). APPLE-1005, 228. Further details of the source encoder (annotated in blue) of Figure 9.1 are shown in Figure 2.3. *Id.* With reference to Figure 2.3, Mualla explains that the waveform encoder of Figure 9.1 “corresponds to the *mapper* and *quantizer* blocks” of Figure 2.3 (annotated in orange, below), whereas “the entropy encoder” of Figure 9.1 “corresponds to the *symbol encoder* block” of Figure 2.3 (annotated in red, below). *Id.*

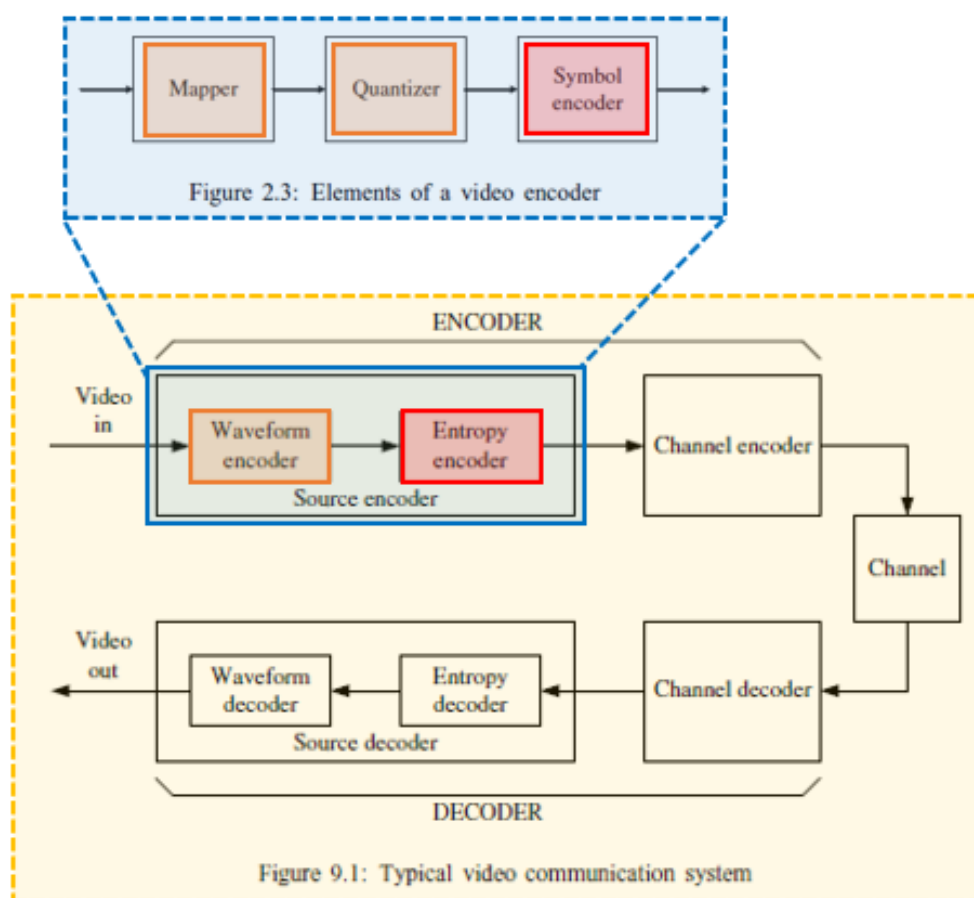


Diagram A (showing the relation between Mualla's Figures 9.1 and 2.3).

35. Mualla explains that the “mapper” in Figure 2.3 “is designed to reduce **statistical redundancy** and make the data more amenable to compression in later stages.” APPLE-1005, 40. Mualla describes two types of statistical redundancy, namely “**spatial** (*intraframe*) and **temporal** (*interframe*) correlations between neighboring pels.” *Id.*

36. Mualla discloses that **spatial** (*intraframe*) redundancy is reduced by “intraframe coding” which can be implemented by “**transform coding**.” APPLE-1005, 50-51. Mualla also discloses that **temporal** (*interframe*) redundancy can be

reduced by “interframe coding” which can be implemented by “**motion estimation (ME)**” and “**motion compensation (MC)**.” APPLE-1005, 60-61. Mualla provides further details of these techniques in Figures 1.1 and 2.9, described next.

37. Diagram B (below) illustrates the relation between Figure 2.3 (annotated in blue in Diagram A, above) and Figures 1.1 and 2.9 of Mualla. APPLE-1005, Figure 1.1, 26, Figure 2.3, 51, Figure 2.9, 52. In particular, Figure 2.9 discloses details of transform coding (to reduce spatial redundancy) while Figure 1.1 discloses details of motion estimation and motion compensation (to reduce temporal redundancy). Beginning with Figure 1.1, Mualla describes a “typical video codec” which includes a “motion estimation (ME) block” (annotated in purple, below) and a “motion compensation (MC) block” (annotated in purple, below, which is included as part of a local “decoder” implemented at the encoder) which are designed to reduce temporal redundancy. APPLE-1005, 26. Figure 1.1 also illustrates a “transform encoder” block (annotated in green, below). Further details of the “transform encoder” are provided in Figure 2.9 (annotated in green, below), which includes a “forward transform” (annotated in purple, below) designed “to decorrelate the pels of the input block” (reduce spatial redundancy). APPLE-1005, 51-52.

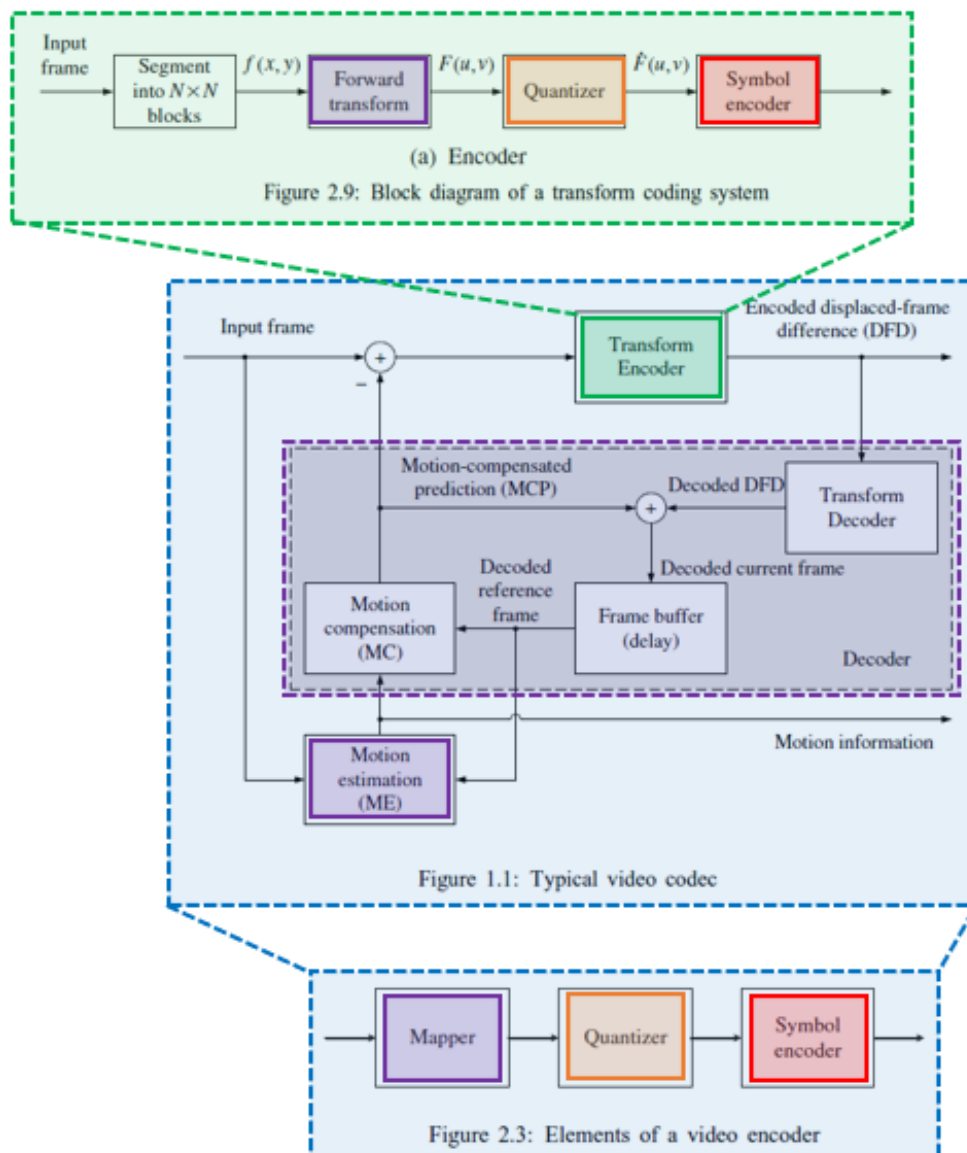


Diagram B (showing the relation between Mualla's Figures 2.3, 1.1, and 2.9).

38. With this background of typical video coding systems, Mualla describes the specific “picture coding structure” of the “H.263 standard.” APPLE-1005, 71-73. Mualla explains that “[t]he input video consists of a sequence of pictures (or frames)” and “[e]ach picture is divided into *groups of blocks* (GOBs)” where “[e]ach GOB is divided into *macroblocks* (MBs)” and each MB “consists of 16×16 samples of Y' ” (which

Mualla refers to as 16x16 pixel elements or “pels” as shown in Figure 3.2). APPLE-1005, 71. Mualla’s Figure 3.2 illustrates the H.263 picture structure for a QCIF picture frame (reproduced below).

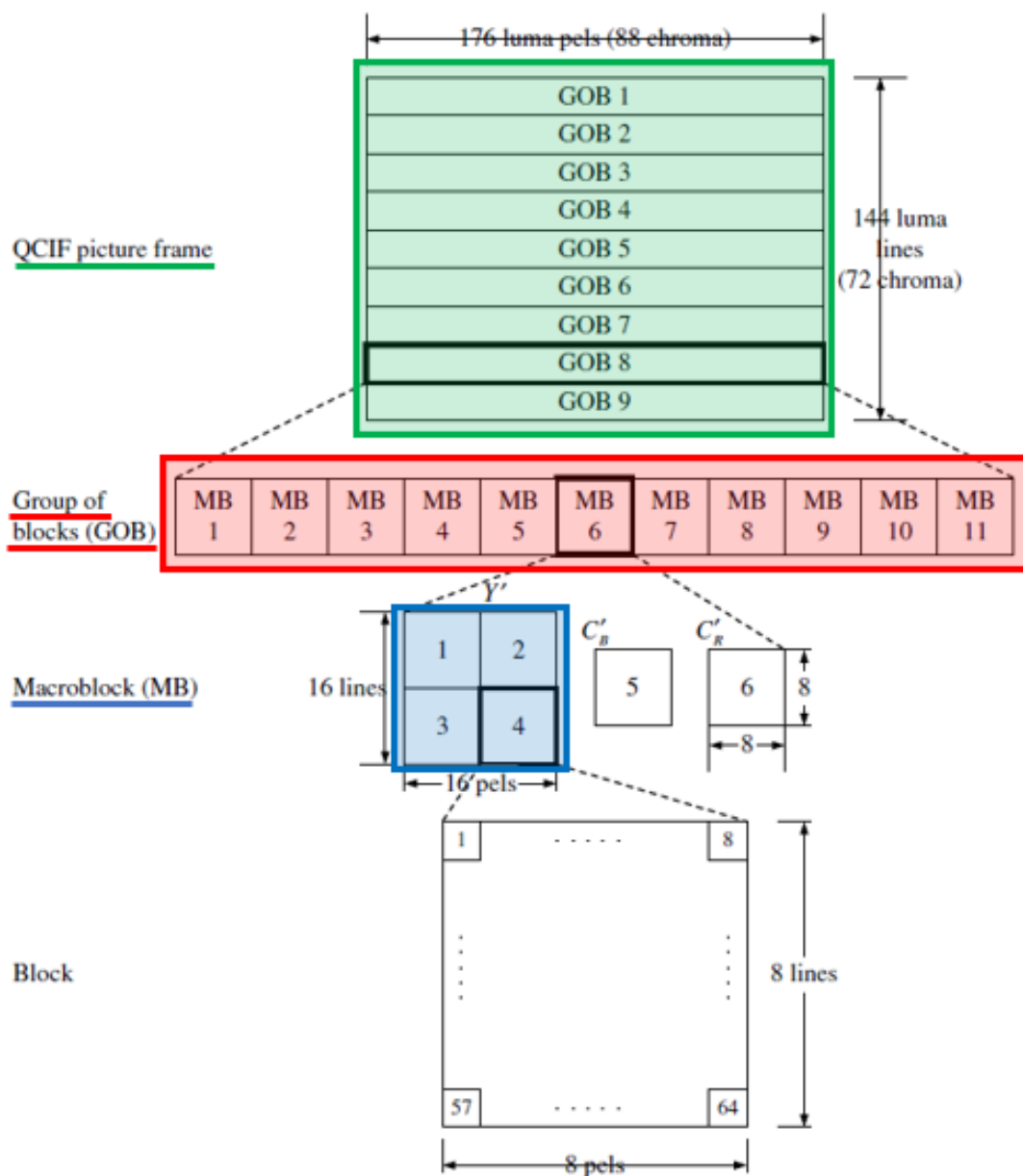


Figure 3.2: H.263 picture structure for a QCIF frame

APPLE-1005, Figure 3.2 (annotated and color added).

39. When the input video is encoded, Mualla explains that in each picture frame, “GOBs are coded from top to bottom in increasing number” and “[w]ithin each GOB, the MBs are coded from left to right (and from top to bottom if the GOB contains more than one row of MBs) in increasing number.” APPLE-1005, 71, Figure 3.2, 73.

40. Referring back to Figure 1.1 (reproduced below), in order to encode an “input frame” of video (also referred to as the “current frame”), Mualla discloses that the encoder: (i) uses “motion estimation (ME)” and “motion compensation (MC)” to generate “a prediction of the current frame” (APPLE-1005, 26, Figure 1.1), and (ii) subtracts the “prediction” of the current frame from the current frame “to produce an error signal known as the displaced-frame difference (DFD)” which is then encoded using the “transform encoder” (APPLE-1005, 26-27, Figure 1.1).

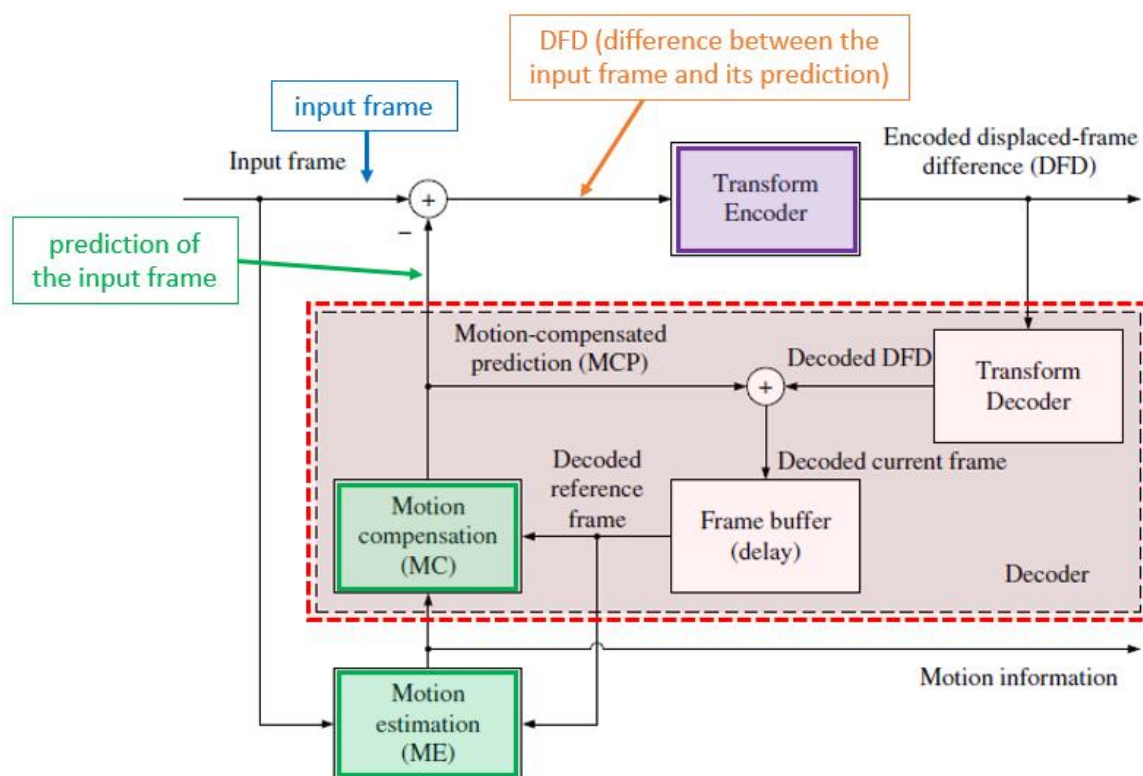


Figure 1.1: Typical video codec

APPLE-1005, Figure 1.1 (annotated and color added)

41. Mualla provides further details of these two operations, which are summarized below.

(i) Generating the “prediction” of the current frame

42. As shown in Figure 1.1 (reproduced again below), for a given input frame (annotated in blue, below, also referred to as the “current frame”), Mualla describes generating the “prediction” of the current frame (annotated in green) by using a “motion compensation (MC) block” (annotated in green) which uses “motion information” estimated by a “motion estimation (ME) block” (also annotated in green).

APPLE-1005, Figure 1.1, 26, *see also* 61.

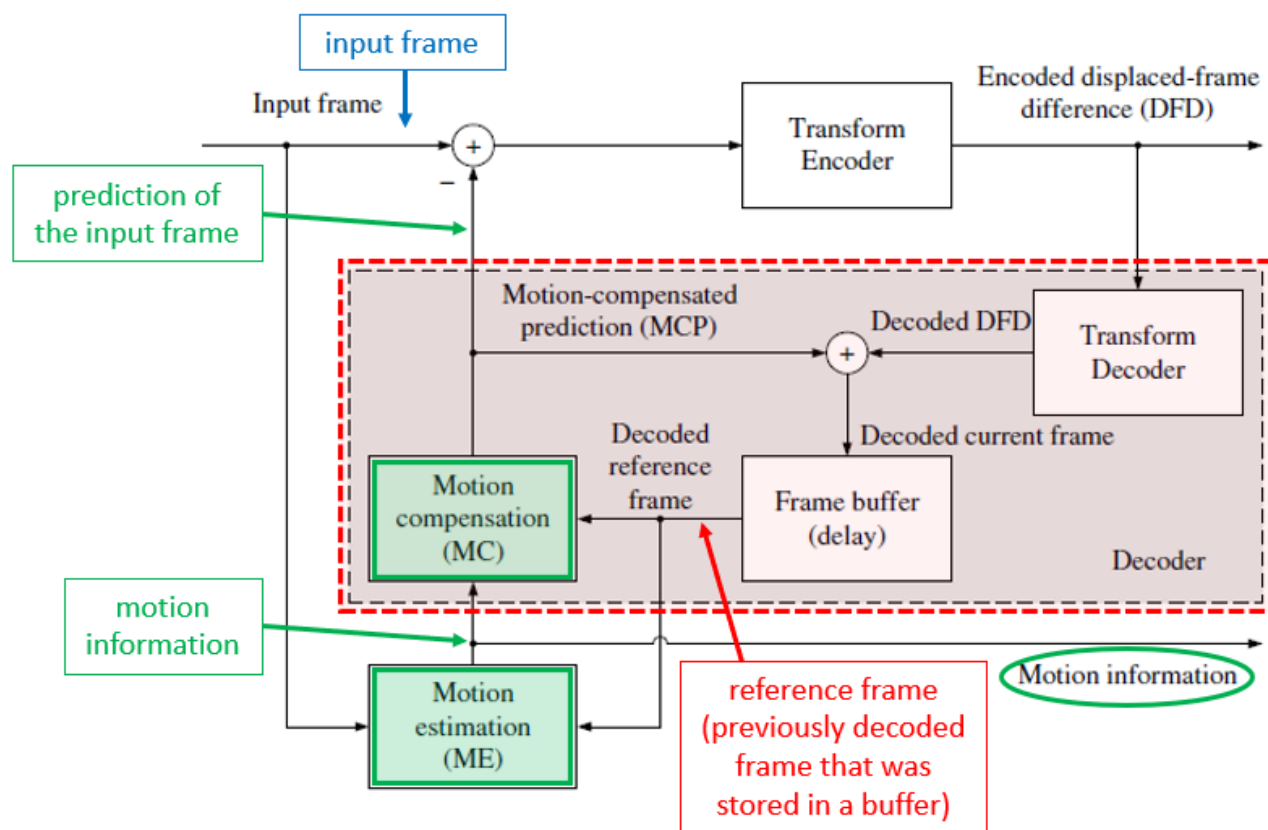


Figure 1.1: Typical video codec

APPLE-1005, Figure 1.1 (annotated and color added)

43. The encoder’s “motion estimation (ME) block” produces “motion information” which is an estimate of “the movement that occurred between the current frame and a reference frame (usually a previously decoded frame that was stored in a frame buffer)” (annotated in red in Figure 1.1, above). APPLE-1005, 26, *see also* 61. Mualla explains that “[t]he most commonly used ME method is the block-matching motion estimation (BMME) algorithm” in which the “motion of each block” is estimated “by searching for the best-match block in the reference frame.” APPLE-1005, 62. The motion of the current block is then “represented by a motion vector,

which is the displacement between the block and its best-match block in the reference frame.” *Id.* Mualla provides an example of motion estimation in Figure 2.16 (reproduced below). Mualla further explains that the BMME technique is supported by the H.263 standard, in which “the encoder estimates one motion vector per MB [(macroblock)].” APPLE-1005, 73-74.

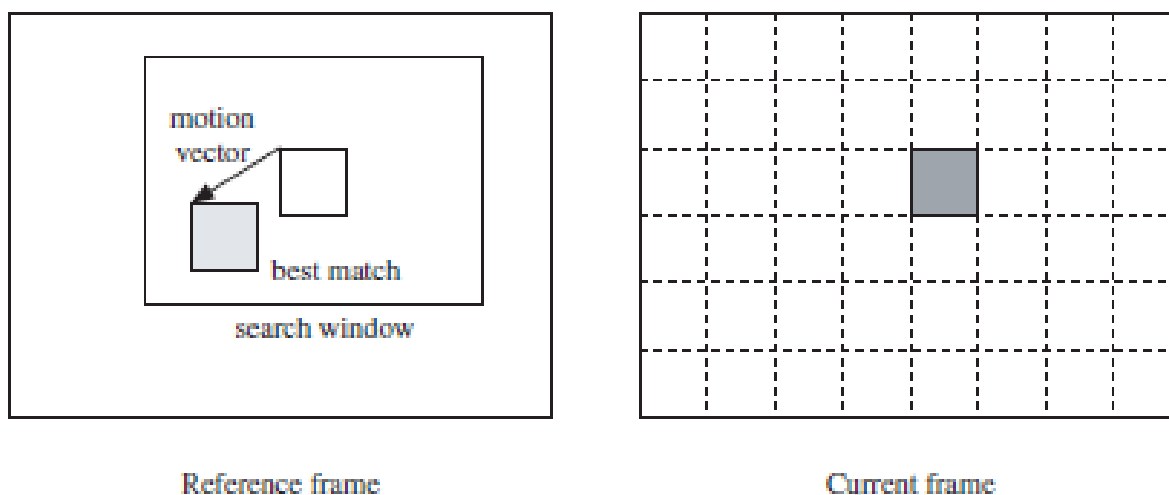


Figure 2.16: Block-matching motion estimation

APPLE-1006, Figure 2.16.

44. Once the motion estimation (ME) process has estimated a motion vector, the encoder then performs “motion compensation (MC)” in which the motion information is utilized “to move the contents of the reference frame to provide a better prediction of the current frame.” APPLE-1005, 61. Mualla refers to the resulting prediction (annotated in green in Figure 1.1, above) as the “the motion-compensated prediction (MCP) or the displaced-frame (DF).” *Id.*

45. As shown in Figure 1.1 (above), the video encoder implements motion compensation (MC) by using a local “decoder” (annotated in red, below) that locally decodes a frame, stores the decoded frame in the local frame buffer, and generates the prediction of the current frame based on the previously decoded and stored frame. APPLE-1005, 4, Figure 1.1. Thus, the “decoder” shown in Figure 1.1 is a local decoder that is implemented in the encoder, which replicates decoding operations implemented at a remote decoder in the receiver.

46. In addition to supplying the estimated motion vector to the motion compensation (MC) block, the motion vector is also encoded and output from the encoder (see the “motion information” circled in the lower-right-hand corner of Figure 1.1, above). APPLE-1005, Figure 1.1. In particular, in the H.263 standard, Mualla explains that for each macroblock, “[t]he estimated motion vector $MV = (MV_x, MV_y)$ is predictively coded” which means that “the motion vector difference $MVD = MV - MVP$ is encoded instead of the motion vector itself.” APPLE-1005, 74. The “MVP” is defined as the “motion vector predictor” which is “the median of three candidate predictors, which are the motion vectors of three surrounding macroblocks.” APPLE-1005, 74, Figure 3.3(a). The motion vector difference (MVD) is then “entropy coded” and the encoded MVD is output from the encoder as encoded motion information. APPLE-1005, 74.

(ii) Encoding the DFD

47. Once a prediction of the current frame has been generated using ME and MC, as described above, Mualla explains that “the prediction is then subtracted from the current frame to produce an error signal known as the displaced-frame difference (DFD)” (annotated in orange, below) which is then encoded using a “transform encoder” to produce an “encoded ... DFD” (annotated in purple, below) which is output from the encoder. APPLE-1005, Figure 1.1 (reproduced again below).

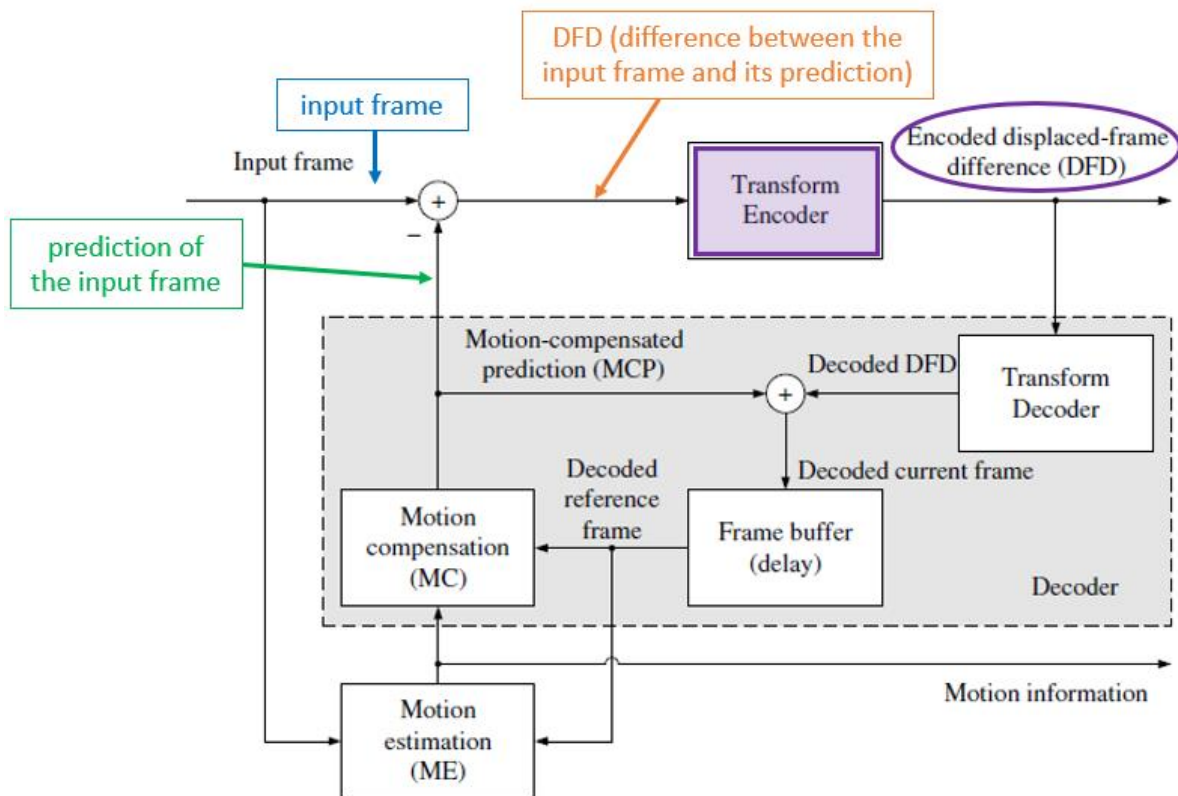


Figure 1.1: Typical video codec

APPLE-1005, Figure 1.1 (annotated and color added).

48. Mualla describes details of the “transform encoder” (annotated in purple, above) in Figure 2.9 (reproduced below), in which “the input frame is first **segmented** into $N \times N$ blocks” (annotated in orange, below), and then “a unitary¹⁶ space-frequency **transform** [(annotated in green, below)] is applied to each block to produce an $N \times N$ block of transform (spectral) coefficients that are then suitably **quantized** [(annotated in blue, below)] and **coded** [(annotated in red, below)].” APPLE-1005, 51-52.

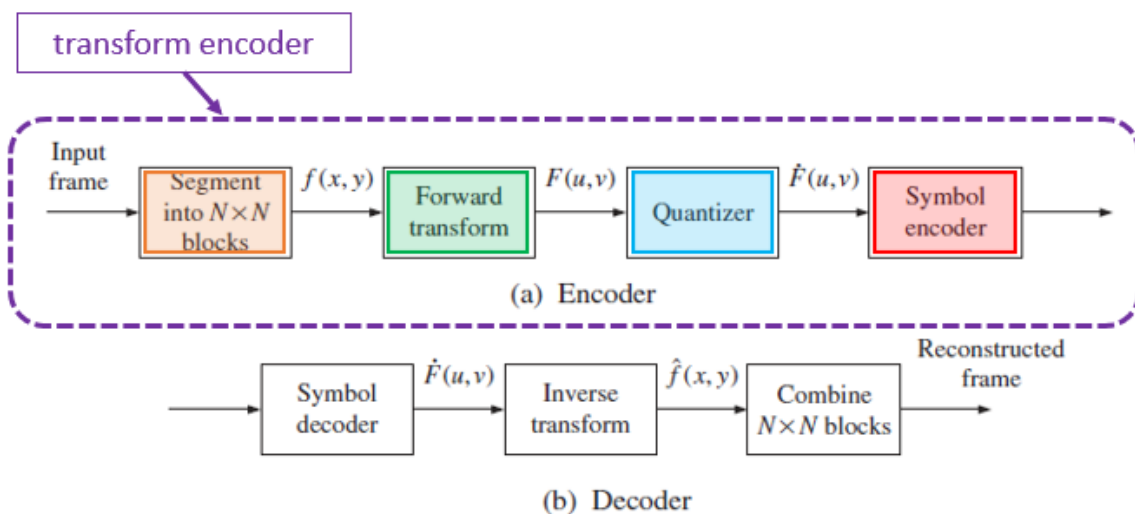


Figure 2.9: Block diagram of a transform coding system

APPLE-1005, Figure 2.9 (annotated and color added).

49. Thus, Mualla discloses that the encoder outputs both the encoded DFD (circled in purple in Figure 1.1, above) and the encoded motion information (circled in green in Figure 1.1, above). APPLE-1005, 26, 52, Figure 1.1.

50. Referring back to Figure 9.1, Mualla explains that “[a]t the decoder, the reverse operations are performed to obtain the output video.” APPLE-1005, 228. Figure 9.1.

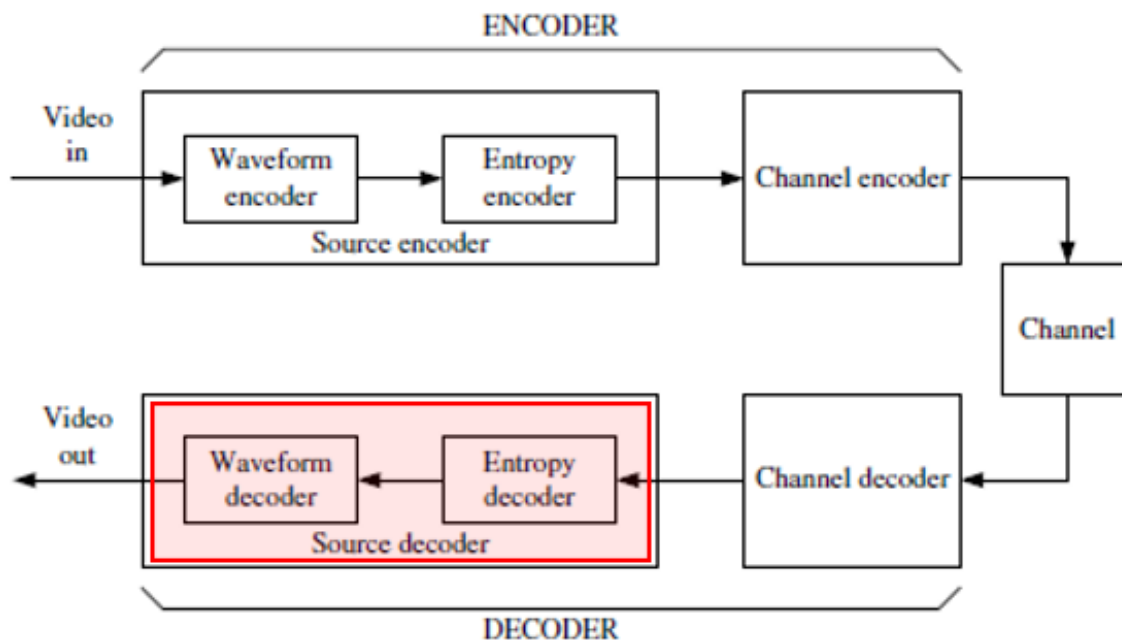


Figure 9.1: Typical video communication system

APPLE-1005, Figure 9.1 (color added).

51. In the specific context of an H.263 system, Mualla discloses that these reverse operations are performed by a “decoding process” that includes (i) “motion vector decoding” in which “for each transmitted inter MB, the decoder calculates the same motion vector predictor MVP used at the encoder and adds it to the decoded motion vector difference MVD to obtain the decoded motion vector MV,” (ii) “motion compensation” in which “[t]he decoded motion vector is used to compensate” the macroblock, (iii) “inverse quantization” for “reconstructing an approximation of the original coefficient,” (iv) “inverse transform” in which “[t]he reconstructed block of coefficients is processed by a separable 2-D 8x8 inverse DCT,” and (v) “reconstruction

of blocks” in which “the reconstructed block is formed by summing the motion-compensated prediction and the result of the inverse DCT.” APPLE-1005, 76.

Error Resilience Techniques

52. In addition to the conventional video coding and decoding operations discussed above, Mualla further describes, in Chapters 9 and 10, techniques for “error resilience” in video coding, including “error detection and error control techniques” applicable to the H.263 standard. APPLE-1005, 11, 227-251. Mualla explains that “when transmitted over a mobile channel, compressed video can suffer severe degradation and the use of error-resilience techniques is vital.” APPLE-1005, 25. In particular, Mualla explains that “[w]hen transmitted over a mobile channel, video can be affected by a number of loss mechanisms, like multipath fading, shadowing, and co-channel interference.” APPLE-1005, 205. Furthermore, “the higher the compression, the more sensitive the bitstream is to errors, since in this case each bit represents a larger amount of decoded video.” APPLE-1005, 227. Therefore, in addition to the compression techniques described above, Mualla also discloses modifying the decoder (and encoder) to implement techniques for detecting and recovering from errors that occur during transmission of the compressed bitstream.

53. To implement error resilience, Mualla describes a system in which “[t]he decoder was modified to perform error detection by detecting syntax and semantic violations.” APPLE-1005, 265. Mualla explains that “[w]hen an error is detected, the

decoding process is stopped” and “[a]ll macroblocks between the point where the error was detected and the synchronization point are marked as damaged macroblocks.” *Id.* Mualla discloses recovering the damaged macroblocks by using an error control technique called “hybrid error concealment” which combines both “spatial techniques” and “temporal techniques” (examples of which are presented in Figures 9.7 and 9.8, reproduced below). APPLE-1005, 242-246. In this hybrid technique, “temporal concealment is first used to get an initial estimate of the damaged block” and “this initial estimate is then refined using spatial concealment.” APPLE-1005, 246.

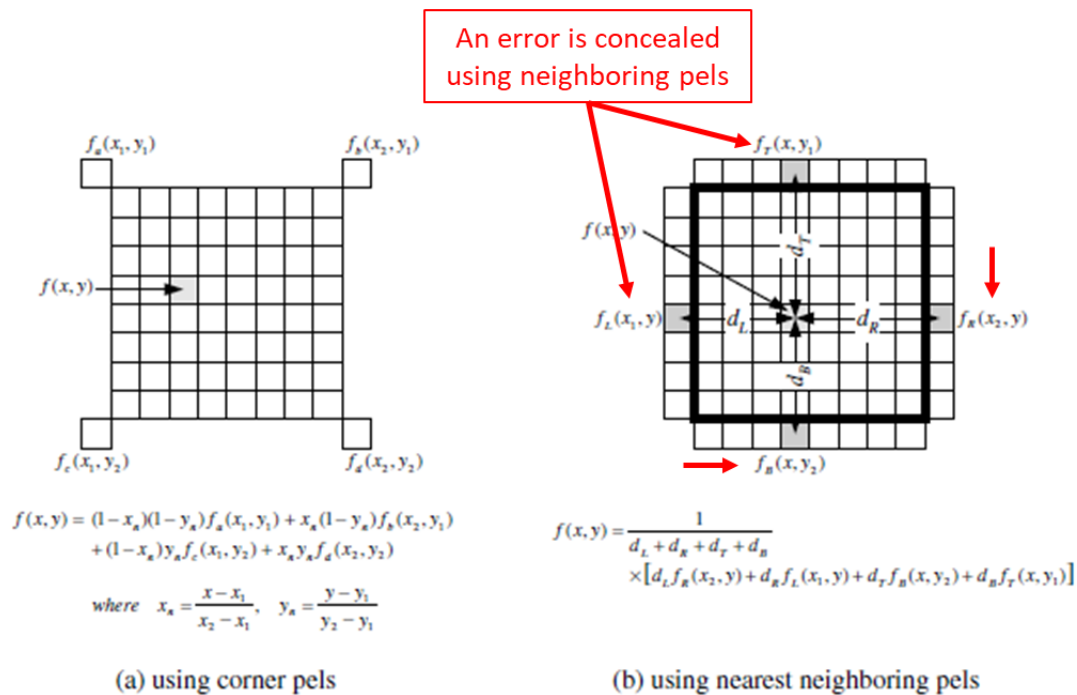


Figure 9.7: Error concealment using spatial interpolation

APPLE-1005, FIG. 9.7 (annotated).

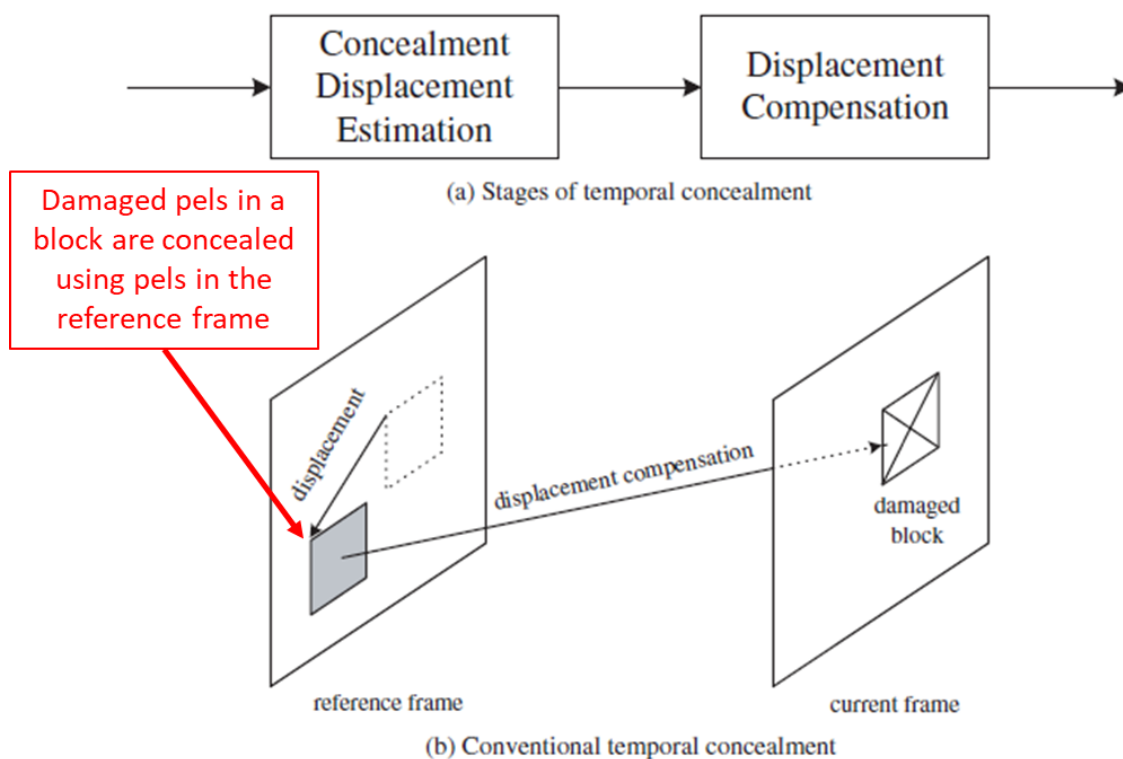


Figure 9.8: Temporal error concealment

APPLE-1005, FIG. 9.8 (annotated).

54. Furthermore, although Mualla describes details of error resilience (including *error detection* to detect errors and subsequent *error concealment* to recover from those errors) at the decoder, Mualla also teaches performing *error concealment* at the **encoder**. APPLE-1005, 246-250. For example, Mualla discloses that “the encoder and decoder cooperate to minimize the effects of transmission errors” and in particular “coding efficiency can also be improved by performing error concealment in the encoder so that both encoder and decoder use the same reference frames for prediction.” APPLE-1005, 249. To implement error concealment at the encoder, Mualla describes “interactive techniques” in which “the decoder uses a feedback

channel to inform the encoder about which parts of the transmitted video have been received in error” and “[b]ased on this feedback information, the encoder adjusts its operation to combat the effects of such errors.” APPLE-1005, 224. Mualla explains that “[w]hen feedback information is received, the encoder can reconstruct the error propagation process” so that “the encoder can track the error propagation.” APPLE-1005, 247.

55. In describing such interactive techniques, Mualla cites to numerous corroborating references that teach additional details of implementing “interactive” error concealment where the same error concealment technique is performed at both the **encoder and decoder**. APPLE-1005, 246-250. For example, Girod (APPLE-1008, cited as reference 201 in Mualla) teaches “error tracking” techniques for H.263-based systems in which the decoder performs “reporting of the temporal and spatial location of MB’s that could not be decoded successfully and had to be concealed” and “[b]ased on the information of an NACK, the encoder can reconstruct the resulting error distribution in the current frame.” APPLE-1008, 7. Girod explains that, in order to perform error tracking, “the coder has to know the decoder’s concealment technique” and that error tracking “does not require any modifications of the bit stream syntax of the motion-compensated hybrid coder” and “is therefore fully compatible with standards such as ... H.263.” APPLE-1008, 9. As another example, Wada (APPLE-1017, cited as reference 203 in Mualla and also cited as reference 50 in Girod)

teaches both a “procedure at the receiver” and “a procedure at the transmitter” for error resilience. APPLE-1017, 1-2. At the **receiver**, Wada teaches that (1) “Packet loss is detected,” (2) “Damaged picture block(s) is (are) specified,” (3) “Notice of packet loss with the address(es) of damaged picture block(s) is sent back to the transmitter,” (4) “Error concealment is carried out over damaged picture block(s),” and then (5) “Decoding is continued.” *Id.* At the **transmitter**, Wada describes a method in which (1) “Notice of packet loss is received with the address(es) of damaged picture block(s),” (2) “The **same error concealment as is performed at the receiver is carried out in the local-decoded frame stored**,” (3) “Local decoding is reexecuted from the point of the concealed block(s) up to the currently encoded block,” and then (4) “Encoding is normally continued.” APPLE-1017, 2.

56. Therefore, in view of the teachings of Mualla (and the references cited by Mualla which reflect knowledge in the art at the time of Mualla’s teachings), a POSITA would have understood or found obvious that (i) an H.263-based **decoder** performs *error detection* to detect errors and *error concealment* to recover from those errors, and (ii) an H.263-based **encoder** receives feedback from the decoder regarding errors that were detected, and performs the same *error concealment* to replicate those same errors in its local decoder so as to use the same reference frames for error prediction.

57. Furthermore, Stockhammer (APPLE-1009, which cites both Girod and Wada as references 62 and 63, respectively, for teachings of error tracking in H.263

systems) provides illustrative diagrams for implementing feedback-based error detection and error correction in an H.264-based system. APPLE-1009, 8, Fig. 6 (reproduced below). In particular, Fig. 6 of Stockhammer illustrates an encoder (on the left-hand side, annotated in blue) that implements a local “decoder” (annotated in red) to perform “video encoding” to generate “packets.” *Id.* The packets are transmitted over a “packet loss channel” in which packets are randomly lost during transmission. *Id.* At the remote decoder (on the right-hand side, annotated in red), Stockhammer explains that “[t]he decoder processes the received sequence of packets” such that “received packets are decoded as usual” whereas “for the lost packet, an error-concealment algorithm has to be invoked.” APPLE-1009, 8.

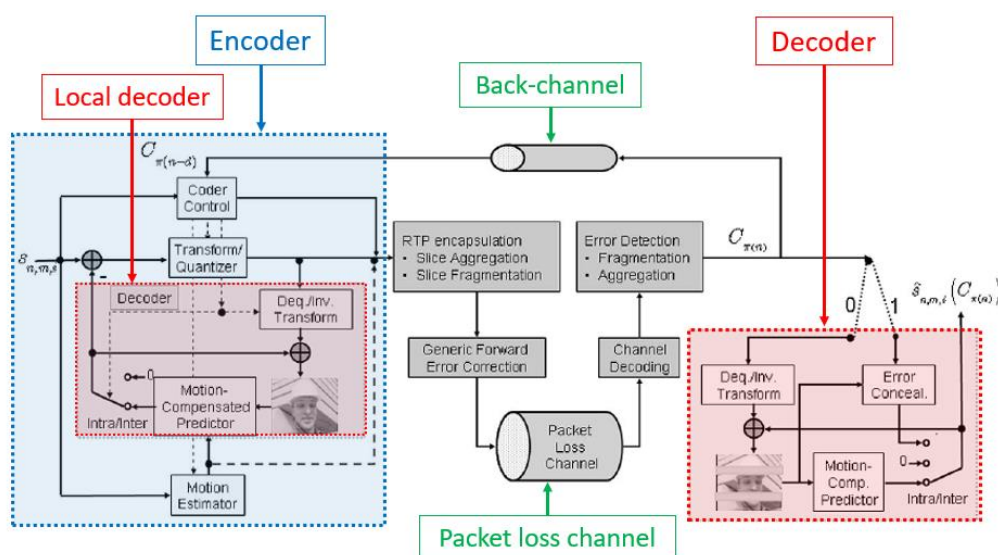


Fig. 6. H.264/AVC in IP-based packet-lossy environment with RTP encapsulation, generic forward error correction, delayed feedback information, and error concealment.

APPLE-1009, FIG. 6 (annotated and color added).

58. Stockhammer also illustrates, in Fig. 6 above, and describes that a “back-channel from the decoder to the encoder is available [(shown in the upper part of Fig.

6))]] which allows reporting ... of the observed channel behavior at the decoder to the encoder.” *Id.* Stockhammer provides further details of error resilience utilizing such “feedback” from the decoder to encoder, and specifically cites to Girod and Wada (as references 62 and 63, respectively) for teachings of “a simple yet powerful approach suitable for video codecs ... such as MPEG-2, H.261, or H.263 ... under the name *error tracking*.” APPLE-1009, 11.

59. To the extent the implementation details of Stockhammer were not already understood to a POSITA with knowledge of error concealment techniques (e.g., from reviewing the disclosures of Mualla and Shirani), a POSITA reviewing the teachings of Stockhammer would have also been motivated to combine these same implementation details into the teachings of Mualla (e.g., thus creating the Mualla-Shirani-Saito-Stockhammer combination of Ground 1B). APPLE-1009, 8-11. Indeed, although the techniques of Stockhammer were well understood, a POSITA would have naturally searched for specific implementation examples (e.g., Stockhammer’s FIG. 6 above) to refine the broader disclosure of Mualla.

60. To summarize, Mualla provides a self-contained teaching of video coding systems, including the concept of feedback-based error tracking in which (i) an H.263-based **decoder** performs *error detection* to detect errors and *error concealment* to recover from those errors, and (ii) an H.263-based **encoder** receives feedback from the decoder regarding errors that were detected, and performs the same *error concealment* to

replicate those same errors in its local decoder so as to use the same reference frames for error prediction. In particular, Mualla refers to (i) as a “post-processing” technique and refers to (ii) as an “interactive” technique, and Mualla explains that a “combination” of these two techniques can be employed in practical systems. APPLE-1005, 251 (“It should be emphasized that the three categories of techniques are not mutually exclusive, and different combinations can be employed in practical systems”).

61. These teachings of Mualla are corroborated by Girod and Wada (both of which are cited in Mualla) and Stockhammer (which also cites to Girod and Wada) which provide additional details and diagrams for the same concepts disclosed in Mualla.

62. Therefore, in view of the teachings of Mualla (as corroborated by Girod, Wada, and Stockhammer), a POSITA would have understood or found obvious that feedback-based error resilience at both the encoder and decoder can be implemented by a system such as the one shown in Diagram C, below. APPLE-1009, Fig. 6. In this diagram, Figure 6 of Stockhammer has been modified to show how error concealment would be implemented at the encoder, based on the teachings of Mualla. APPLE-1009, Fig. 6. In particular, the modified portions of Stockhammer’s Fig. 6 are annotated and shaded in red in Diagram C. APPLE-1009, Fig. 6. As shown, the modification simply amounts to replacing the encoder’s local “decoder” with an analogous error

concealment structure enabled as already implemented in the remote decoder. APPLE-1009, Fig. 6.

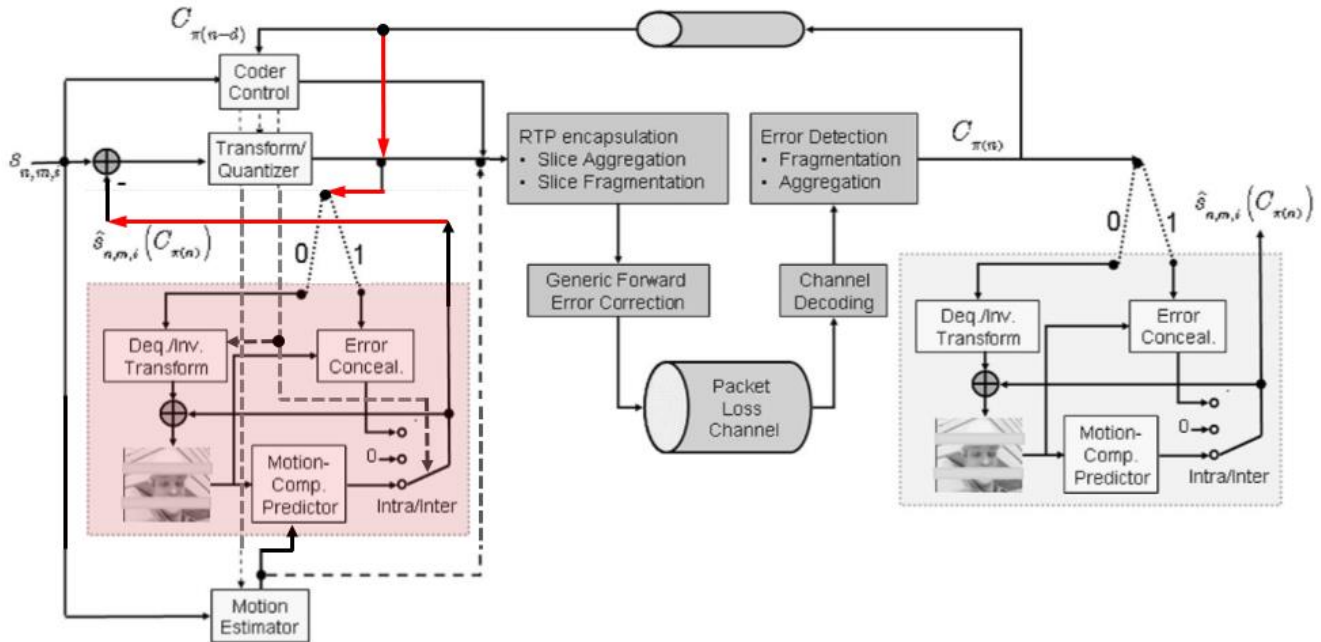


Diagram C (showing a video coding system with interactive error concealment).

63. Diagram D, below, illustrates a detailed view of the modified encoder of Diagram C. APPLE-1009, Fig. 6. As discussed previously, the modified encoder implements a local decoder (shaded in red) that performs error concealment. APPLE-1009, Fig. 6.

reception of the macroblock). APPLE-1009, 8, Fig. 6. If the feedback indicates that no error occurred (“0”), then the modified encoder performs the conventional steps of dequantization and inverse transform (upper-left-hand block in the red shaded area of Diagram D) with “motion compensated-predictor” (lower block in the red shaded area of Diagram D) and the second selector at the bottom-right-hand corner of the red shaded area is in the lower-most position. APPLE-1009, 8, Fig. 6. Otherwise, if the feedback indicates that an error occurred (“1”), then the modified encoder performs “error concealment” (upper-right-hand block in the red shaded area of Diagram D) and the second selector at the bottom-right-hand corner of the red shaded area is in the upper-most position. APPLE-1009, 8, Fig. 6.

65. Specifically, in the case of an error (“1”), POSITA would have understood or found obvious, based on the technique of “error tracking” as described in Mualla (as corroborated by Wada) that “the encoder can track the error propagation from the original occurrence up to the current frame” (APPLE-1005, 247) by using a method in which “[t]he same error concealment as is performed at the receiver is carried out in the local-decoded frame stored” and then “[l]ocal decoding is reexecuted from the point of the concealed block(s) up to the currently encoded block” (APPLE-1017, 2).

66. In both scenarios of the feedback indicating error and no error, the encoder’s local “decoder” generates a “reconstructed image” (i.e., the aggregate signal $\hat{s}_{n,m,i}(o, C_{\pi(n)})$) that labels the red annotated line on the left-hand side of Diagram D)

which is provided to a subtractor (left-hand side of Diagram D) which subtracts the reconstructed image from the input image (i.e., the input signal $s_{n,m,i}$). APPLE-1009, Fig. 6. This is consistent with the teachings of Mualla for conventional encoding (APPLE-1005, Figure 1.1, discussed above) where the encoder's local decoder generates a "prediction of the input frame" (the reconstructed image) is subtracted from the input frame (the input image).

67. Therefore, in view of the teachings of Mualla (as corroborated by Girod, Wada, and Stockhammer), a POSITA would have understood or found obvious that an error resilience technique (such as the "hybrid error concealment" technique described in Mualla) can be implemented at both the encoder and the decoder in a feedback-based video coding system.

B. Overview of Shirani

68. Shirani is cited in Mualla (as reference [199]) for teaching details of the "hybrid error concealment" technique that was described in Mualla. APPLE-1005, 246. Specifically, Shirani teaches a "two-stage error-concealment method for block-based compressed video which was transmitted in an error-prone environment" in an H.263 video coding framework. APPLE-1006, Abstract; 1. Shirani's "first stage" "obtain[s] an initial estimate of the missing block using information from the previous frame," which Shirani refers to as "temporal" concealment (consistent with Mualla). APPLE-1005, 243-245; APPLE-1006, 1-2. In Shirani's "second stage," "the information around

each missing block is used to refine the initial estimate,” which Shirani refers to as “spatial” concealment (consistent with Mualla). APPLE-1005, 242-243; APPLE-1006, 1-3.

69. For the “first stage,” Shirani describes a technique that utilizes motion vectors of “subblocks adjacent to the missing block” (in particular, subblocks that are “adjacent above and left” as well as “subblocks ... to the right and below of the missing block”) to derive an “initial estimate” of the missing block that has the smallest sum of “border errors.” APPLE-1006, 3. Shirani illustrates an example of “subblocks adjacent to the missing block, i.e., $u1$, $u2$, $l1$, and $l2$ in Fig. 1(a)” (annotated in blue, below). APPLE-1006, 3, FIG. 1(a) (reproduced below).

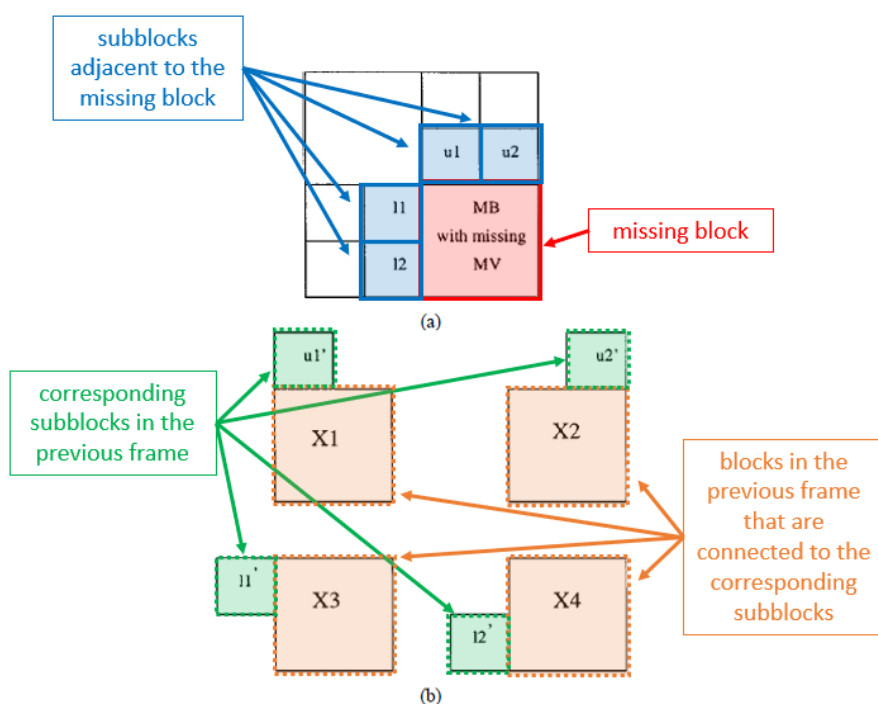


Fig. 1. (a) The four subblocks, (b) their corresponding subblocks in the previous frame, and the blocks connected to them.

APPLE-1006, FIG. 1(a) (annotated and color added).

70. Once these adjacent subblocks ($u1$, $u2$, $l1$, and $l2$, annotated in blue, above) are identified, Shirani discloses that “for each of these subblocks, a corresponding subblock in the previous frame is determined” (denoted $u1'$, $u2'$, $l1'$, and $l2'$ at the bottom of FIG. 1(a) of Shirani, annotated in green, above). APPLE-1006, 3. Then, “four blocks, namely X1, X2, X3, and X4 [annotated in orange in FIG. 1(a), above], which are connected to $u1'$, $u2'$, $l1'$, and $l2'$, and (respectively), are determined” and “a block from the above four blocks [(X1, X2, X3, and X4)] that minimizes the squared sums of border errors, between the estimated block and its adjacent above and left blocks, is selected.” APPLE-1006, 3. This is accomplished by defining “border error[s]” in “terms of pixels,” including an error for the “bottom line pixels of the block to the top of the missing block” and an error for the “right column pixels of the block to the left of the missing block” and applying the same technique to define border errors for pixels adjacent to “the subblocks ... to the right and below of the missing block.” *Id.*

71. To estimate the motion of the adjacent subblocks ($u1$, $u2$, $l1$, and $l2$, annotated in blue, above), Shirani discloses that “computational overhead can be reduced if the search for displacement of each of the subblocks is restricted to a set of candidate motion vectors,” where the candidate motion vectors can include “the motion vectors of available neighboring blocks, the median of the motion vectors of available neighboring blocks, the average of the motion vectors of available neighboring

blocks.” APPLE-1006, 3. Furthermore, although the above description focused on adjacent subblocks above and to the left of the missing block, Shirani also discloses that “the same method can be extended to include the subblocks of the blocks to the right and below of the missing block.” APPLE-1006, 3.

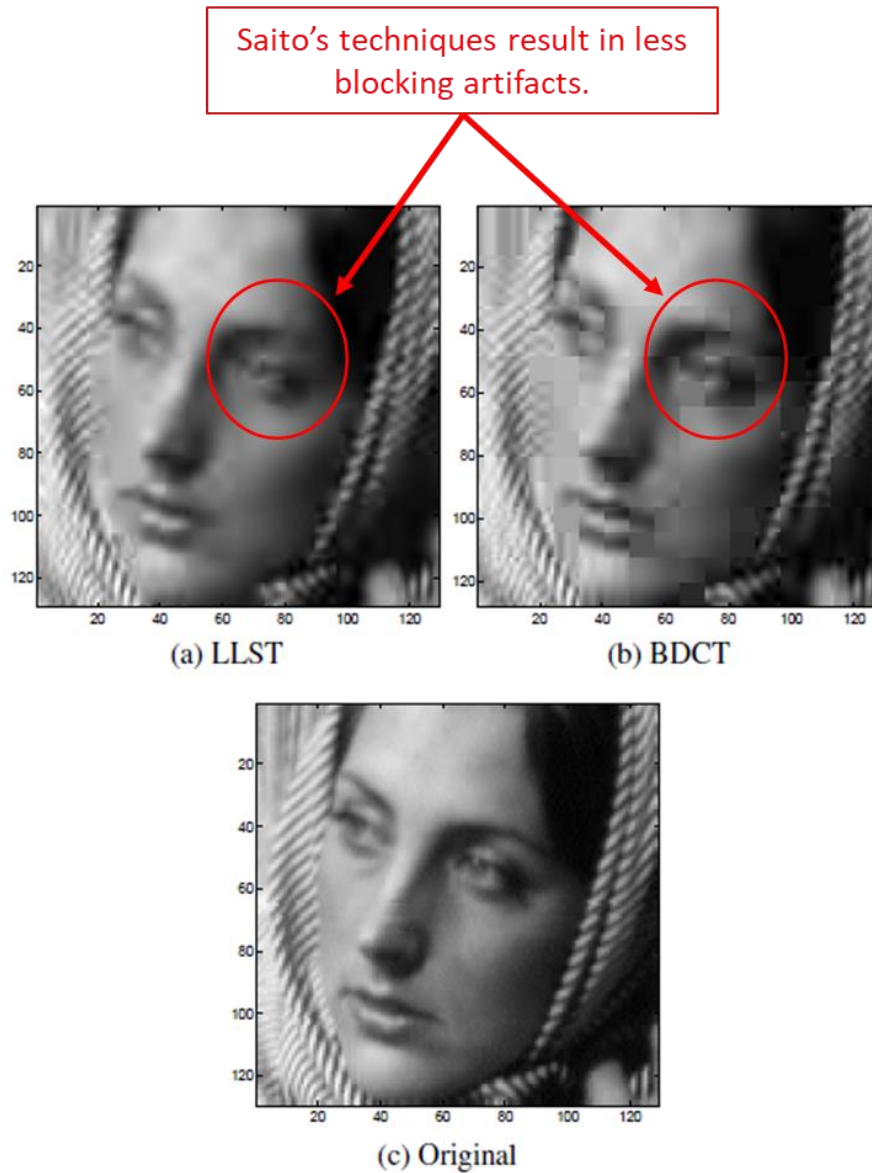
72. For the “second stage,” Shirani describes various techniques of “spatial error concealment” that can “refine the initial estimate” (obtained in the first stage, above) by utilizing “information around each missing block.” APPLE-1006, 1, 3. As examples of “spatial error concealment,” Shirani describes techniques in which neighboring pixels around the missing block are used, to “refine the initial estimate” that was obtained in the first stage. APPLE-1006, 1 (“each pixel in a damaged block is interpolated from the corresponding pixels in its four neighboring blocks”), 3 (“[i]n the second stage of our proposed error-concealment method, the information around each missing block is used to refine the initial estimate”).

C. Overview of Saito

73. Saito discloses “image approximation” using techniques that are based on solving Poisson’s equation. APPLE-1007, 6, 27. Saito expresses an overarching goal of improving “the perceptual quality of these approximations” and a desire for a “perceptually correct metric” that can improve the “visual quality” of approximated images. APPLE-1007, 18. Saito also discusses the relevance of “psychophysical

experiments” in selecting appropriate image approximation techniques that improve “visual fidelity” of reconstructed images. APPLE-1007, 24.

74. To achieve these goals, Saito discloses a “polyharmonic local sine transform” (PHLST) and a “polyharmonic local cosine transform” (PHLCT) that both solve Poisson’s equation and are “effective for image approximation.” APPLE-1007, 6, 27. Saito explains that “PHLST can represent smooth regions of an image very efficiently” and therefore “image approximation and compression are immediate and important applications of PHLST.” APPLE-1007, 8-9. Saito further discloses “extensions and applications of PHLST” which include a version called “polyharmonic local cosine transform (PHLCT).” APPLE-1005, 27. Saito explains that the PHLCT technique can “solve the ... Poisson equation with the Neumann boundary condition.” *Id.* Saito further explains that the PHLCT utilizes “the first order normal derivative of data at the boundary.” *Id.* In particular, Saito discloses that the solution to Poisson’s equation has “the same normal derivative at the boundary with the original function” by ensuring that “the residual function v_j ... clearly satisfies $\partial v_j / \partial v = 0$ on $\partial \Omega_j$.” APPLE-1007, 27. Thus, Saito’s PHLCT technique ensures that the derivative of the estimated signal at a boundary of a block is equal to the derivative of the signal to be estimated at the boundary, thus ensuring smoothness of the estimated image across block boundaries with less “blocking artifacts”. APPLE-1007, 27; *see also* 5, 58, Abstract, FIG. 11 (reproduced below).



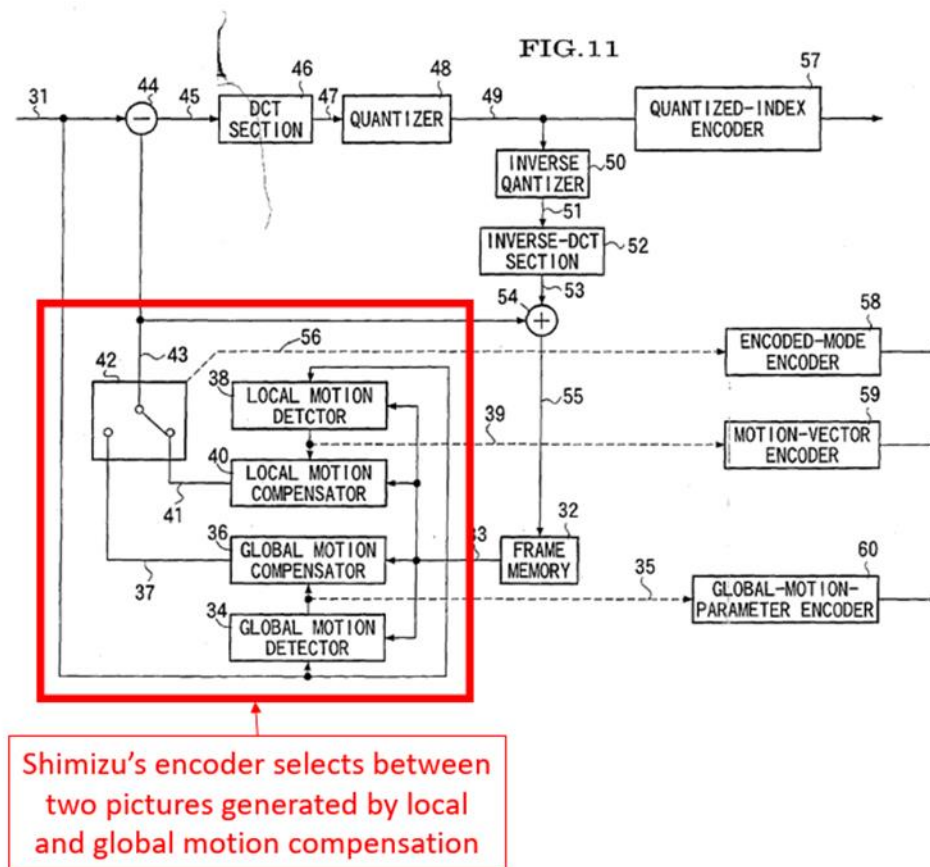
APPLE-1007, FIG. 11 (Cropped and annotated).

D. Overview of Shimizu

75. Shimizu discloses techniques for improving the efficiency of interframe predictive coding by switching between two different modes of motion compensation. APPLE-1024, ¶¶[0047]-[0059], FIG. 11. Specifically, Shimizu discloses “local motion

compensation” which “detects, for each macro block ... a motion vector between input picture [] and reference picture” and “generates a local motion-compensating predicted picture [] based on the motion vector.” *Id.*, ¶[0031]. Shimizu notes that “[t]his method equals the conventional motion-compensating method used in the conventional MPEG or the like.” *Id.* As an alternative to the conventional “local” motion compensation, Shimizu also discloses “global motion compensation” which “generates a global motion-compensating predicted picture [] by making the motion vector of each pixel ... act on the reference picture.” *Id.*, [0030]. As such, Shimizu explains that global motion compensation uses a “motion vector representing a global motion over a plurality of areas” while local motion compensation uses a “motion vector for each area.” *Id.*, ¶¶[0049]-[0050]-[0052].

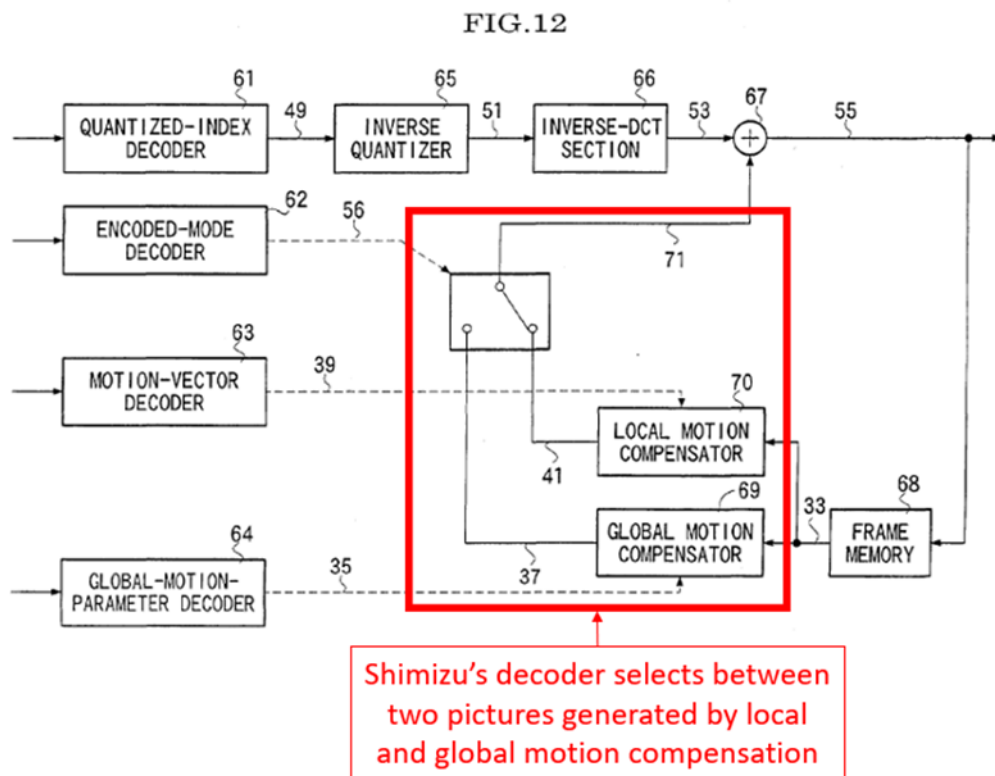
76. Using a reference picture, Shimizu’s encoder generates both a “global motion-compensating predicted picture” and a conventional “local motion-compensating predicted picture,” and then selects between these two predicted pictures based on “whichever has the smaller error with respect to the input picture.” *Id.*; ¶¶[0030]-[0036], FIG. 11 (reproduced below, showing the encoder implementing encoding mode selector 42 that selects between the two predicted pictures).



APPLE-1024, FIG. 11.

77. Analogously, Shimizu's decoder also generates and selects between two motion-compensating predicted pictures generated by global motion compensation and conventional local motion compensation. APPLE-1024, ¶¶[0034], [0035], FIG. 12 (reproduced below, showing the decoder implementing a switch 71 that selects between the two predicted pictures). Specifically, Shimizu discloses that the decoder's switch 71 is controlled by encoded-mode choice information 56 received from the encoder. *Id.*, ¶[0035]. As such, Shimizu's encoder and decoder both generate global and local motion

compensating predicted pictures and select between the two predicted pictures, such that the same predicted picture is selected at the encoder and decoder.



APPLE-1024, FIG. 12.

E. The combination of Mualla and Shirani (and the Combination of Mualla-Stockhammer and Shirani in Ground 1B¹)

78. As discussed above, Mualla describes “hybrid error concealment” techniques for “error resilience” in video coding that implements both temporal and

¹ Although my discussion in this section focuses on the combination of Mualla and Shirani, it is similarly applicable to the combination of Mualla-Stockhammer and Shirani in Ground 1B, with Stockhammer supplementing Mualla merely to provide

spatial concealment. APPLE-1005, 241-246. Mualla specifically cites Shirani for details of this “hybrid error concealment” technique. APPLE-1005, 241-246. Given Mualla’s explicit reference to Shirani, a POSITA would have naturally looked to Shirani and its “two-stage error concealment” technique for further details of how to implement “hybrid error concealment” as described in Mualla. APPLE-1005, 246; APPLE-1006, 1-6. A POSITA implementing the supplemental teachings of Shirani into the existing disclosure of Mualla would have created the Mualla-Shirani combination (and the Mualla-Stockhammer-Shirani combination in Ground 1B).

79. In particular, the hybrid error concealment techniques of the Mualla-Shirani combination perform error detection to detect whether errors exist in a frame (also referred to as a picture). APPLE-1005, 241-246; APPLE-1006, 2-4. If errors are detected in a frame/picture, a two-stage motion-compensated error concealment algorithm is applied to perform both temporal and spatial concealment to conceal the errors and generate a predicted frame. APPLE-1005, 242-246; APPLE-1006, 2-4. Otherwise, if no errors are detected, conventional motion compensation is applied. *Id.* Specifically, as discussed above, the two-stage (hybrid) error concealment algorithm of the Mualla-Shirani combination implements a “first stage” which applies “temporal”

illustrative details of implementing what a POSITA would have understood or found obvious to already be taught by Mualla’s error concealment disclosure.

concealment and a “second stage” which applies “spatial” concealment. APPLE-1005, 242-245; APPLE-1006, 1-3.

80. Furthermore, in the combination of Mualla and Shirani, and in particular in Shirani’s “two-stage error concealment” technique, Shirani describes various alternatives for the “second stage” (in which “spatial” concealment is performed). As discussed above, as an example of the second stage, Shirani describes a spatial concealment technique in which “each pixel in a damaged block is interpolated from the corresponding pixels in its four neighboring blocks such that the total squared border error is minimized.” APPLE-1006, 1.

81. Furthermore, as discussed above, the two-stage hybrid error concealment is implemented in both the encoder and the decoder (“interactive” error concealment), as taught by Mualla, so that the encoder and decoder can “cooperate to minimize the effects of transmission errors” and in particular so that “coding efficiency can also be improved by performing error concealment in the encoder so that both encoder and decoder use the same reference frames for prediction.” APPLE-1005, 246-250.

82. As explained below in more detail, combining Mualla and Shirani would have been obvious at least because such a combination would have merely involved (1) combining prior art elements according to known methods to yield predictable results; and the (2) use of known techniques to improve similar devices in the same way. Indeed, Mualla describes a similar hybrid error concealment technique as Shirani, and

the combination would have simply involved adding Shirani's teachings into the compatible teachings of Mualla, thus, for at least this reason, making the Mualla-Shirani combination predictable and foreseeable with a reasonable expectation of success. APPLE-1005, 246; APPLE-1006, 1-6. Moreover, because Mualla explicitly cites to Shirani's teachings when discussing its own techniques of hybrid error concealment, the use of Shirani's techniques in Mualla would have improved a similar device in the same way. APPLE-1005, 246. Additionally, Mualla and Shirani implement their teachings in similar video coding standards (e.g., H.263). APPLE-1005, 71-94, 231; APPLE-1006, 4-5.

F. The combination of Mualla, Shirani, and Saito (and the Combination of Mualla-Stockhammer-Shirani and Saito in Ground 1B²)

83. As discussed above, the combination of Mualla and Shirani (and the combination of Mualla-Stockhammer and Shirani in Ground 1B) implements a two-stage (hybrid) error concealment technique. In particular, the second stage applies

² Although my discussion in this section focuses on the combination of Mualla-Shirani and Saito, it is similarly applicable to the combination of Mualla-Stockhammer-Shirani and Saito in Ground 1B, with Stockhammer supplementing Mualla merely to provide illustrative details of implementing what a POSITA would have understood or found obvious to already be taught by Mualla's error concealment disclosure.

“spatial error-concealment” to “restore the missing blocks using the information in the current frame.” APPLE-1006, 1; *see also* APPLE-1005, 242 (explaining that spatial concealment techniques “conceal damaged pels in a frame using information from correctly received and/or previously concealed neighboring pels within the same frame”). Both Mualla and Shirani disclose that “spatial” concealment can be implemented using various techniques from the field of conventional image-processing, each with benefits and tradeoffs. APPLE-1005, 242-243; APPLE-1006, 1.

84. Therefore, as evidenced in the teachings of both Mualla and Shirani, a POSITA would have understood or found obvious that **image-processing** techniques are a natural solution for implementing the **second-stage “spatial”** concealment of the Mualla-Shirani two-stage hybrid technique. It was well-known to use image-processing techniques to perform spatial concealment within an individual frame of a video. APPLE-1011 (disclosing a hybrid-type “space-time video completion” techniques for “[c]orrection of missing/corrupted video frames” in which “classical spatial image completion and synthesis” is implemented for “spatial” correction within an individual video frame).

85. Furthermore, a POSITA would have understood or found obvious that image processing can be performed by techniques that involve solving Poisson’s equations. Numerous research papers and patents had, several years before the Critical Date, described techniques for image editing and image reconstruction that involved

solving Poisson's equation. APPLE-1010 (disclosing "Poisson image editing" which is "based on solving Poisson equations" for "seamless editing of image regions"); APPLE-1012 (disclosing techniques for "image reconstruction" by "solving the Poisson differential equation"); APPLE-1013 and APPLE-1014 (disclosing techniques for "natural image matting" by "solving Poisson equations"); APPLE-1015 (disclosing a technique that "constructs a low dynamic range image by solving a Poisson equation").

86. A POSITA would have understood or found obvious that image processing techniques involving Poisson's equation are particularly effective in addressing the same challenges and achieving the same goals emphasized by Mualla and Shirani for error concealment applications. For example, Mualla explains the fundamental importance of considering the "human visual system (HVS)" in video codec techniques. APPLE-1005, 33, 36, 40, 52, 55, 59. Mualla explains that the "classical view of the image coding problem" has a disadvantage because it "does not place enough emphasis on exploiting the properties of the HVS [human visual system]. Efforts to utilize models of the HVS and to use more representative coding entities (real objects) led to a new class of coding methods known as the second-generation coding methods." APPLE-1005, 59. Specifically, in the context of error resilience and error concealment, Mualla explains that a "decoder attempts to conceal the effects of errors by providing a **subjectively acceptable** approximation to the original data. This

is achieved by exploiting the limitations of the **human visual system** and the high temporal and/or spatial correlation of video sequences.” APPLE-1005, 242; 251. Indeed, Mualla measures the performance of different error concealment techniques by the “[s]**ubjective quality**” of error-concealment in a video frame, as viewed by the human visual system. APPLE-1005, 265; 268 Figures 10.8, 10.10. In addition to these challenges of providing good subjective quality of error-concealed images for the human visual system, Mualla also explains a mathematical challenge in that “[e]rror concealment is an ill-posed problem since it **does not have a unique solution.**” APPLE-1005, 242; 251. Like Mualla, Shirani also stresses the fundamental importance of considering the “limitations of the **human visual system**” when designing an error concealment technique, as well as the benefits of using a technique that can achieve a “**a unique global solution.**” APPLE-1006, 1, 4.

87. In view of Mualla and Shirani emphasizing a fundamental goal of improving the “subjective quality” of error concealment techniques for the “human visual system,” a POSITA would have understood that an image approximation technique based on **solving Poisson’s equation**, as taught by Saito (APPLE-1007), is an effective way to achieve this goal. The Poisson equation has been used extensively in field of image processing and computer vision due to the specific benefits it provides for improving the perceptual quality of reconstructing images. APPLE-1010 (disclosing “[t]he Poisson equation has been used extensively in computer vision” because “it is

well known to psychologists [Land and McCann 1971] that slow gradients of intensity, which are suppressed by the Laplacian operator, can be superimposed on an image with barely noticeable effect. Conversely, the second-order variations extracted by the Laplacian operator are the most significant perceptually”).

88. Therefore, as discussed above: (i) Mualla and Shirani both recognize that **image processing** techniques can be utilized to implement **second-stage spatial** error concealment in the Mualla-Shirani two-stage hybrid error concealment technique for video frames, (ii) image processing techniques that involve **solving Poisson’s equation** were well-known to provide specific benefits for improving the perceptual quality of reconstructed images for the human visual system, thus addressing a fundamental objective of Mualla and Shirani’s error concealment. As such, a POSITA would have understood or found obvious that image-processing techniques based on solving Poisson’s equation would have been naturally applicable for implementing the second-stage “spatial” concealment of the Mualla-Shirani two-stage hybrid error concealment algorithm for video frames. Indeed, literature in video coding spatial error concealment and literature in image processing by solving Poisson’s equation both cited to similar techniques. For example, Wexler (APPLE-1011, which describes using classical spatial image processing techniques for correcting video frames) and Perez (APPLE-1010, which describes Poisson image editing as an example of an image processing technique) both discuss a technique called “image inpainting” as an example

of image processing and cite to many of the same references as related art for details of image inpainting.

89. Saito provides details of implementing solutions to Poisson's equation for image approximation. A POSITA would have understood that Saito, which was published in 2006 (over 4 years after Mualla and Shirani), was a natural advancement of applying Poisson's equation to improve the visual quality of image approximation and represented a state-of-the-art solution at the time of the Critical Date. Like Mualla and Shirani, Saito expresses an overarching goal of improving "the perceptual quality of these approximations" and a desire for a "perceptually correct metric" that can improve the "visual quality" of approximated images. APPLE-1007, 18. Saito also discusses the relevance of "psychophysical experiments" in selecting appropriate image approximation techniques that improve "visual fidelity" of reconstructed images. APPLE-1007, 24.

90. As discussed above, Saito discloses a "polyharmonic local sine transform" (PHLST) and a "polyharmonic local cosine transform" (PHLCT) that solve Poisson's equation and are "effective for image approximation." APPLE-1007, 6, 27. In particular, Saito explains that its PHLCT technique "shall solve the $\square$ Poisson equation with the Neumann boundary condition." APPLE-1007, 27.

91. Furthermore, as discussed above, a POSITA would have recognized or found obvious that Mualla, Shirani, and Saito all strive to achieve similar goals in spatial

image approximation, and in correspondence with that, a POSITA would have had a reasonable expectation of success in combining Saito's techniques into Mualla-Shirani. For example, both Shirani and Saito strive to improve reconstruction of high-frequency edges and discontinuities in an image. *See, e.g.*, APPLE-1006, 5 (explaining a key goal of Shirani's second-stage spatial error concealment is to improve "reconstruction quality, particularly in retrieving the edges and in the areas of the frame that correspond to adjacent missing blocks."), and 7 (describing that a "performance advantage is demonstrated in the blocks that contain edges"); and APPLE-1007, 1 (explaining that Saito's techniques "can distinguish intrinsic singularities in the data from the artificial discontinuities created by the local windowing"), 2 (explaining that a goal of Saito's techniques is to avoid "artificial discontinuities due to the local windowing or the brute-force periodization so that we can focus on the analysis of intrinsic discontinuities and singularities in the signal"), 4 (explaining that Saito's techniques "can distinguish intrinsic singularities in the data from the artificial discontinuities created by the local windowing").

92. As discussed above, Saito's PHLCT technique ensures that the derivative of the estimated signal at a boundary of a block is equal to the derivative of the signal to be estimated at the boundary. APPLE-1007, 27; *see also* 5, Abstract; *see above* §VI.C. A POSITA would have understood or found obvious that this is consistent with Shirani's "second stage" technique generating a "refined initial estimate" that has border

pixel values with a “border error” that is equal to the “border error” of the “initial estimate” that was generated in Shirani’s “first stage.” APPLE-1006, 1, 3; APPLE-1007, 27; *see also* 5, Abstract. Shirani’s “border error” is equivalent to Saito’s “derivative at the boundary” (which is equivalent to the ’025 patent’s “gradient” value at a boundary) because both Shirani’s “border error” and Saito’s “derivative at the boundary” are equal to a difference of adjacent pixel values across a border/boundary between two blocks. Furthermore, a POSITA would have understood or found obvious that because Saito’s PHLCT technique can achieve a faster “decay rate” for the error signal at the boundaries of blocks, this is consistent with Shirani’s goal of “improv[ing] the video reconstruction quality” by ensuring that “image continuity inside the block and across its boundaries is preserved.” APPLE-1007, 27; APPLE-1006, Abstract, 3.

93. As explained below in more detail, combining Mualla-Shirani and Saito would have been obvious at least because such a combination would have merely involved (1) combining prior art elements according to known methods to yield predictable results; and the (2) use of known techniques to improve similar devices in the same way.

94. In the resulting combination of Mualla, Shirani, and Saito, if no errors are detected in a frame of video, then conventional motion compensation is applied to the frame “to provide a prediction of the current frame,” as taught by Mualla and Shirani.

APPLE-1005, 27, Figure 1.1, 115-116; APPLE-1006, Abstract 2-3. Otherwise, if an error is detected in one or more blocks of a frame, then a motion-compensated two-stage hybrid error concealment technique is applied to the frame. The “first stage” applies Shirani’s “temporal” concealment to find a block X_i in the previous frame with border pixels that have the smallest sum of “border errors” relative to surrounding blocks, as taught by Shirani. APPLE-1005, 242-245; APPLE-1006, 1-3. The resulting block X_i is an “initial estimate” of the erroneous/missing block.

95. Then, the “second stage” of the Mualla-Shirani two-stage hybrid error concealment technique refines the “initial estimate” X_i by applying “spatial” concealment in which “the information around each missing block” is utilized to estimate pixels values in the interior of the estimated block X_i . APPLE-1005, 242-245; APPLE-1006, 1-3. Here, the second-stage spatial concealment of Mualla-Shirani is modified to implement Saito’s PHLCT to interpolate the interior pixels of the Mualla-Shirani initial estimate X_i . In particular, the second-stage spatial concealment obtains a solution to Poisson’s equation with Neumann boundary conditions equal to the normal derivatives at boundaries of the missing block (as taught by Saito). These normal derivatives at the boundaries are based on Shirani’s “border errors” that were obtained in Shirani’s first stage. As a result, the Mualla-Shirani-Saito combination uses a Poisson-equation-solving image approximation technique (e.g., PHLCT as taught in Saito) to implement spatial error concealment in the second stage of the Mualla-Shirani two-

stage hybrid error concealment technique, thereby generating a refinement of the “initial estimate” that was obtained in Shirani’s first stage. The result is an estimated frame in which erroneous/missing blocks have been concealed. A POSITA would have recognized and found obvious that Saito’s image approximation techniques based on solving Poisson’s equation would have enhanced Shirani’s “second stage” techniques, “improv[ing] the video reconstruction quality” in order to achieve similar goals of image approximation. APPLE-1007, 27; APPLE-1006, Abstract, 3.

96. Furthermore, as discussed above, the modified two-stage hybrid error concealment of the Mualla-Shirani-Saito combination is implemented in both the encoder and the decoder, as taught by Mualla, so that the encoder and decoder can “cooperate to minimize the effects of transmission errors” and in particular so that “coding efficiency can also be improved by performing error concealment in the encoder so that both encoder and decoder use the same reference frames for prediction.” APPLE-1005, 246-250.

G. The combination of Mualla, Shirani, Saito, and Shimizu

97. As discussed above, the combination of Mualla, Shirani, and Saito in Ground 1A (and the combination of Mualla-Stockhammer-Shirani and Saito in Ground 1B) implements a two-stage hybrid error concealment technique where in the first stage, an “initial estimate” X_i of the erroneous/missing block is generated using “temporal” error concealment and then, the second stage refines the initial estimate X_i by applying

“spatial” concealment in which “the information around each missing block” is utilized to estimate pixels values in the interior of the estimated block X_i (as taught by Mualla-Shirani). APPLE-1005, 242-245; APPLE-1006, 1-3. The Mualla-Shirani-Saito combination uses a Poisson-equation-solving image approximation technique (e.g., PHLCT, as taught by Saito) to implement the spatial error concealment in the second stage of the two-stage hybrid error concealment technique.

98. Furthermore, a POSITA would have understood that error resilience techniques, such as the Mualla-Shirani-Saito hybrid two-stage motion-compensated technique discussed above, are not limited to error-prone environments, but can also be used to enhance coding performance in error-free environments. APPLE-1009, 10 (explaining “the tools for increased **error resilience**, in particular those to limit error propagation, do not significantly differ from those used for compression efficiency. Features like multiframe prediction or intra MB coding are **not exclusively error-resilience** tools. They are **also** used to **increase coding efficiency** in **error-free** environments providing a **trade-off** that is left to the encoder”). In particular, Mualla notes the similarities between motion compensated prediction (for error-free environments) and temporal concealment (for error resilience), explaining that “[a]s in motion-compensated prediction, the process of temporal concealment involves two stages: concealment displacement estimation and displacement compensation, as

shown in Figure 9.8(a). For this reason, temporal concealment is sometimes referred to as motion-compensated concealment.” APPLE-1005, 243.

99. Indeed, a POSITA would have understood that the Mualla-Shirani-Saito hybrid 2-stage motion compensated predictor using a Poisson-equation-solving image approximation technique could naturally operate as a motion compensated predictor in error-free environments (as suggested by Mualla and corroborated by Stockhammer, above) because it requires similar inputs (motion vectors and a reference picture stored in frame memory) as a motion compensated predictor to generate similar outputs (a predicted picture). Further, a POSITA would have understood that Poisson approximation techniques, as disclosed in Saito, are not limited to error concealment but instead is more generally applicable to “image approximation” with a goal of improving “the perceptual quality of these approximations” and a desire for a “perceptually correct metric” that can improve the “visual quality” of approximated images. APPLE-1007, 6, 18, 27. As explained above, numerous research papers and patents had, several years before the Critical Date, described techniques for image editing and image reconstruction that involved solving Poisson’s equation. *See e.g.*, Perez, APPLE-1010, Raskar, APPLE-1012, Sun/Sun-128, APPLE-1013 and APPLE-1014, and Fattal, APPLE-1015. Therefore, a POSITA would have understood and found obvious that Saito’s Poisson approximation technique, as implemented in the

second stage of the Mualla-Shirani hybrid 2-stage prediction, is also applicable to general motion compensated prediction, even in an error-free environment.

100. Thus, a POSITA would have understood that error resilience techniques, such as the Mualla-Shirani-Saito hybrid two-stage motion-compensated technique described above, could also be used in error-free environments to improve coding efficiency. In particular, a POSITA would have understood and found obvious that a coding system could utilize an error resilience technique, such as the Mualla-Shirani-Saito hybrid two-stage motion-compensated technique, as an alternative to conventional motion compensated prediction to achieve a desired trade-off of performance metrics such as coding efficiency.

101. Shimizu describes details of how to implement a system to adaptively achieve such a trade-off. As discussed in section VI.D, above, Shimizu discloses a coding system that dynamically selects, on a per-block basis, between two different motion compensation techniques and Shimizu further explains that this technique can “reduce the amount of generated code with respect to the motion vector” and thus “improve the efficiency of the motion-vector prediction.” APPLE-1024, ¶[0046]. In particular, Shimizu’s system selects between (i) a conventional motion compensation technique that obtains motion vectors for each macroblock and generates predicted pictures for the motion vector and (ii) an alternative motion compensation technique that operates on individual pixels to provide a global motion compensation over a larger

area. Furthermore, a POSITA would have understood that Shimizu's alternative motion compensation technique ("global motion compensation") was also a well-known error resilience technique. *See e.g.*, Salama, APPLE-1025, 1, as disclosing "[e]rror concealment of shape using global motion compensation" and Soares, APPLE-1026, 2, as disclosing "[g]lobal motion compensation concealment").

102. Therefore, in view of the knowledge in the art that error resilience techniques (such as the Mualla-Shirani-Saito hybrid two-stage motion-compensated technique) could also be used in error-free environments as an alternative to conventional motion compensation, and in view of Shimizu's teaching of a system that adaptively selects between conventional motion compensation and an alternative motion compensation to "reduce the amount of generated code with respect to the motion vector" and thus "improve the efficiency of the motion-vector prediction," and a POSITA would have found it obvious to implement a hybrid 2-stage motion compensated predictor using a Poisson-equation-solving image approximation technique (as taught by Mualla-Shirani-Saito) in Shimizu's system in error-free environments to switch/select between (i) the hybrid 2-stage motion compensated prediction and (ii) the conventional motion compensated prediction.

103. The modified portions of Mualla's encoder (in Fig. 1.1) are shown in Diagram E, below, where the components added to Mualla's encoder are annotated in red (based on annotated Fig. 11 of Shimizu that includes the Mualla-Shirani-Saito hybrid

2-stage motion compensated predictor to facilitate explanation). APPLE-1005, Fig. 1.1.

As shown, the modification simply amounts to adding two components to Mualla's encoder: (i) a hybrid 2-stage motion compensated predictor using a Poisson-equation-solving image approximation technique (as taught by Mualla-Shirani-Saito, annotated in red) and (ii) an encoding mode selector 42 (as taught by Shimizu, annotated in red) that selects between Mualla's conventional motion compensation/estimation (annotated in blue and green) and the hybrid 2-stage motion compensated predictor of Mualla-Shirani-Saito.

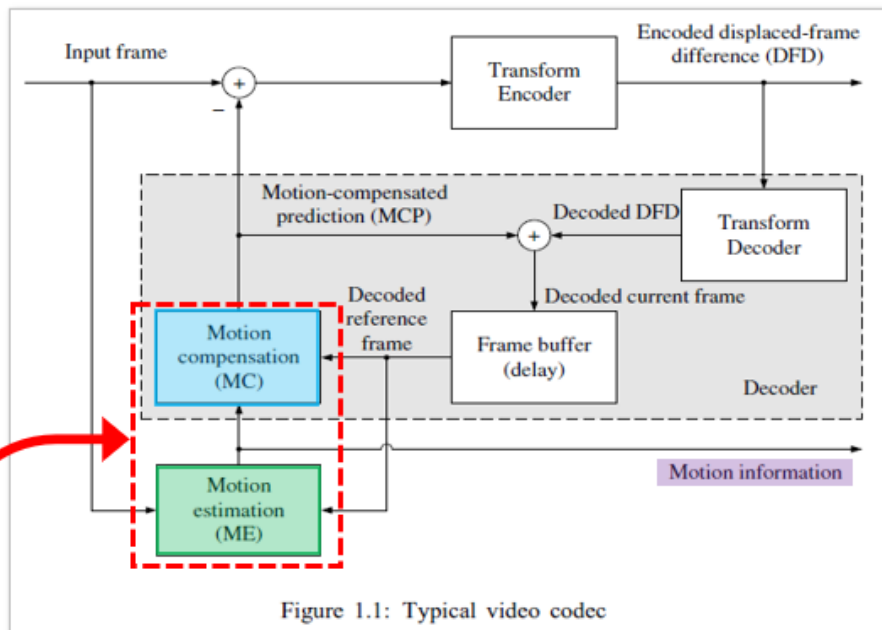
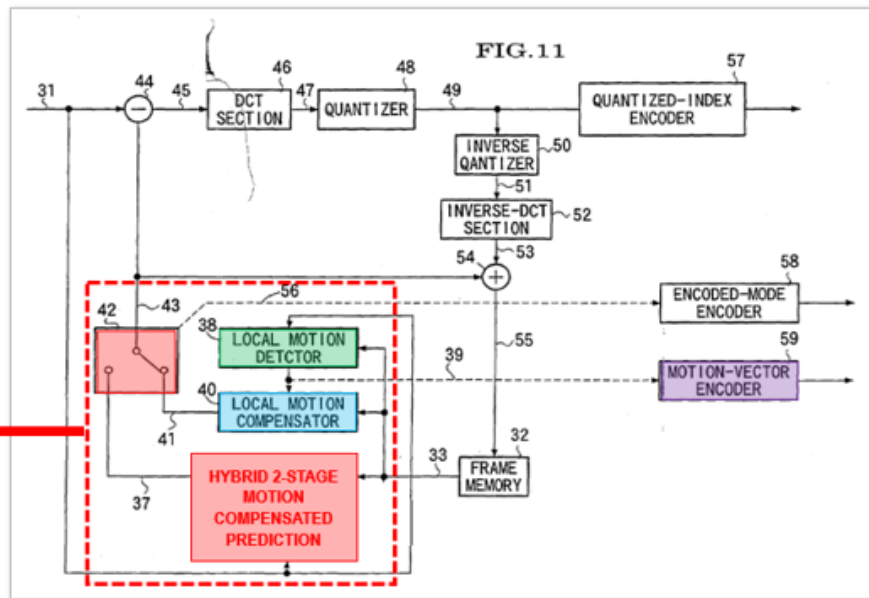


Diagram E (encoder with selective motion compensation/estimation)

104. In Mualla's modified encoder, the hybrid 2-stage motion compensation predictor operates using the basic principles described in sections VI.E-F, namely by implementing a "first stage" that applies Shirani's "temporal" concealment to find a

block X_i in the previous frame with border pixels that have the smallest sum of “border errors” relative to surrounding blocks, as taught by Shirani. APPLE-1005, 242-245; APPLE-1006, 1-3. The resulting block X_i is an “initial estimate” of the block to be decoded. Then, the “second stage” refines the “initial estimate” X_i by applying “spatial” concealment in which “the information around” the block to be decoded is utilized to estimate pixels values in the interior of the initially estimated block X_i . APPLE-1005, 242-245; APPLE-1006, 1-3. Here, the second-stage spatial concealment of Mualla-Shirani is modified to implement Saito’s PHLCT to interpolate the interior pixels of the Mualla-Shirani initial estimate X_i .

105. An analogous modification would be made to Mualla’s decoder, as shown in Diagram F, below (based on annotated Fig. 12 of Shimizu that includes the Mualla-Shirani-Saito hybrid 2-stage motion compensated predictor to facilitate explanation), by adding: (i) a hybrid 2-stage motion compensated predictor using a Poisson-equation-solving image approximation technique (as taught by Mualla-Shirani-Saito) and (ii) a switch 71 (as taught by Shimizu) that receives encoded-mode choice information 56 from the encoder and selects between Mualla’s conventional motion compensation/estimation and the hybrid 2-stage motion compensated predictor of Mualla-Shirani-Saito. APPLE-1024, [0035], FIG. 12.

FIG.12

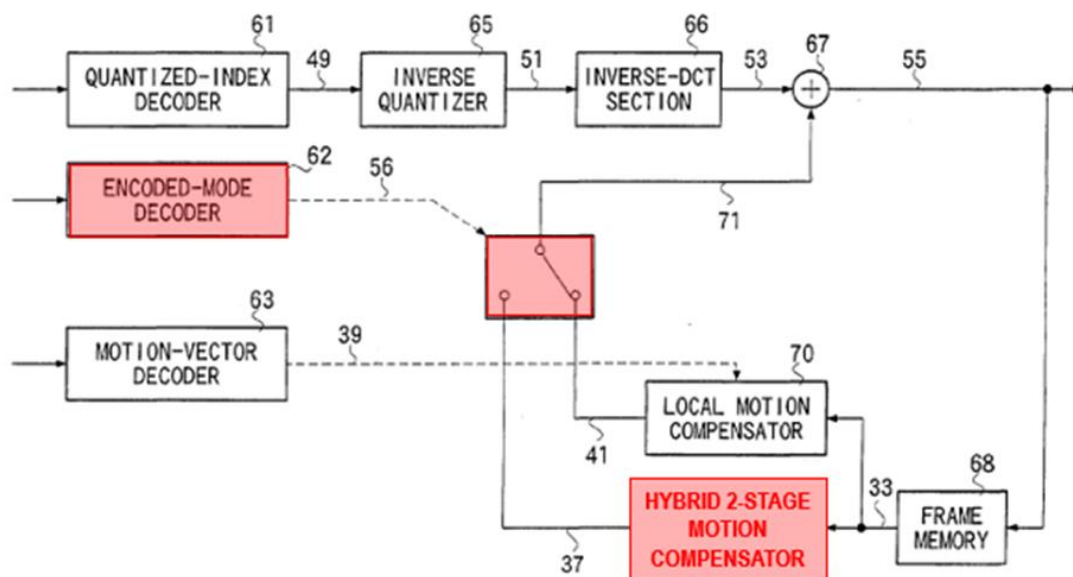


Diagram F (decoder with selective motion compensation/estimation)

106. As explained below in more detail, combining Mualla-Shirani-Saito-Shimizu (with or without the error-resilience details of Stockhammer) would have been obvious at least because such a combination would have merely involved (1) combining prior art elements according to known methods to yield predictable results; and the (2) use of known techniques to improve similar devices in the same way.

107. In view of the applicability of the Shirani-Mualla-Saito hybrid 2-stage prediction technique to error-free motion compensated prediction, a POSITA would have recognized the advantages of further applying Shimizu's technique to select between the Shirani-Mualla-Saito hybrid 2-stage prediction technique and conventional motion compensated prediction, particularly because this is aligned with Mualla's goal

of minimizing information transmitted between encoder and decoder would have led to greater system efficiency. APPLE-1005, 40 (“The aim of video coding is to reduce, or compress, the number of bits used to represent video”), 90 (“The radio spectrum is a limited and scarce resource. ... Given the enormous amount of data generated by video, the use of efficient coding techniques is vital. One of the most important factors that decide the coding efficiency of a video codec is the motion estimation and compensation technique”). Using this knowledge, a POSITA would have been motivated to apply Shimizu’s techniques of selecting between two different forms of motion compensation to the Mualla-Shirani-Saito system to select between (i) conventional motion compensation and (ii) the Mualla-Shirani-Saito hybrid 2-stage motion compensation.

108. In the resulting combination of Mualla, Shirani, Saito, and Shimizu, the encoder would have produced two predictive pictures—one using conventional motion compensation and one using hybrid 2-stage motion compensated prediction—and compared the results to determine which picture produced the most efficient result (as disclosed in Shimizu, e.g., “reduce the amount of generated code with respect to the motion vector” and thus “improve the efficiency of the motion-vector prediction”). APPLE-1024, ¶¶[0032], [0037], [0046], [0058]-[0059]. The encoder would notify the decoder of this selection, through the encoded-mode choice information 56 which controls the decoder’s switch 71. APPLE-1024, ¶¶[0032], [0035]. In the scenario of

error-free operation, the hybrid 2-stage motion compensated prediction of Mualla-Shirani-Saito would generate predictions of blocks to be encoded/decoded, rather than blocks that are missing/erroneous.

109. As explained above, A POSITA would have understood and found obvious that Shimizu's techniques of reducing the amount of generated code would aligned with Mualla's goal of reducing the number of bits used to represent video by using efficient coding techniques. For example, Shimizu's techniques of comparing the results of two different motion compensation techniques would have reduced the amount of information transitted by the encoder, allowing the combined system to more efficiently encode information and make the most of precious bandwidth—motivations that are echoed by Mualla. APPLE-1024, ¶¶[0032], [0037], [0046], [0058]-[0059].

VI. Ground 1A/1B – Claims 1-10 are Obvious under 35 U.S.C. § 103 based on Mualla, Shirani, and Saito (1A) and Mualla, Shirani, Saito, and Stockhammer

A. Analysis³

110. In my opinion, a person of ordinary skill in the art would have found claims 1-10 of the '025 patent to have been obvious based on Mualla, Shirani, and Saito, and additionally based on Mualla, Shirani, Saito, and Stockhammer.

³ Although my discussion in this section focuses on the combination of Mualla-Shirani-Saito, it is similarly applicable to the combination of Mualla-Stockhammer-Shirani-Saito in Ground 1B, with Stockhammer supplementing Mualla merely to

111. As an initial matter, the '025 Patent includes claims that recite both encoding and decoding operations (despite the claim being directed to an “encoding” or “decoding” apparatus by the preamble). *See, e.g.*, APPLE-1006, Claim 6. To indicate which limitations include predominately encoding or decoding steps, I have added the annotations of COD (“encoding”) and DEC (“decoding”) to the title of each claim limitation. This annotation is solely an aide to the reader and should not be viewed as an argument that a limitation discloses only one operation or the other.

1. “Moving picture decoding” claims 6-8, and 10;

[6.pre] A moving-picture decoding apparatus comprising:

112. Mualla teaches extensive details of an H.263-based video codec system, which implements a ***decoding apparatus*** for decoding ***moving pictures*** (e.g., “video”). APPLE-1005, 23-26, 31, 36, 51-52, 227-228, 241-242, 265. For example, in describing “Transform Coding” which “forms the basis of almost all video coding standards,” Mualla describes a ***decoder*** implemented in a “transform coding system.” APPLE-1005, 51 (last paragraph), Figure 2.9 (reproduced below). As another example, in describing techniques for “error resilience” in video coding systems, Mualla discloses a ***decoder*** implemented in a “typical video communication system.” APPLE-1005, 227-228, Figure 9.1 (reproduced below).

provide illustrative details of implementing what a POSITA would have understood or found obvious to already be taught by Mualla’s error concealment disclosure.

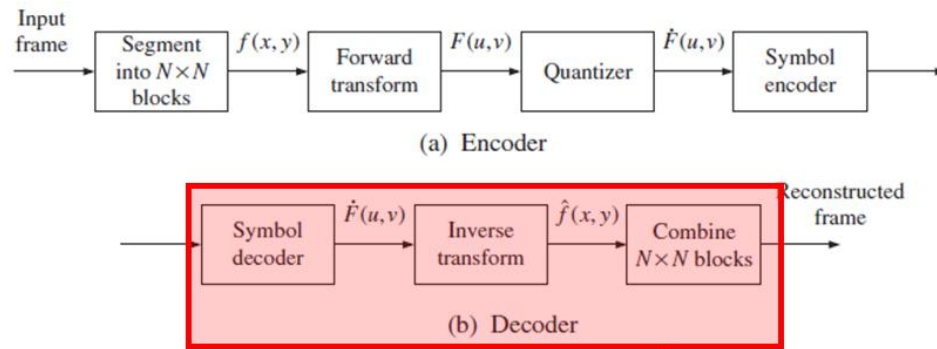


Figure 2.9: Block diagram of a transform coding system

A “moving-picture
decoding apparatus”

APPLE-1005, FIG. 2.9 (annotated and color added).

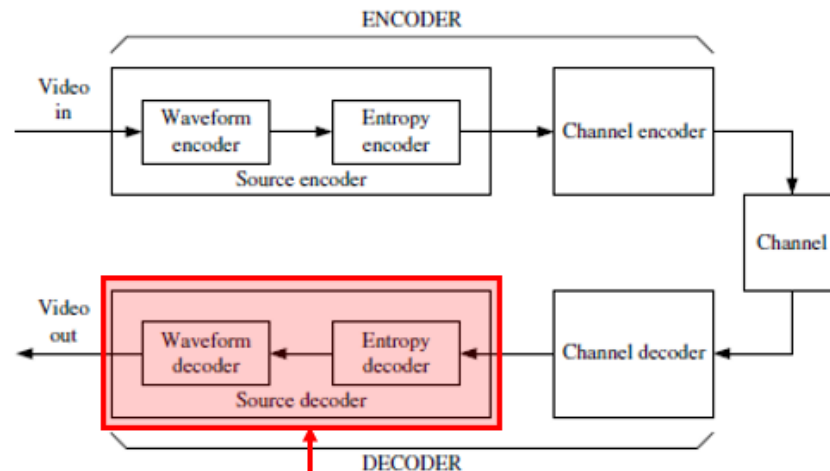


Figure 9.1: Typical video communication system

A “moving-picture
decoding apparatus”

APPLE-1005, FIG. 9.1 (annotated and color added).

113. Shirani similarly discloses using the H.263-based video codec system and its associated *decoding apparatus*. APPLE-1006, 2-4 (“[w]hen channel errors occur, **the decoder** usually discards the erroneous data”), 4 (“H.263”).

[6.1.DEC] a demultiplexer to demultiplex coded data from an input signal based on a specific syntax structure,

114. Shirani discloses that “[c]oded video information [(“*coded data from an input signal*”)] is first grouped into packets” and the “video packets are ... multiplexed with audio information” using an “H.223 multiplexing” protocol. APPLE-1006, 5. Multiplexing video packets at an encoder would have required a means for “*demultiplex[ing]*” the video packets at the decoder, for example, by using a *demultiplexer*. Indeed, the H.263 standard (the standard used by Mualla and Shirani) corroborates the use of demultiplexers in H.263 codecs for “*demultiplex[ing] coded data from an input signal.*” APPLE-1016, 2.

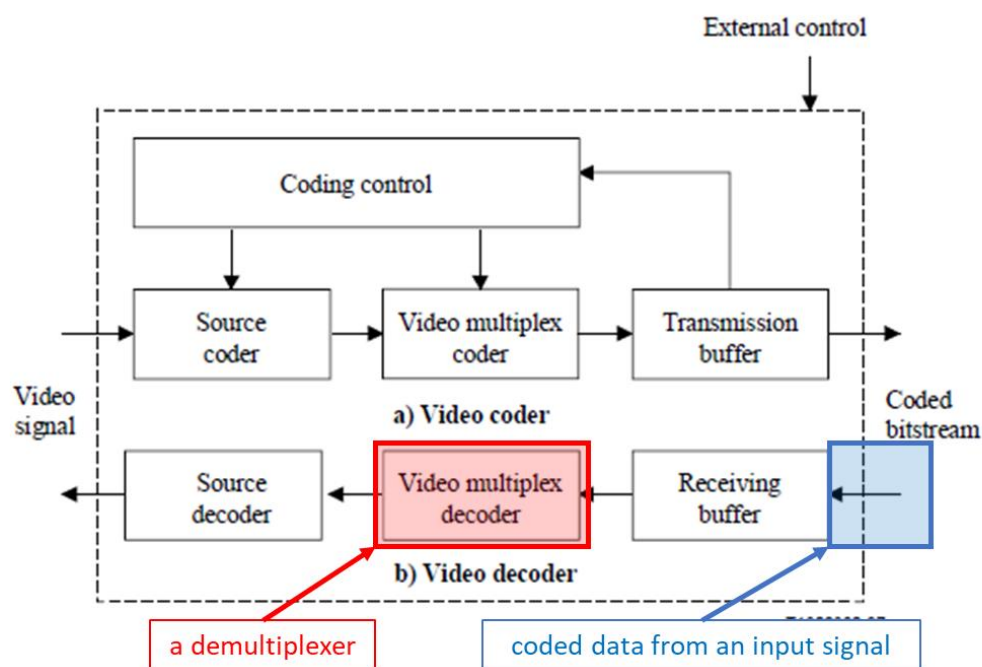
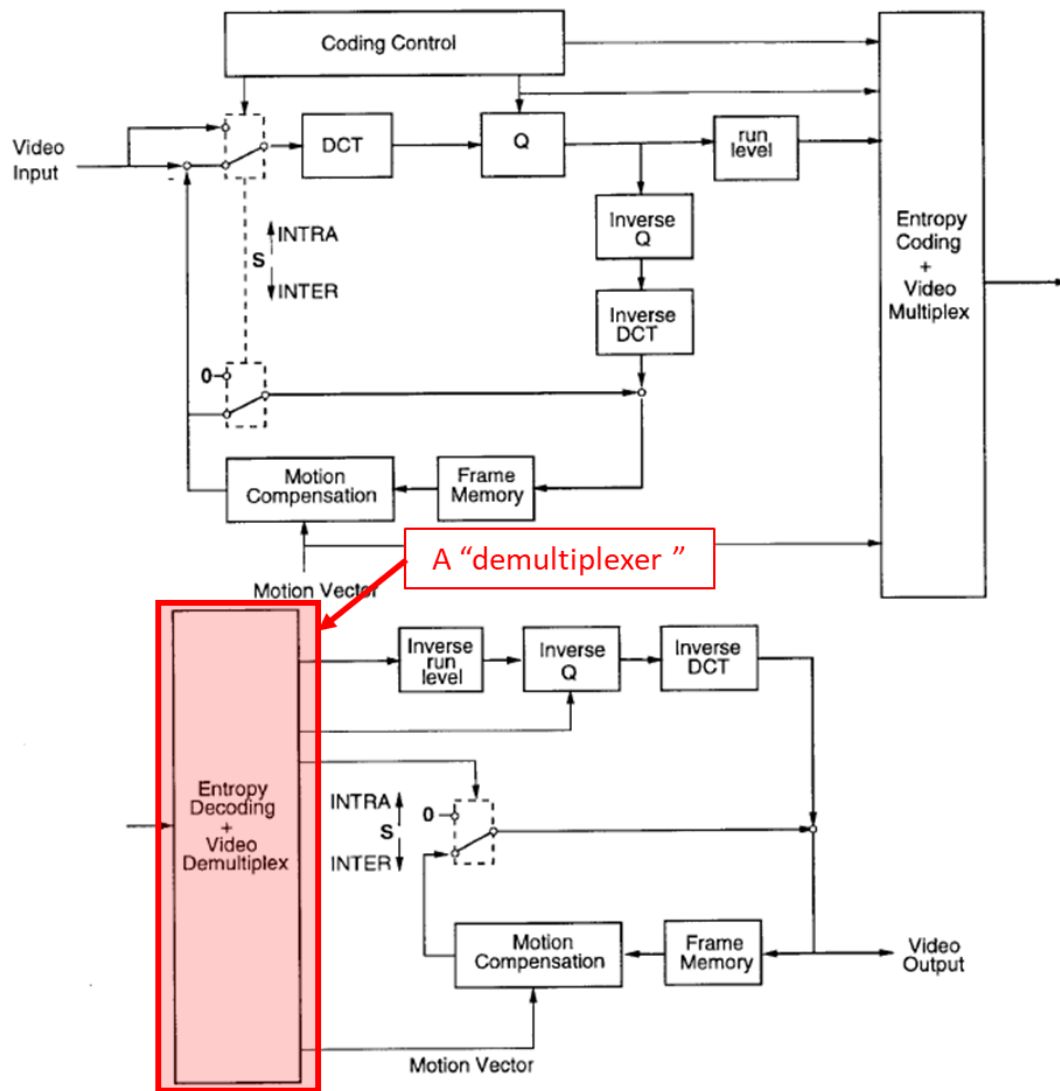


Figure 1/H.263 – Outline block diagram of the video codec

APPLE-1016, FIG. 1 (annotated and color added).

115. Additionally, Girod – a H.263 codec reference cited by Mualla as reference 201 – discloses that information is “multiplexed to the video bitstream.” APPLE-1008, 2, FIG. 1(b). FIG. 1(b) illustrates an example decoder with a “*demultiplexer*.”



APPLE-1008, FIG. 1(a) (“encoder”) and 1(b) (“decoder”) (annotated and color added).

116. Furthermore, Mualla and Shirani both disclose the H.263 *specific syntax structure*. APPLE-1005, 93, 232; APPLE-1006, 2, 4-5. Indeed, Mualla refers to the

H.263 codec standard as “the ***syntax*** of H.263.” APPLE-1005, 93. Mualla and Shirani also both use the specific syntax structure of the H.263 codec standard as a gauge for detecting errors in a video bitstream. APPLE-1005, 231-232; APPLE-1006, 2. For example, Mualla’s process of “error correction” uses “***syntax*** ... violations” to detect errors in a video bitstream. APPLE-1005, 231-232. Shirani discloses a similar process where a decoder determines the “location of missing blocks” by “detecting ... semantic or ***syntactic*** violations.” APPLE-1006, 2.

[6.2.COD] the input signal being obtained by multiplexing a coded bitstream obtained by predictive coding, border motion-vector data and post-quantization data obtained by quantization in the predictive coding,

117. As described above in 6.1.DEC, Shirani discloses ***multiplexing a coded bitstream***, and a POSITA would have understood or found obvious that the H.263 codec standard, as used in Mualla and Shirani, included ***multiplexing*** operations. APPLE-1006, 5; *see above*, [6.1.DEC]. Indeed, the H.263 standard discloses multiplexing and demultiplexing a “***coded bitstream***.” APPLE-1016, 2, 9.

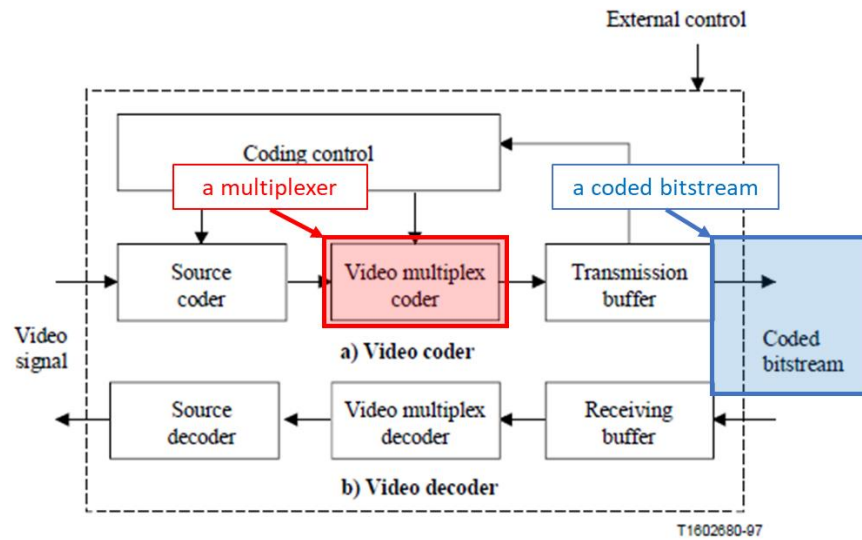


Figure 1/H.263 – Outline block diagram of the video codec

APPLE-1016, FIG. 1 (annotated and color added).

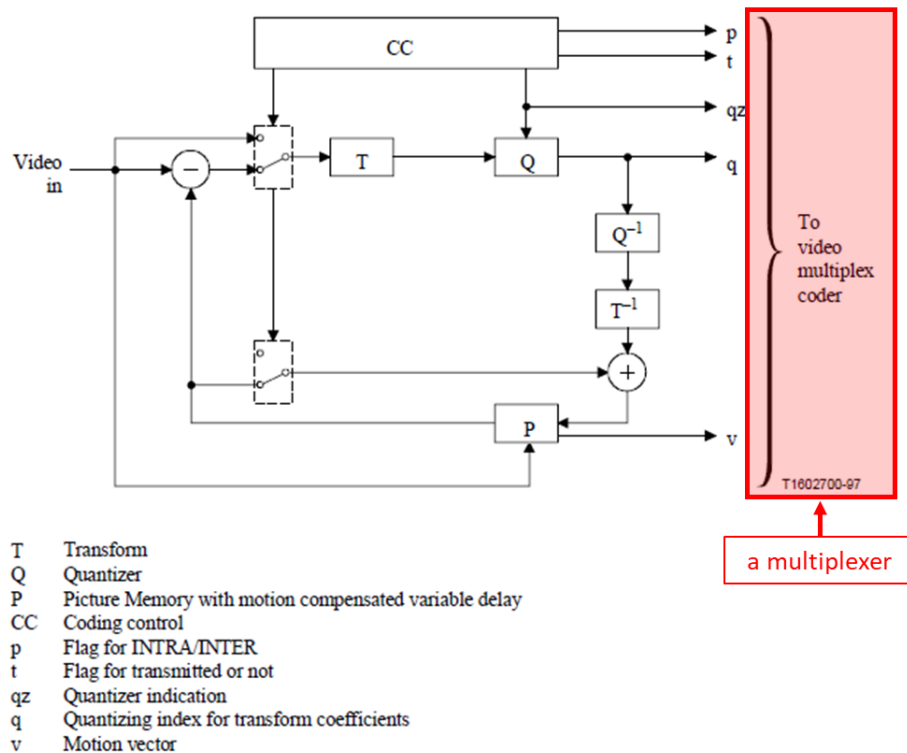


Figure 3/H.263 – Source coder

APPLE-1016, FIG. 3 (annotated and color added).

118. Furthermore, as shown in Mualla's Figure 3.1 and explained in further detail below, a POSITA would have understood or found obvious, based on the teachings of Mualla, that the coded bitstream is obtained by encoding motion vectors (which include the claimed "***border motion-vector data***") and a quantization index (the claimed "***post-quantization data***"), along with various coding control information. APPLE-1005, Figure 3.1 (reproduced below), 71-75.

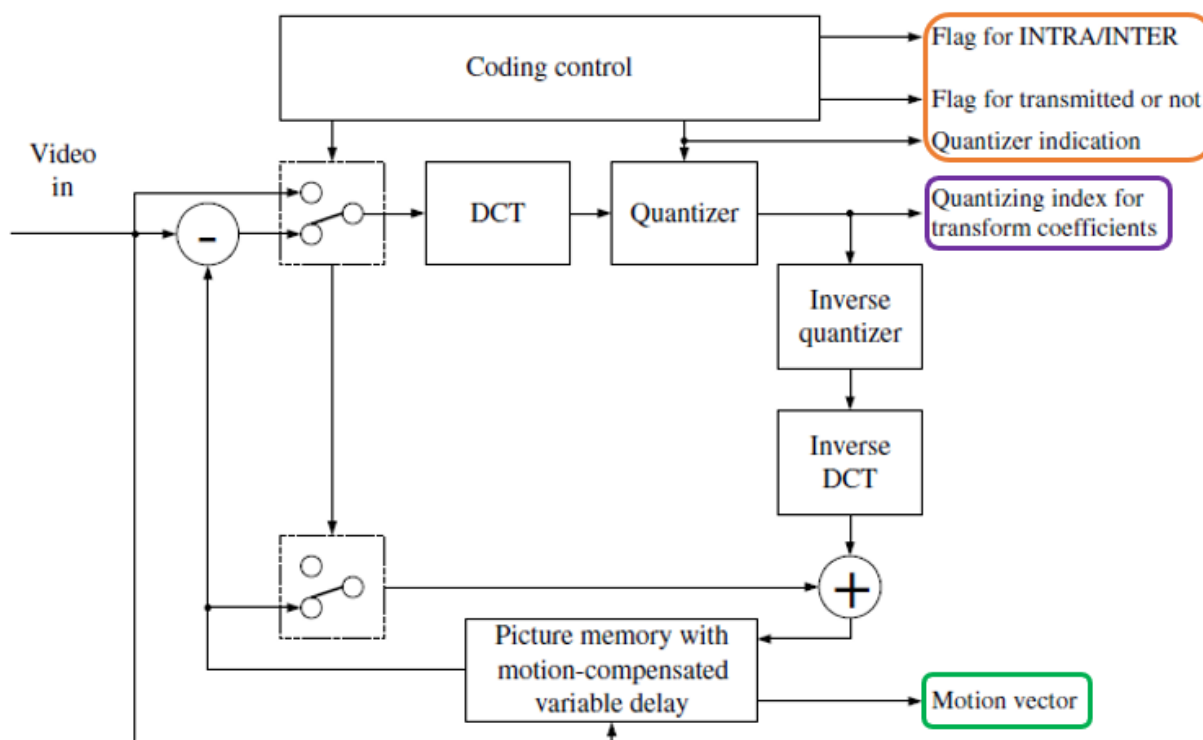


Figure 3.1: H.263 video encoder

APPLE-1005, Figure 3.1 (annotated).

...obtained by predictive coding

119. Mualla describes numerous operations at the encoder that perform predictive coding. For example, Mualla discloses a "video codec" that includes a

“motion estimation (ME) block ... to estimate the movement that occurred between the current frame and a reference frame.” APPLE-1005, 26-27, 115-117, FIG. 1.1. Mualla refers to this estimation as “motion information.” *Id.* Motion information is then “utilized by the motion compensation (MC) block to move the contents of the reference frame to provide a prediction of the current frame” (“*predictive coding*”) which Mualla also refers to as the “motion-compensated prediction (MCP).” *Id.* Mualla refers to “motion compensated prediction” as a type of “predictive coding” in which regions of an input frame are predictively coded “with respect to the corresponding regions in the reference frame.” APPLE-1005, 61. Mualla’s “typical video codec” illustrates these components.

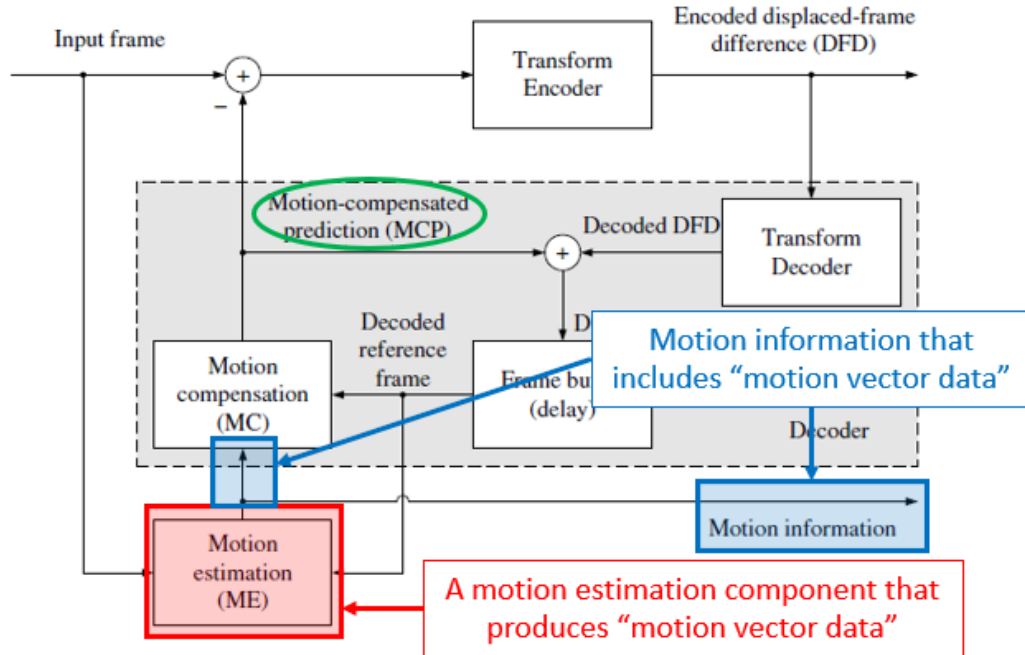


Figure 1.1: Typical video codec

APPLE-1005, FIG. 1.1 (annotated and color added).

120. As another example of predictive coding, Mualla discloses that the “motion information” (motion vector) itself is predictively coded. Mualla discloses that the “motion of the [a] current block” (e.g., the motion information) is “represented by a motion vector” (“*motion-vector data*”) which is the “displacement between the block and its best-match block in the reference frame.” APPLE-1005, 62, FIG. 2.16. An example motion vector is illustrated by Mualla in FIG. 2.16 below.

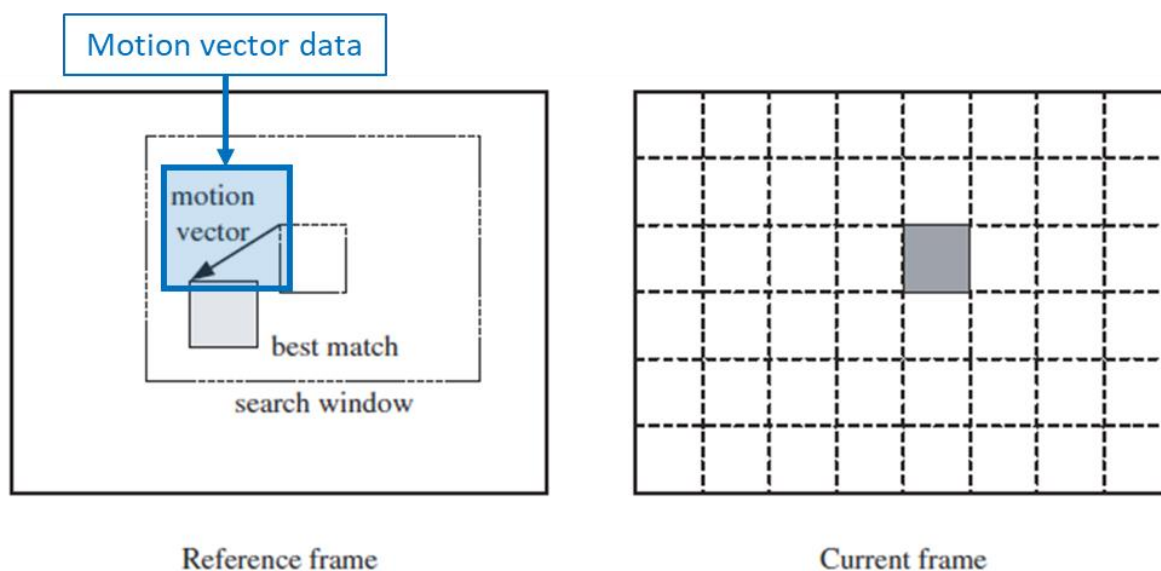


Figure 2.16: Block-matching motion estimation

APPLE-1005, FIG. 2.16 (annotated and color added).

121. Mualla discloses that the “estimated motion vector” is “predictively coded” (part of “*a coded bitstream obtained by predictive coding*”), meaning that the “motion vector difference $MVD = MV - MVP$ is encoded instead of the motion vector itself.” APPLE-1005, 74, *see also* 115-117. The MVP is “the median of three candidate predictors, which are the motion vectors of three surrounding macroblocks”

(“a motion vector from a border of the rectangular zone”). One example of this grouping of motion vectors is annotated in Mualla’s FIG. 3.3.

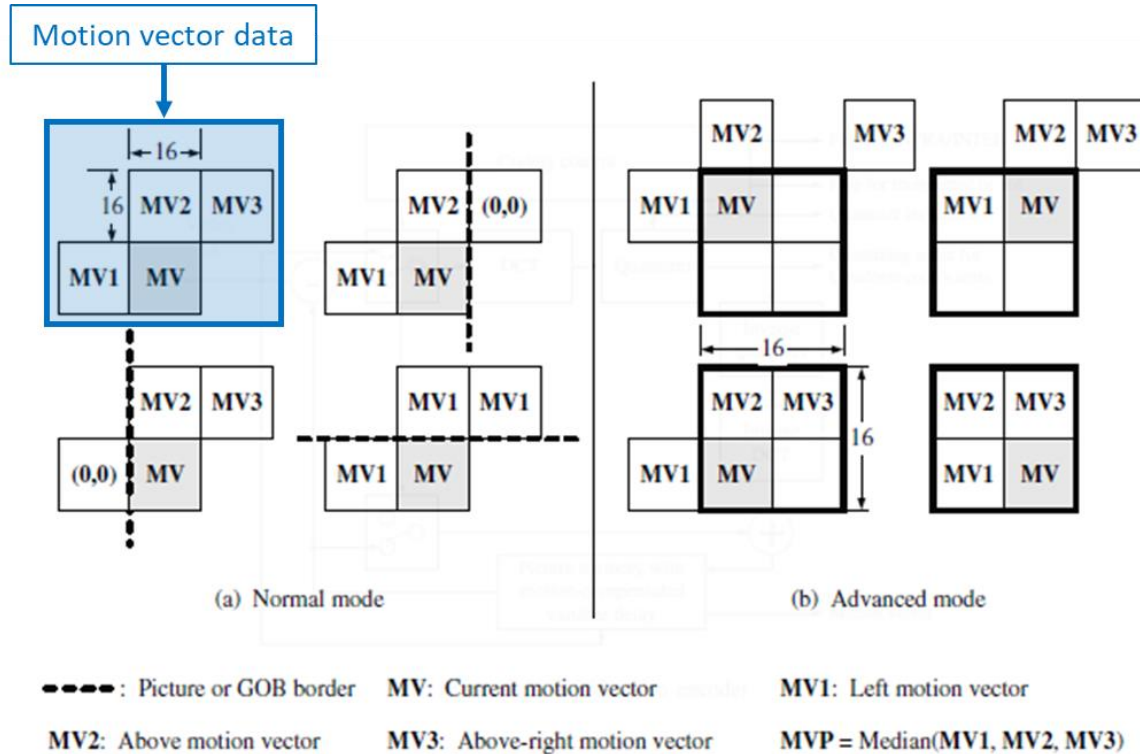


Figure 3.3: H.263 motion vector prediction

APPLE-1005, FIG. 3.3 (annotated and color added).

border motion-vector data

122. As an initial matter, the '025 patent describes “**border motion-vector data**” as “data on a motion vector from a border of the rectangular zone in the picture to be coded to the border of the reference picture thus found.” APPLE-1001, 2:59-61; *see below*, [6.6.COD].

123. As discussed above, the Mualla-Shirani-Saito combination implements a two-stage hybrid error concealment in the encoder (as well as the decoder), as taught

by Mualla. APPLE-1005, 246-250. In particular, the encoder of the Mualla-Shirani-Saito combination implements the first-stage of Shirani's two-stage error concealment technique to the motion of a missing/erroneous macroblock by performing temporal concealment. *See above*, VI.B, E. Notably, in the combination, Shirani's first stage uses motion vectors of neighboring blocks to obtain estimates of pixels at the borders of a missing block. *See above*, VI.B, E; APPLE-1006, 2-3. In particular, the first stage of Shirani estimates motion vectors of subblocks adjacent to the missing block, and in doing so, utilizes “candidate motion vectors” (“data on a motion vector”) which can include motion vectors of “neighboring blocks.” *See above*, VI.B, VI.D, VI.E; APPLE-1006, 2-3. These motion vectors of neighboring blocks are used to obtain an estimate of pixels at each border of the missing block (“***from a border of the rectangular zone in the picture to be coded***”), by minimizing the “squared sums of border errors” (in total, “***border motion-vector data***” or, “data on a motion vector from a border of the rectangular zone in the picture to be coded to the border of the reference picture thus found”). *Id.*

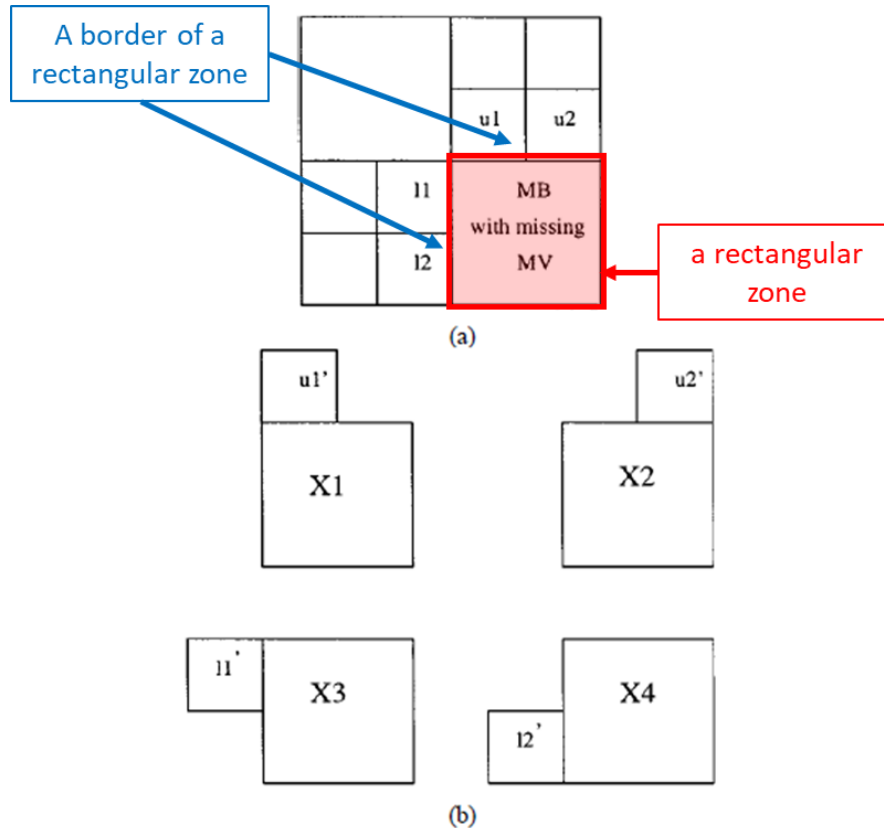


Fig. 1. (a) The four subblocks, (b) their corresponding subblocks in the previous frame, and the blocks connected to them.

APPLE-1005, FIG. 1(a) (annotated and color added).

124. As discussed above, after Shirani's first stage of the hybrid two-stage error concealment technique estimates the pixels at the borders of the missing block, the second stage of the Mualla-Shirani-Saito combination estimates the pixels in the interior of the missing block using Saito's technique for solving Poisson's equation with the border pixels (specifically, Shirani's "border errors" of the missing block) providing boundary conditions in Saito's techniques. *See above*, VI.E; see below [6.7.COD]. Therefore, because Shirani's first stage temporal concealment uses the motion vectors

of neighboring blocks to estimate only the motion of pixels at the border of the missing block, Shirani discloses the claimed “border motion vector data.”

post-quantization data obtained by quantization in the predictive coding

125. Mualla discloses that “quantization is a key element of a video coding system” and illustrates a “quantizer” in its example “video encoder” and “transform coding system.” APPLE-1005, 40-42, 52, FIGS. 2.3, 2.9, 3.1. Mualla discloses that, in “transform coding” (also known as “DCT coding”), “coefficients can be quantized according to their visual importance” (“*post-quantization data*”). APPLE-1005, 52, 75.

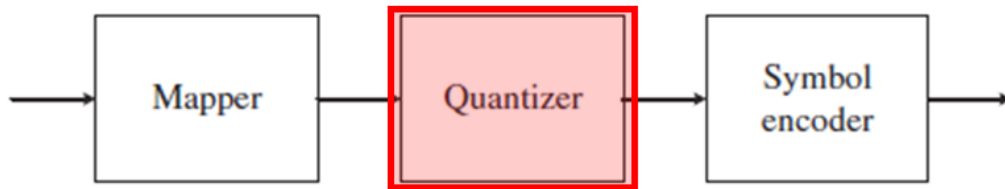


Figure 2.3: Elements of a video encoder

APPLE-1005, FIG. 2.3 (annotated and color added).

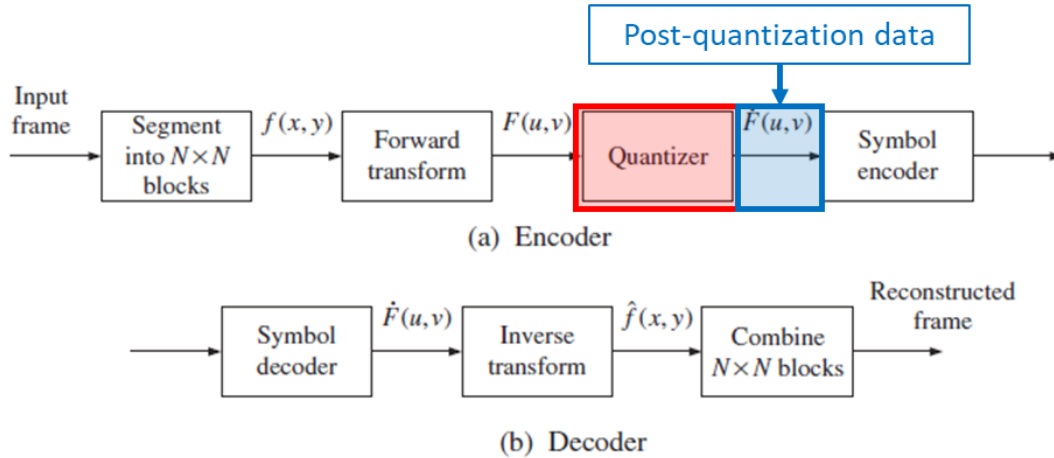


Figure 2.9: Block diagram of a transform coding system

APPLE-1005, FIG. 2.9 (annotated and color added).

126. In particular, Mualla discloses that these coefficients are derived by obtaining a “displaced frame difference (DFD)” that represents “the coded prediction error signal” (“*the predictive coding*”). APPLE-1005, 61, FIG. 2.15. The DFD signal can be coded “using any of the intraframe coding methods discussed in Section 2.6” and “the most commonly used method is transform coding, in particular block-based DCT transform coding.” APPLE-1005, 62. Mualla discloses that the DCT transform “is applied to the DFD values” and that this “results in ... transform coefficients for each [macro block].” APPLE-1005, 74. These coefficients are then “quantized using a uniform scalar quantizer” (“*post-quantization data obtained by quantization in the predictive coding*”). APPLE-1005, 75, FIG. 3.1. This process is illustrated in Mualla’s example “H.263 video encoder.”

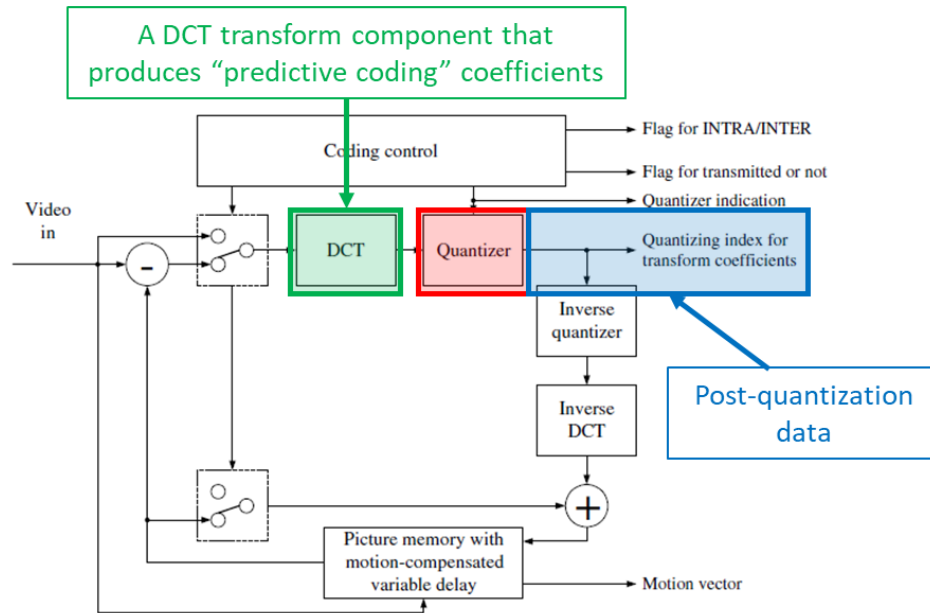


Figure 3.1: H.263 video encoder

APPLE-1005, FIG. 3.1 (annotated and color added).

[6.3.COD] the coded bitstream obtained by producing and encoding a residual picture that is a residual signal between a picture to be coded that is an input moving-picture video signal to be subjected to coding and a predictive picture produced from a reference picture that is a local decoded video signal for each of a plurality of rectangular zones, each composed of a specific number of pixels, into which a video area of the moving-picture video signal is divided,

127. As discussed above in [6.2.COD], Mualla's DFD represents "the coded prediction error signal" ("***residual picture that is a residual signal***") which is created by subtracting a "motion compensation prediction (MCP)," produced from the "reference frame" ("***a predictive picture produced from a reference picture that is a local decoded video signal***"), from the "current frame" ("***a picture to be coded that is an input moving-picture video signal to be subjected to coding***"). APPLE-1005, 26-27, FIG. 1.1. Mualla's "typical video codec" illustrates this process.

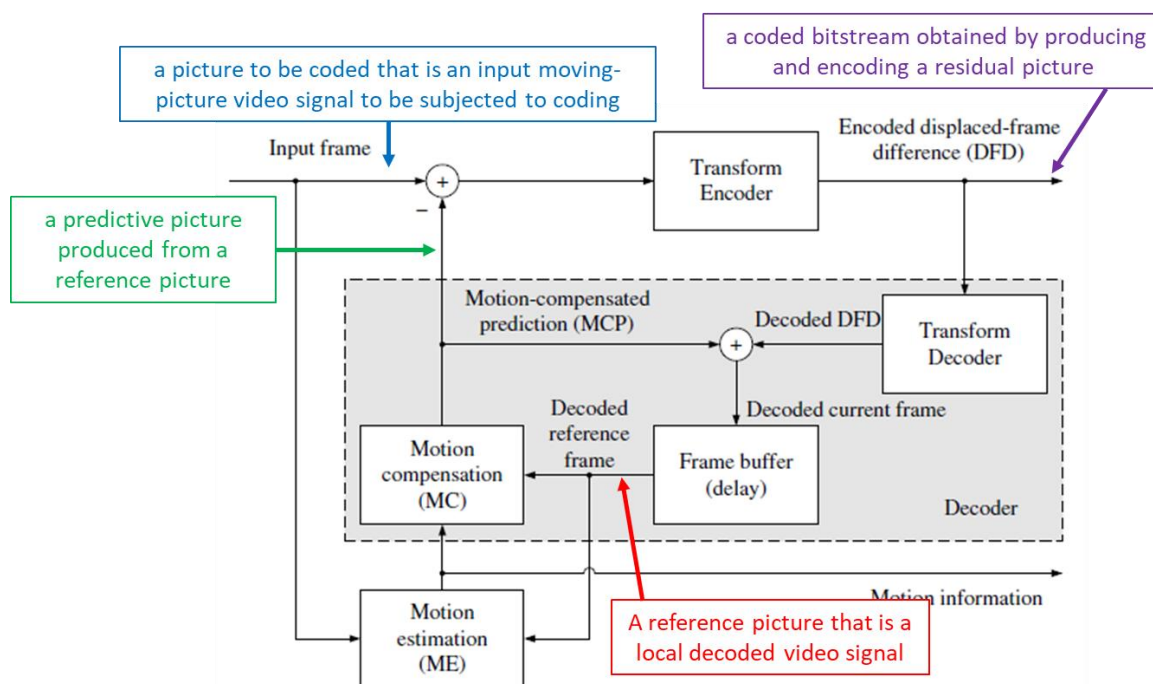


Figure 1.1: Typical video codec

APPLE-1005, FIG. 1.1 (annotated).

128. Mualla also discloses that an input video signal “consists of a sequence of pictures (or frames)” where “[e]ach picture is divided into groups of blocks (GOBs)” and each GOB “is divided into macroblocks (MBs)” (“*each of a plurality of rectangular zones*”). APPLE-1005, 71-72. These MBs are further divided into individual “pixels,” or “pels” (“*each composed of a specific number of pixels, into which a video area of the moving-picture video signal is divided*”). APPLE-1005, 36, 71-72, FIG. 3.2. FIG. 3.2 of Mualla illustrates this breakdown.

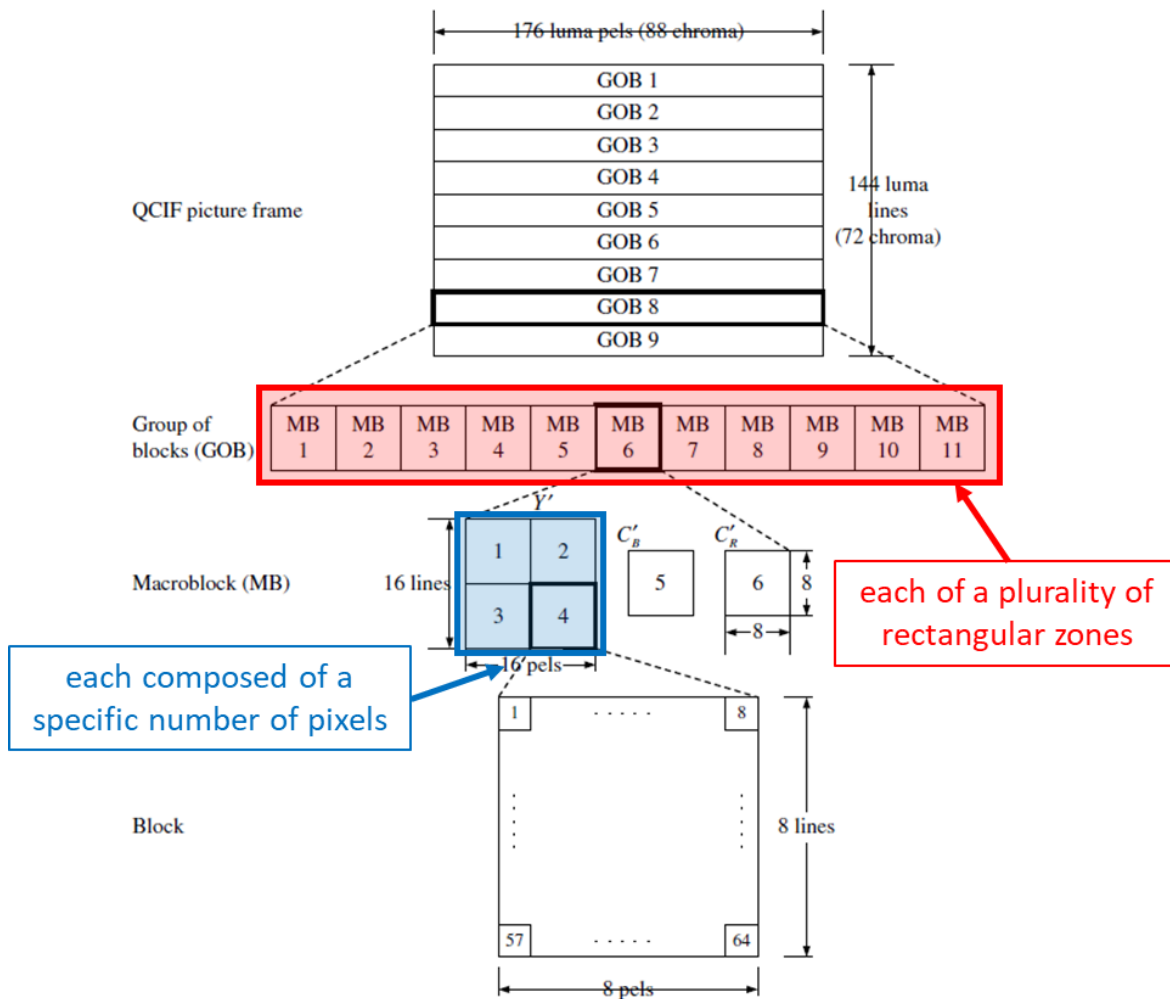


Figure 3.2: H.263 picture structure for a QCIF frame

APPLE-1005, FIG. 3.2 (annotated and color added).

[6.4.COD] obtaining a boundary condition of each of a plurality of borders between the rectangular zones and another plurality of rectangular zones adjacent to the rectangular zones,

129. As discussed above, the Mualla-Shirani-Saito combination implements a two-stage hybrid error concealment in the encoder (as well as the decoder), as taught by Mualla. APPLE-1005, 246-250.

130. In particular, for the first stage, as discussed above in [6.2.COD], Mualla discloses “boundary matching (BM),” a temporal error concealment technique, which selects a “suitable replacement [motion vector] from a set of candidate [neighboring] motion vectors. APPLE-1005, 245; *see above* [6.2.COD]. Shirani’s “first stage” of its two-stage error concealment technique applies a similar technique to estimate a missing motion vector by considering “subblocks adjacent to the missing block.” APPLE-1006, 2-3, FIG. 1(a); *see above* [6.2.COD].

131. In more detail, Shirani explains that in order to obtain an “initial estimate” for each of the missing blocks (“***the rectangular zones***”), “subblocks adjacent to the missing block, i.e., $u1$, $u2$, $l1$, and $l2$ in Fig. 1(a), are considered” (“***another plurality of rectangular zones adjacent to the rectangular zones***”). APPLE-1006, 3, FIG. 1(a) (reproduced below).

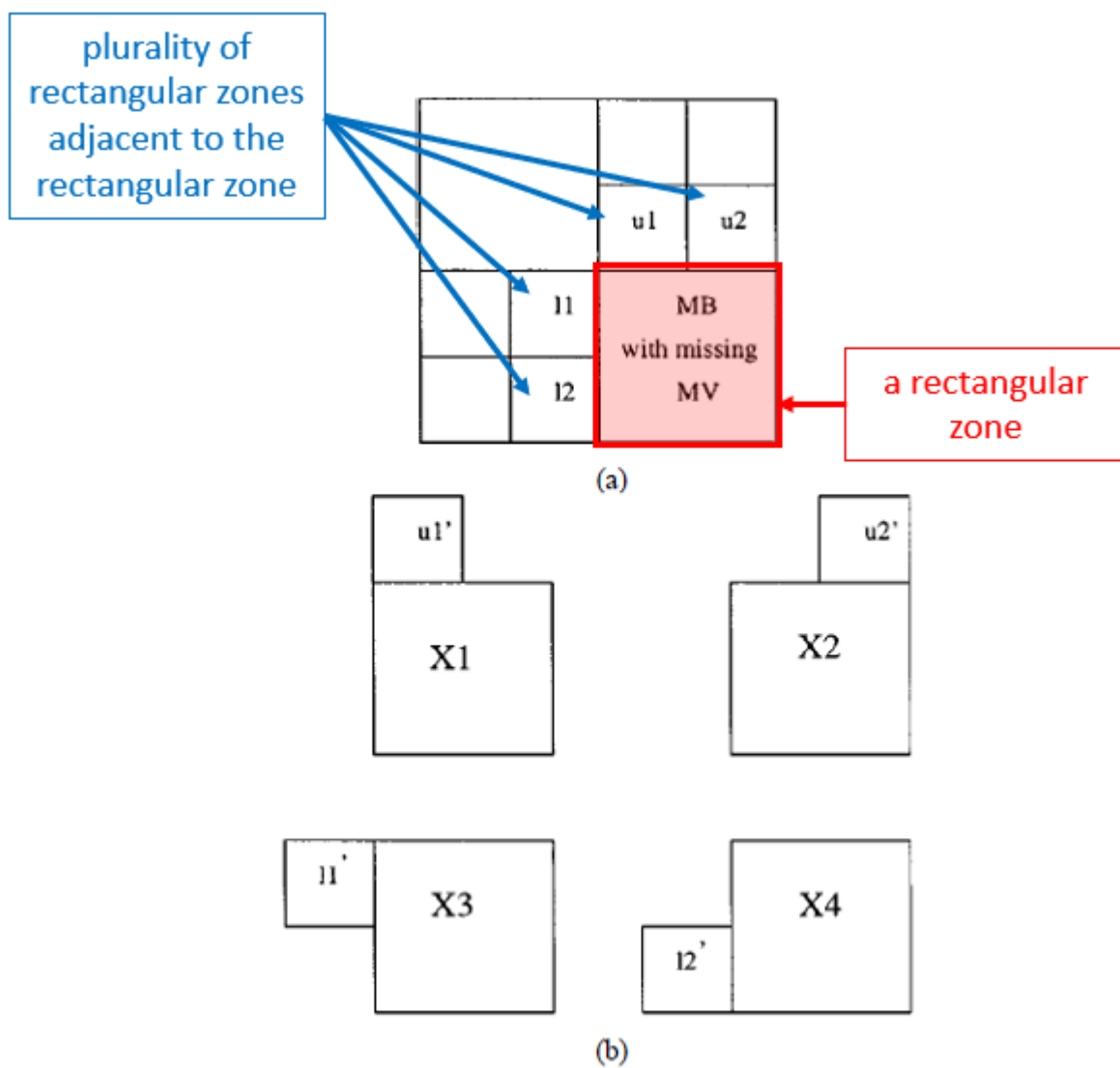


Fig. 1. (a) The four subblocks, (b) their corresponding subblocks in the previous frame, and the blocks connected to them.

APPLE-1006, FIG. 1(a) (annotated and color added).

132. As explained in Section VI.B, above, Shirani discloses that “for each of these subblocks [$u1$, $u2$, $l1$, and $l2$], a corresponding subblock in the previous frame is determined” (denoted $u1'$, $u2'$, $l1'$, and $l2'$ at the bottom of FIG. 1(a), above). APPLE-1006, 3. Then, Shirani discloses that “four blocks, namely $X1$, $X2$, $X3$, and $X4$, which

are connected to $u1'$, $u2'$, $l1'$, and $l2'$, and (respectively), are determined” and “a block from the above four blocks [(X1, X2, X3, and X4)] that minimizes the squared sums of border errors, between the estimated block and its adjacent above and left blocks, is selected.” APPLE-1006, 3. This is accomplished by defining “border error[s]” in “terms of pixels,” including an error for the “bottom line pixels of the block to the top of the missing block” and an error for the “right column pixels of the block to the left of the missing block” and applying the same technique to define border errors for pixels adjacent to “the subblocks ... to the right and below of the missing block” (“***obtaining a boundary condition of each of a plurality of borders between the rectangular zones and another plurality of rectangular zones adjacent to the rectangular zones***”). *Id.* Furthermore, although the above description focused on adjacent subblocks above and to the left of the missing block, Shirani also discloses that “the same method can be extended to include the subblocks of the blocks to the right and below of the missing block” (“... ***of each of a plurality of borders between the rectangular zones and another plurality of rectangular zones adjacent to the rectangular zones***”). *Id.*

133. FIG. 5 of Shirani illustrates an example of how these techniques can be applied to conceal errors for multiple damaged macroblocks (a “***plurality***” of “***rectangular zones***”) in a frame. APPLE-1006, FIG. 5.

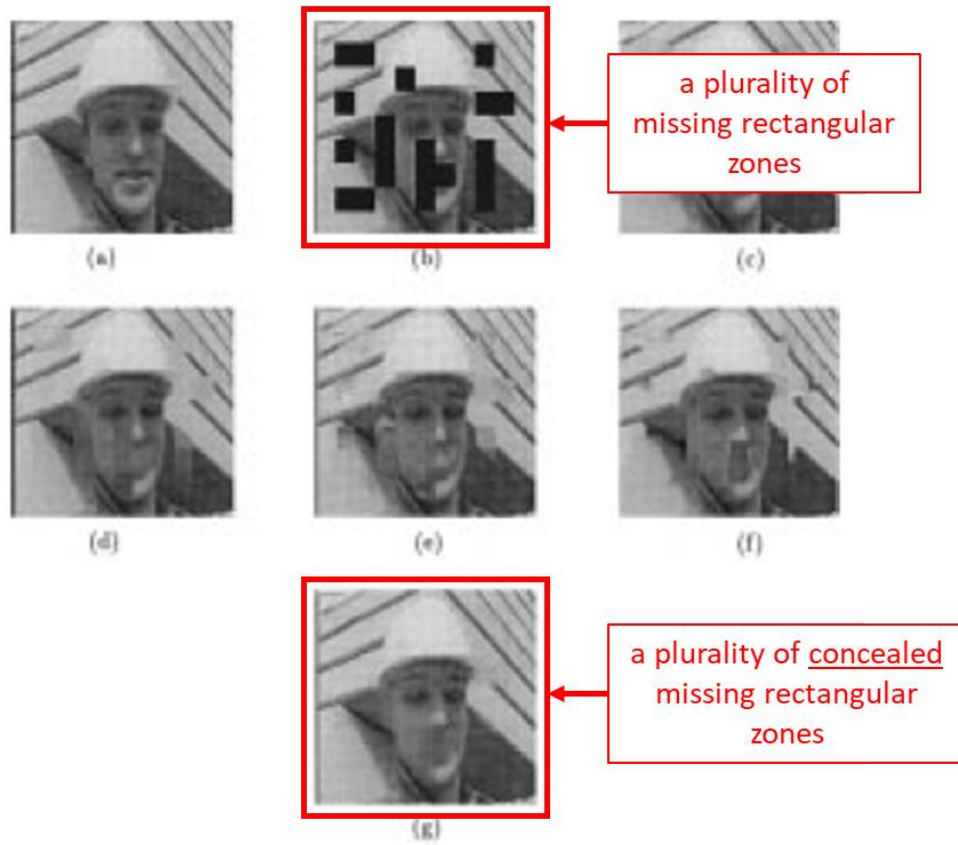


Fig. 5. A frame from the video sequence Foreman: (a) original; (b) missing blocks; reconstructed using (c) a nonadaptive GMRF model; (d) a suboptimal MRF model; (e) the method proposed in [4]; (f) the method proposed in [3]; and (g) our adaptive MRF model.

APPLE-1006, FIG. 5 (annotated).

[6.5.COD] finding a border, of the reference picture, having a boundary condition that matches the boundary condition, by motion-vector search in the reference picture,

134. As discussed above, the Mualla-Shirani-Saito combination implements a two-stage hybrid error concealment in the encoder (as well as the decoder), as taught by Mualla. APPLE-1005, 246-250.

135. In particular, as described above in [6.4.COD], Shirani finds and evaluates the “border error” of a plurality of neighboring subblocks when considering the

suitability of these subblocks in concealing missing or damaged data (“***finding a border, of the reference picture, having a boundary condition that matches the boundary condition***”). APPLE-1006, 2-3, FIG. 1; *see above* [6.2.COD], [6.4.COD]. Additionally, Shirani discloses that the “search for displacement of each of the subblocks is restricted to a set of candidate motion vectors,” specifically, “the motion vectors of available neighboring blocks” (“***finding a border ... by motion-vector search in the reference picture***”). APPLE-1006, 3, FIG. 1(a); *see above* [6.2.COD], [6.4.COD].

[6.6.COD] and generating the border motion-vector data that is data on a motion vector from a border of the rectangular zone in the picture to be coded to the border of the reference picture thus found, defining a boundary condition of a border that corresponds to the border motion vector data, from the reference picture based on the border motion vector data,

136. As discussed above, the Mualla-Shirani-Saito combination implements a two-stage hybrid error concealment in the encoder (as well as the decoder), as taught by Mualla. APPLE-1005, 246-250.

137. In particular, as described in [6.2.COD], [6.4.COD], and [6.5.COD] above, Shirani’s “first stage” temporal error concealment technique searches for candidate replacement motion vectors and generates border errors that define the similarity of the neighboring subblock’s motion vector (“***border motion-vector data***”). *See above*, [6.2.COD], [6.4.COD], [6.5.COD]. Indeed, Shirani’s “candidate motion vectors” are “***data on a motion vector from a border of the rectangular***

zone in the picture to be coded to the border of the reference picture thus found,”

at least because these candidate motion vectors conceal missing motion vectors between “*the reference picture*” and “*the picture to be coded.*” *Id.*

138. Moreover, as described above, Shirani generates border errors that quantify the similarity of the neighboring subblocks’ motion vectors compared to the missing block to be concealed (“*defining a boundary condition of a border that corresponds to the border motion vector data, from the reference picture*”). *See above*, [6.4.COD], [6.5.COD]. Shirani’s border errors evaluate the similarity of the neighboring subblocks’ motion vectors, so they are therefore “*based on the border motion vector data*” of the neighboring subblocks. *Id.*

[6.7.COD] and generating an estimated video signal in each rectangular zone in the picture to be coded, that satisfies Poisson's Equation, thus producing the predictive picture;

139. As discussed above, the Mualla-Shirani-Saito combination implements a two-stage hybrid error concealment in the encoder (as well as the decoder), as taught by Mualla. APPLE-1005, 246-250.

140. In particular, as described above in [6.6.COD], Shirani generates *border motion-vector data* for each damaged or missing subblock. *See above*, [6.2.COD], [6.4.COD]-[6.6.COD]. Additionally, the “second stage” of the Mualla-Shirani-Saito combination (similar to the “spatial error concealment” methods of Mualla) uses “the information around each missing block ... to refine the initial estimate” (as taught by

Shirani) by using Saito's technique for solving Poisson's equation with known boundary conditions. APPLE-1006, 3; APPLE-1007, 27; *see above* VI.B, VI.C, VI.E.

141. As discussed above in the combination, a POSITA would have recognized and found obvious that Saito's image approximation techniques based on solving Poisson's equation would have enhanced Shirani's "second stage" techniques, "improv[ing] the video reconstruction quality" in order to achieve similar goals of image approximation. APPLE-1007, 27; APPLE-1006, Abstract, 3. Saito's Polyharmonic Local Cosine Transform (PHLCT) is an enhancement of a Polyharmonic Local Sine Transform (PHLST) technique for image approximation. APPLE-1007, Abstract, 27. Saito discloses that the PHLST method "segments an image into local pieces using ... characteristic functions, then decomposes each piece into two components: the polyharmonic component and the residual." APPLE-1007, Abstract, 4. Saito explains that the polyharmonic component is "obtained by solving the elliptic boundary value problem associated with the so-called polyharmonic equation (e.g., Laplace's equation, biharmonic equation, etc.) given the boundary values (the pixel values along the boundary created by the characteristic function)." *Id.* The PHLCT variation of PHLST approximates an image between two boundaries by "solv[ing] the ... Poisson equation with the Neumann boundary condition" ("***generating an estimated video signal in each rectangular zone in the picture to be coded, that satisfies Poisson's Equation***"). APPLE-1007, 27.

142. In implementing Saito's teachings into the Mualla-Shirani combination, a POSITA would have recognized and found obvious that the "border errors" of Shirani are suitable to use as the "Neumann boundary condition" for Saito's the PHLCT method, and that PHLCT would have been capable of approximating the image between these boundary conditions ("*thus producing the predictive picture*"). APPLE-1007, 27 ("this method of course requires to estimate the **first order normal derivative** of data at the **boundary**"). Indeed, as described above, Saito's techniques represent a natural improvement of image approximation techniques, at least because they can achieve a faster "decay rate" for the error signal at the boundaries of blocks – an improvement that is consistent with the goals of Mualla-Shirani. APPLE-1007, 27; APPLE-1006, Abstract, 3.

143. Moreover, Saito's process of PHLCT is described by the '025 patent itself, and the '025 patent cites a subsequent publication by Dr. Naoki Saito that explains the PHLCT method. APPLE-1001, Cover, 11:34-12:25.

[6.8.DEC] an entropy decoder to perform entropy decoding to the data thus demultiplexed to generate, at least, motion-vector data, the post-quantization data, the border motion-vector data and parameter data required for constructing a specific syntax structure;

144. As discussed above in [6.2.COD], Mualla-Shirani-Saito discloses "***border motion-vector data***" and "***post-quantization data***." See above, [6.2.COD]. In particular, as discussed above, the first stage of Shirani's two-stage hybrid error concealment technique uses motion vectors of "neighboring blocks" ("***border motion-***

vector data”) to estimate motion vectors of subblocks adjacent to the missing block. APPLE-1006, 3. Furthermore, as discussed in Section VI.A, above, the motion vectors of these neighboring blocks (“*border motion-vector data*”) are encoded and transmitted to the decoder. In particular, when a frame of video is encoded, Mualla explains that all the macroblocks in the frame are “coded from left to right (and from top to bottom if the GOB contains more than one row of MBs) in increasing number.” APPLE-1005, 71, Figure 3.2. The motion vector information for the macroblocks are then “entropy coded” and output from the encoder as encoded motion information. APPLE-1005, 74. Because the encoding and transmission of motion vector information is performed for all macroblocks in a frame/picture, Mualla teaches that the motion vectors of neighboring blocks (“*border motion-vector data*”) around a missing block are encoded and transmitted to the decoder, and can be used by the decoder to perform temporal error concealment in Shirani’s first-stage.

145. Mualla-Shirani-Saito also discloses conventional “*motion vector data*.” *See above*, VI.A; *see below*, [6.14.DEC]. As discussed above, Mualla encodes and transmits motion information for each macroblock in a frame, which includes motion information for the macroblock being decoded (“*motion vector data*”) as well as motion information for neighboring blocks (“*border motion-vector data*”) which can be used for error concealment in case the macroblock being decoded is received in error or corrupted. APPLE-1005, 71, 74.

146. In particular, a POSITA would have understood or found obvious that, in the system of Mualla-Shirani-Saito, motion information for a macroblock being decoded (“***motion vector data***”) can be received and decoded, even if the macroblock is detected as having errors. For example, Mualla explains that a macroblock is detected as having an “error” if the “**decoded motion vector** points outside the permissible range.” APPLE-1005, 232; 244 (explaining that “the motion vector of a damaged block is usually lost or **erroneously received**” and disclosing techniques for recovering a “damaged motion vector”); *see also* Girod, 4 (“Transmission errors can be detected in a variety of ways ... **detect** that the **decoded motion vectors**, DCT coefficients, or quantizer step sizes **exceed their permissible range** (semantic violations)”). In view of these teachings, even if a macroblock is detected as having errors, and even if a particular example disclosed in Mualla or Shirani refers to motion vectors as “missing,” “lost,” or “not available,” a POSITA would have understood or found obvious that the techniques of Mualla and Shirani are applicable to motion vectors (“***motion vector data***”) that are received and decoded and detected as having errors. As such, a POSITA would have understood or found obvious that, according to the teachings of Mualla and Shirani, “motion vector data” for a macroblock is received and decoded regardless of whether the macroblock is detected as having errors (in which case the motion vectors are received and decoded with errors) or without errors (in which case the motion vectors are received and decoded without errors).

147. As discussed in [6.1.DEC], above, Mualla-Shirani-Saito includes a multiplexer that “demultiplex[es]” received data. In addition, Mualla-Shirani-Saito implements an entropy decoder to perform entropy decoding on the demultiplexed data. *See above*, [6.1.DEC]. In particular, Mualla also discloses an “**entropy decoder**” in a “[t]ypical video communication system” that “obtain[s] the output video” (“*generate ... motion-vector data, the post-quantization data, the border motion-vector data and parameter data required for constructing a specific syntax structure*”). APPLE-1005, 227-228, FIG. 9.1. Illustrated below is Mualla’s typical video communication system.

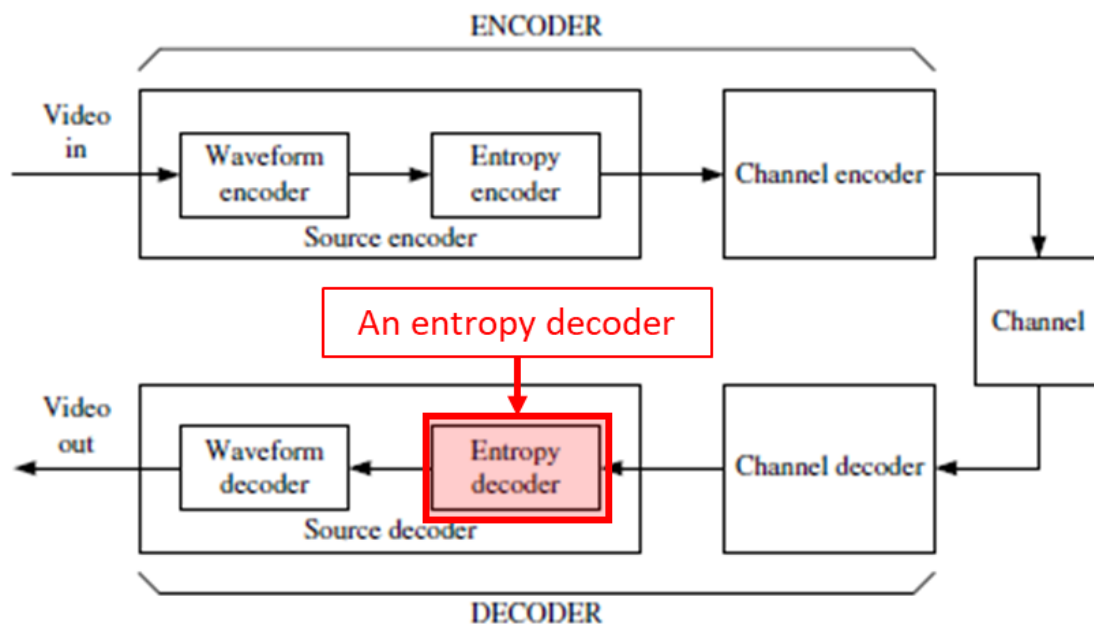


Figure 9.1: Typical video communication system

APPLE-1005, FIG. 9.1 (annotated and color added).

[6.9.DEC] an inverse-quantizer to perform inverse-quantization to the post-quantization data to generate post-quantization orthogonal transform coefficients data;

148. Mualla discloses that the H.263 standard includes the techniques of inverse-quantization. APPLE-1005, 51-52, 76. Specifically, Mualla discloses that “quantization is achieved by dividing the transform coefficient by a quantization step size and rounding the result (“***post-quantization data***”) ... [i]nverse quantization is the process of reconstructing an approximation of the original coefficient by multiplying the quantized coefficient by the same step size” (“***inverse-quantization to the post-quantization data to generate post-quantization orthogonal transform coefficients data***”). APPLE-1005, 76. Mualla illustrates an “***inverse quantizer***” in its example H.263 video encoder. APPLE-1005, FIG. 3.1. A POSITA would have recognized and found obvious that a similar component would have been included in the decoder of a codec.

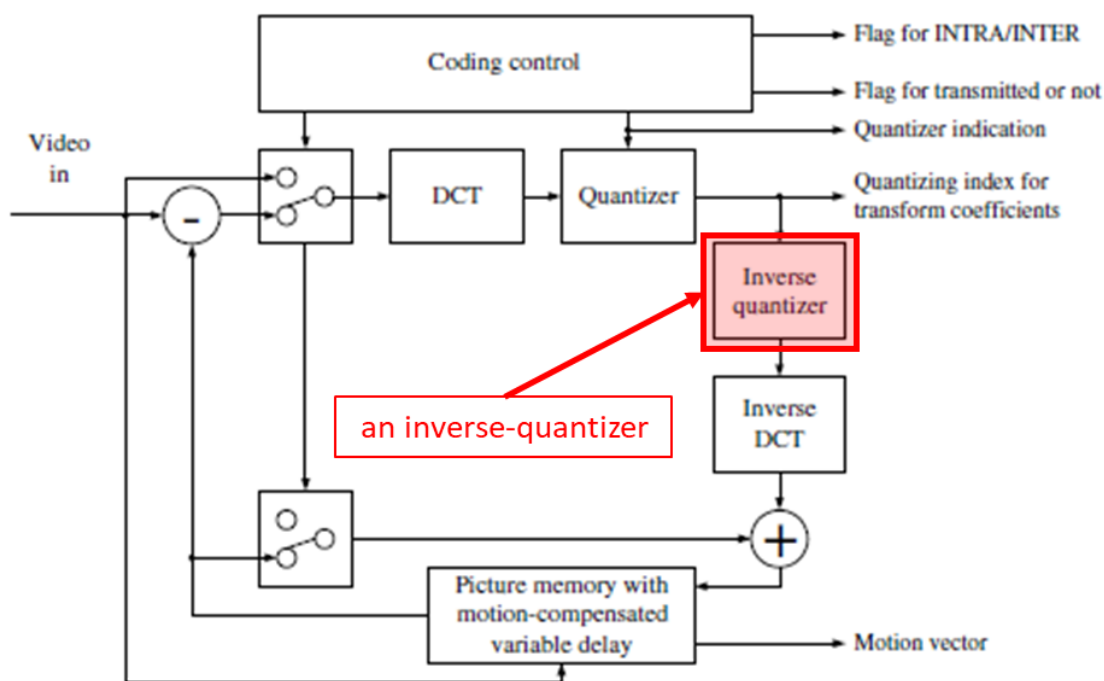
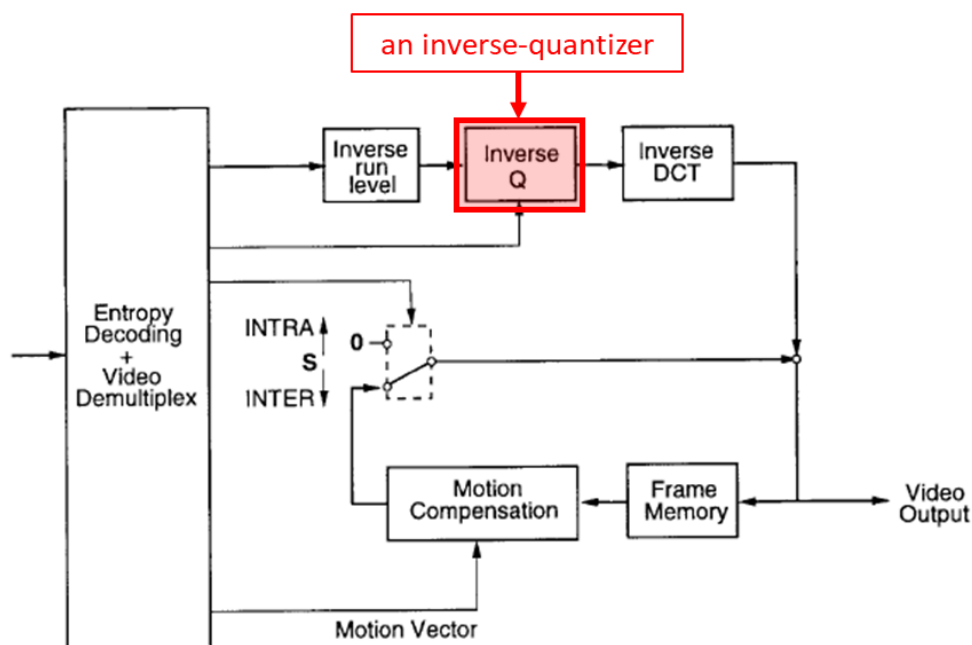


Figure 3.1: H.263 video encoder

APPLE-1005, FIG. 3.1 (annotated and color added).

149. Moreover, a POSITA would have recognized or found obvious that the decoder would “*perform inverse quantization*,” for example, by using an “*inverse-quantizer*,” as this was well-known before the Critical Date. Indeed, Girod corroborates the use of “inverse-quantizer[s]” in H.263 decoders and illustrates this component in its example H.263 decoder. APPLE-1008, 2, FIG. 1(b)



APPLE-1008, FIG. 1(b) (annotated and color added).

[6.10.DEC] an inverse-orthogonal transformer to perform inverse-orthogonal transform to the post-quantization orthogonal transform coefficients data to produce a decoded residual picture of one video area;

150. As discussed in Section VI.A, above, Mualla discloses that the H.263 standard includes the techniques of inverse-orthogonal transforms. APPLE-1005, 51-52, 76. Specifically, Mualla discloses the encoder performs “transform coding” where a “unitary space-frequency transform is applied to each block [in an input frame] to produce an $N \times N$ block of transform (spectral) coefficients that are then suitably quantized” (“***post-quantization orthogonal transform coefficients data***”). APPLE-1005, 52, FIG. 2.9. Next, at the decoder, “an inverse transform is applied to reconstruct the frame” (“***an inverse-orthogonal transformer to perform inverse-orthogonal transform to the post-quantization orthogonal transform coefficients data***”). *Id.*

FIG. 2.9 of Mualla illustrates an “[i]nverse transform” component in an example “transform coding system.” *Id.*

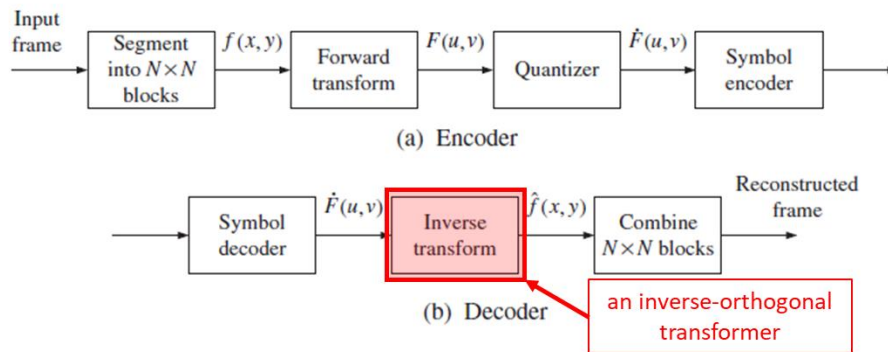
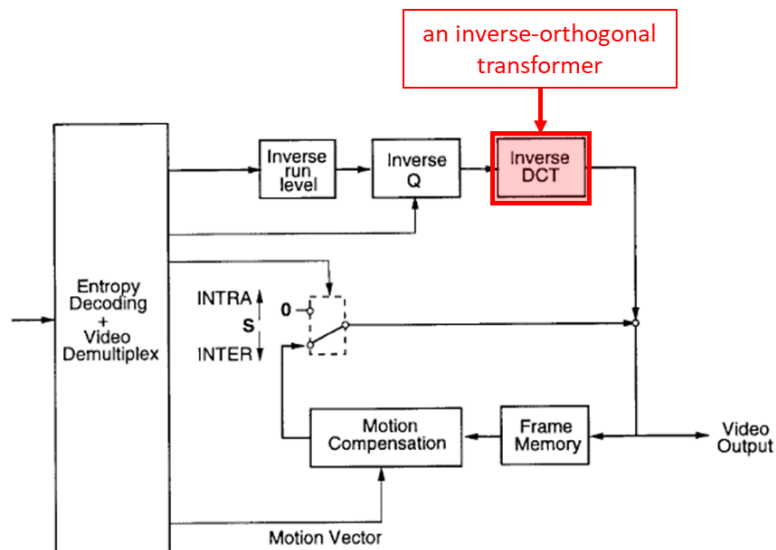


Figure 2.9: Block diagram of a transform coding system

APPLE-1005, FIG. 2.9 (annotated and color added).

151. Moreover, a POSITA would have recognized or found obvious that the decoder would include an “*inverse-orthogonal transformer*” as this was well-known in the art before the Critical Date. Indeed, Girod corroborates the use of inverse transforms in H.263 decoders. APPLE-1008, 2, FIG. 1(b).



APPLE-1005, FIG. 1(b) (annotated and color added).

[6.11.DEC] a zone-border motion compensator to define a boundary condition of a border that corresponds to the border motion vector data, from the reference picture based on the border motion-vector data, and generate an estimated video signal in each rectangular zone in the picture to be coded, that satisfies Poisson's Equation, thus producing a first predictive picture;

152. As discussed above, the Mualla-Shirani-Saito combination implements a two-stage hybrid error concealment in **both** the **encoder** and the **decoder** by using “interactive techniques,” as taught by Mualla. APPLE-1005, 246-250. As described above in [6.2.COD] and [6.6.COD]-[6.7.COD], the **encoder** of the Mualla-Shirani-Saito combination defines “*a boundary condition of a border that corresponds to the border motion vector data, from the reference picture based on the border motion vector data*” and “*generate[s] an estimated video signal in each rectangular zone in the picture to be coded, that satisfies Poisson's Equation, thus producing a first predictive picture.*” See above, [6.2.COD], [6.6.COD]-[6.7.COD]. Thus, a POSITA would have understood or found obvious that the **decoder** of the Mualla-Shirani-Saito combination would perform analogous operations by using the same two-stage hybrid error concealment technique.

153. Furthermore, Mualla refers to the first-stage temporal concealment as “**motion-compensated** error concealment.” APPLE-1005, 27. Mualla explains that “[a]s in **motion-compensated prediction**, the process of temporal concealment involves two stages: *concealment displacement estimation* and *displacement compensation*, as shown in Figure 9.8(a). For this reason, temporal concealment is sometimes referred to

as **motion-compensated concealment.**” APPLE-1005, 243, Figure 9.8(a)
(reproduced below, annotated).

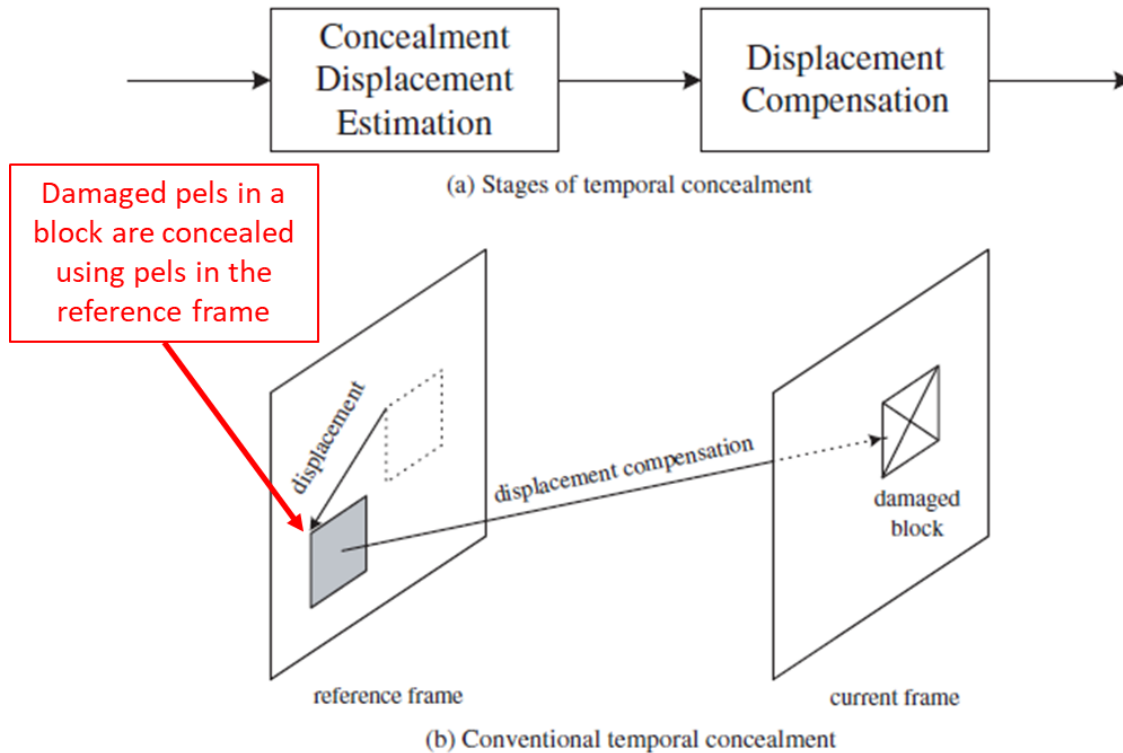


Figure 9.8: Temporal error concealment

APPLE-1005, FIG. 9.8 (annotated).

154. Moreover, the additional techniques of Shirani and Saito are simply ‘algorithms’ that can be executed by computer program modules (“***a zone-border motion compensator***”). APPLE-1006, 1-2; APPLE-1007, 6. Therefore, the encoding features discussed in encoding limitations [6.2.COD], [6.6.COD]-[6.7.COD] would be similarly implemented within the decoder of Mualla-Shirani-Saito.

155. Thus, a POSITA would have understood or found obvious that the **decoder** of the Mualla-Shirani-Saito combination implements “motion compensated

error concealment techniques” as part of a two-stage hybrid “error concealment” algorithm (the claimed “***zone-border motion compensator***”), which includes a first-stage temporal concealment stage (which defines “***a boundary condition of a border that corresponds to the border motion vector data, from the reference picture based on the border motion vector data***”) and a second-stage spatial concealment stage (which “***generate[s] an estimated video signal in each rectangular zone in the picture to be coded, that satisfies Poisson's Equation, thus producing a first predictive picture***”).

[6.12.DEC] a combiner to combine the first predictive picture and the decoded residual picture to generate a decoded moving picture signal;

156. Mualla describes a well-known decoding process in which a “prediction” (“***the first predictive picture***”) generated by motion-estimation and motion-compensation (the “***zone border motion compensation***” of Mualla-Shirani-Saito) is “added to” (or summed with) (“***combine the first predictive picture and the decoded residual picture***”) an “error signal” (“***the decoded residual picture***”), which is the result of inverse DCT, to “reconstruct the current frame” (“***generate a decoded moving picture signal***”). APPLE-1005, 27, 76, FIG. 10.8; *see above* [6.6.11.DEC]. Indeed, Mualla’s error concealment technique “***generate[s] a decoded moving picture signal***” by concealing missing/erroneous/damaged blocks, as shown in Figure 10.8. *Id.*

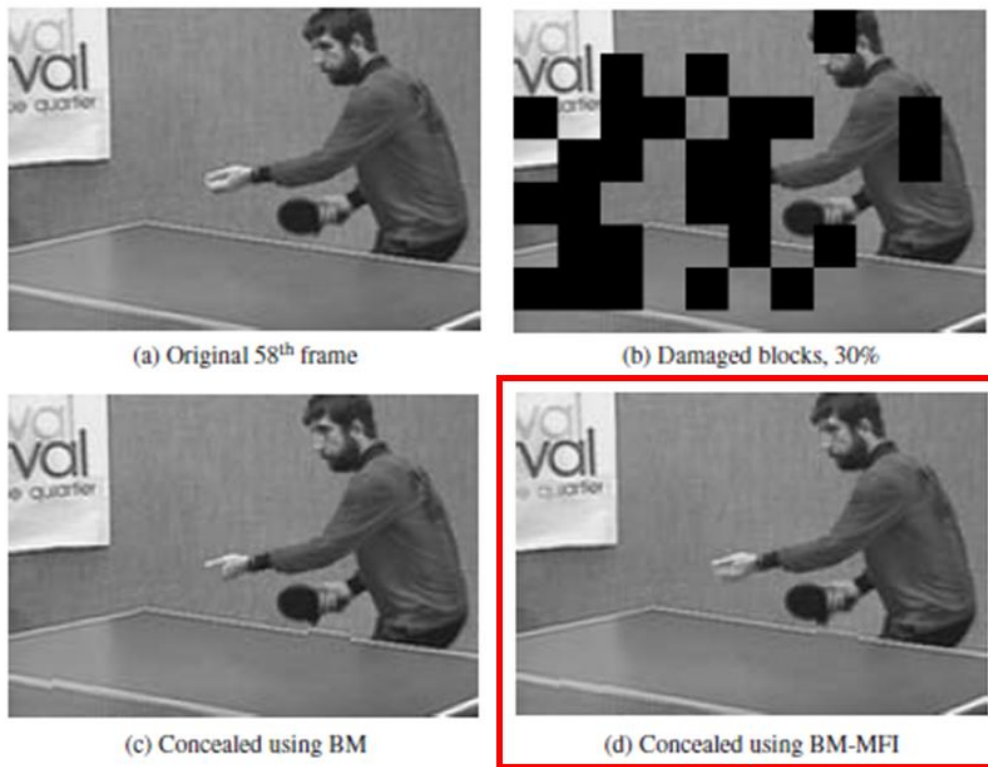


Figure 10.8: Subjective quality of concealed 58th frame of QSIF TABLE TENNIS at 30 frames/s with a block loss rate of 30%

combin[ing] the first predictive picture
and the decoded residual picture to
generate a decoded moving picture signal

APPLE-1005, FIG. 10.8 (annotated).

157. Thus, for a given frame (picture) that is being decoded, (i) coded data for some macroblocks of the frame are received without error and are decoded using Mualla's conventional "motion estimation" and "motion compensation," whereas (ii) coded data for other macroblocks of the frame are erroneously received and concealed using the Mualla-Shirani-Saito two-stage hybrid error concealment technique. The result is an aggregate predicted frame ("*the first predictive picture*") that is combined with Mualla's "decoded [displaced-frame difference] DFD" ("*the decoded residual*

picture”). The combining technique is analogous to the combining technique implemented in Mualla’s conventional motion-estimation-compensation decoding. APPLE-1005, FIG. 1.1.

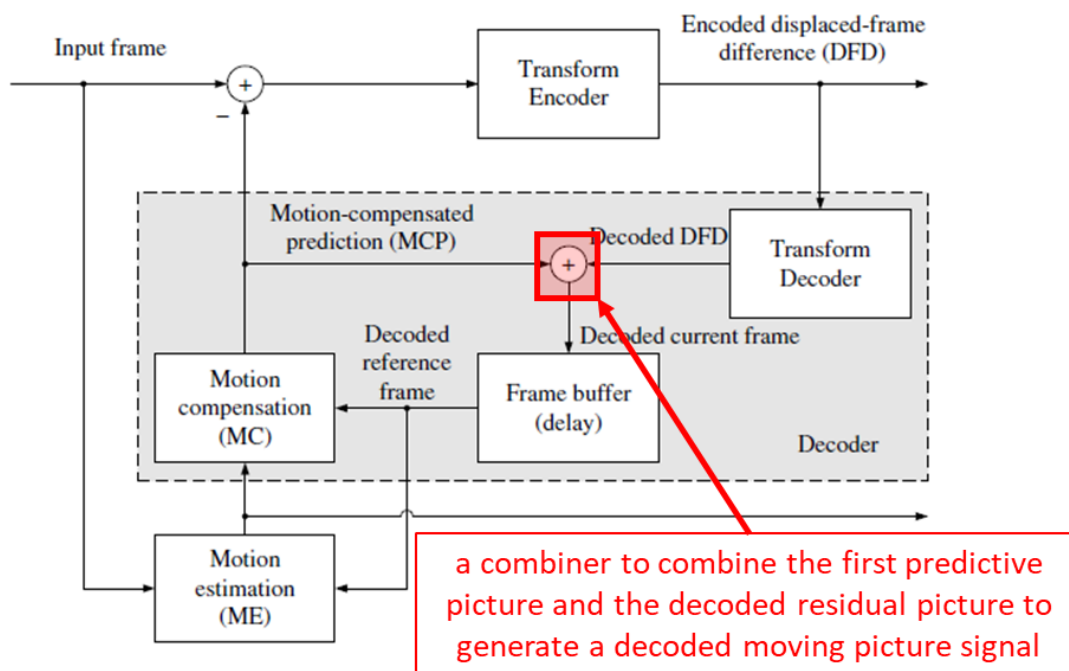
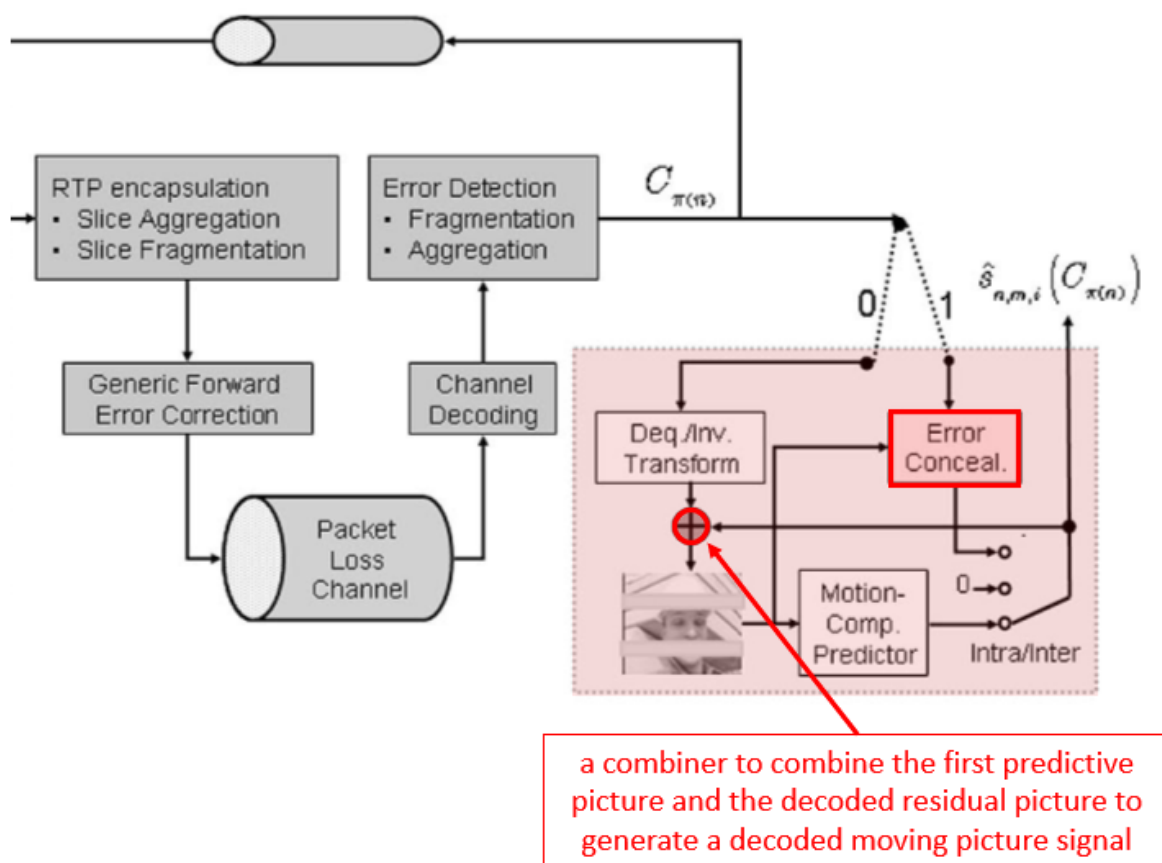


Figure 1.1: Typical video codec

APPLE-1005, FIG. 1.1 (annotated and color added).

158. A detailed example of such a combining step for error concealment is provided in Stockhammer (APPLE-1009), which discloses an example of error concealment implemented in an H.264-based system in Figure 9.8 (reproduced below, annotated). As discussed in Section VI.A, above, decoding is performed on a per-macroblock basis. For a given macroblock of the frame, if an error is detected in the coded data of the macroblock, then the decoder performs “error concealment” and the second selector at the bottom-right-hand corner of the red shaded area is in the upper-

most position and provides the error concealment output (the “***first predictive picture***”) to a combiner (annotated). APPLE-1009, 8, Fig. 6 (reproduced below, annotated). As shown in Fig. 6, the other input to the combiner is the output of the “dequantizer/inverse transform.” *Id.* As explained in [6.9.DEC] and [6.10.DEC], the output of dequantizer/inverse transform is a “***decoded residual picture***.”



APPLE-1009, FIG. 6 (annotated and color added).

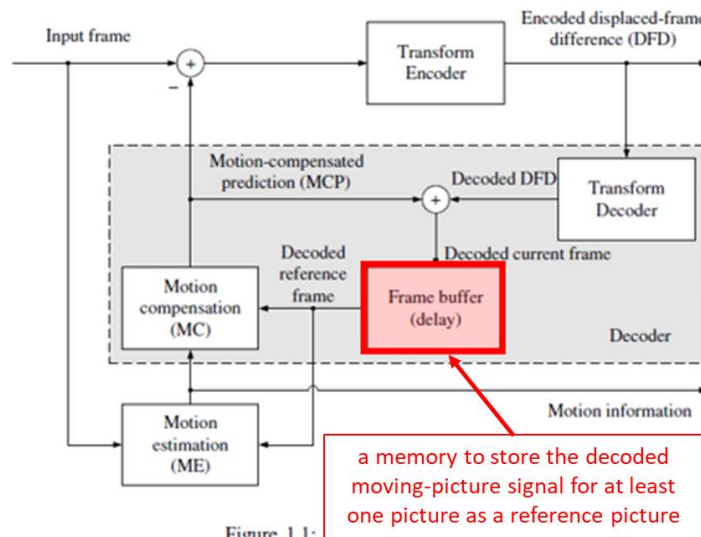
159. Conversely, if no errors are detected in the coded data of the macroblock, then the decoder applies the conventional “motion compensated predictor” and the second selector at the bottom-right-hand corner of the red shaded area is in the lower-

most position and provides the output of the motion compensated predictor to the combiner (annotated). APPLE-1009, 8, Fig. 6.

160. Ultimately, for all macroblocks in the frame (both those received in error and without error), the decoder generates reconstructed samples $\hat{s}_{n,m,i}(o, C_{\pi(n)})$ that form a reconstructed image (the “*decoded moving picture signal*”).

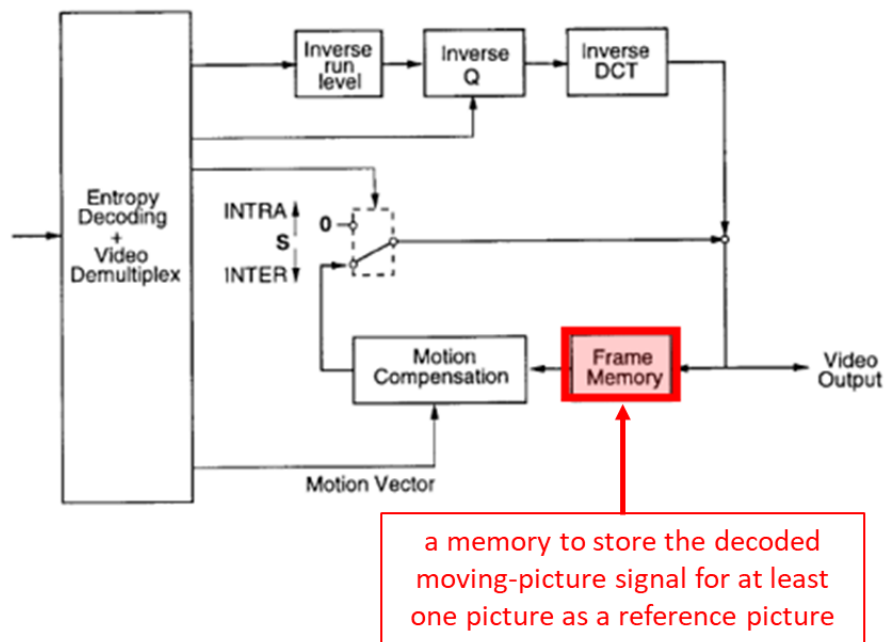
[6.13.DEC] a memory to store the decoded moving-picture signal for at least one picture as a reference picture;

161. Mualla describes the well-known feature of a decoder including a “*memory*” to store a “*reference picture*” which is the “*decoded moving-picture signal*” that was generated by combining the residual picture and the predictive picture. APPLE-1005, 26-27, FIG. 1.1; *see above*, [6.12.DEC]. For example, Mualla discloses that “reference frame[s]” (“*reference picture[s]*”) are “stored in a frame buffer” (“*a memory*”). *Id.*



APPLE-1005, FIG. 1.1 (annotated and color added).

162. Additionally, the use of a “*memory*” to “*store ... a reference picture*” was well-known in the art before the Critical Date. For example, Girod discloses that a H.263 decoder includes a “frame memory” which stores “decoded frames.” APPLE-1008, 2.



APPLE-1008, FIG. 1(b) (annotated and color added).

[6.14.DEC] a motion compensator to specify a corresponding rectangular zone in the reference picture based on the motion vector data, thus generating a second predictive picture;

163. Mualla’s “typical video codec” includes the well-known feature of “motion compensation.” APPLE-1005, 26-27, 76, 115-116, FIG. 1.1, 2.16. Indeed, Mualla discloses that a “motion estimation (ME) block uses a motion model to estimate the movement that occurred between [a] current frame and a reference frame” (“*specify a corresponding rectangular zone in the reference picture based on the*

motion vector data”). APPLE-1005, 26-27, 116-117. Then, “[a]t the decoder, the same reference frame is used along with the received motion information to produce the same prediction” (“*thus generating a second predictive picture*”). *Id.* FIG. 1.1 below illustrates motion compensation in Mualla’s typical video codec.

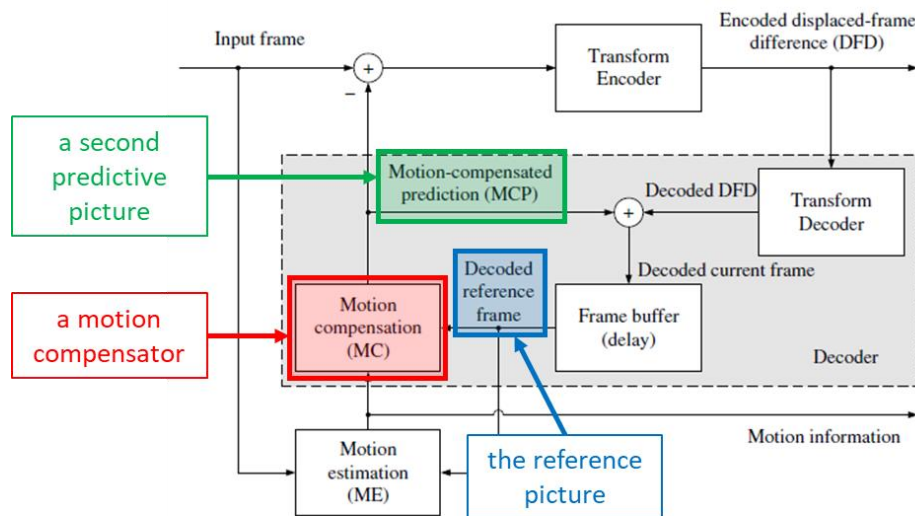
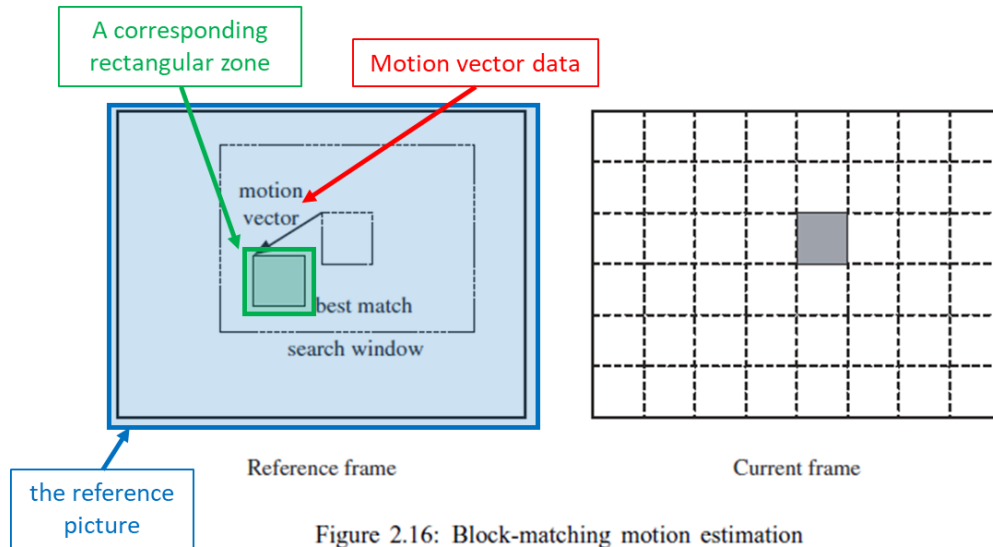


Figure 1.1: Typical video codec

APPLE-1005, FIG. 1.1 (annotated and color added).

164. Additionally, Mualla discloses a process of using a “motion vector” (“*based on the motion vector data*”) to determine a “block” in the reference frame (“*a corresponding rectangular zone in the reference picture*”) that matches the current frame. APPLE-1005, 76. This process is illustrated in FIG. 2.16 below.



APPLE-1005, FIG. 2.16 (annotated and color added).

165. Moreover, the techniques of motion compensation were well-known before the Critical Date. Indeed, Shirani describes the use of “motion compensation” (“*a motion compensator*”) and “motion vectors” (“*motion vector data*”) to identify “motion compensated blocks” (“*a corresponding rectangular zone in the reference picture*”). APPLE-1006, 1-2.

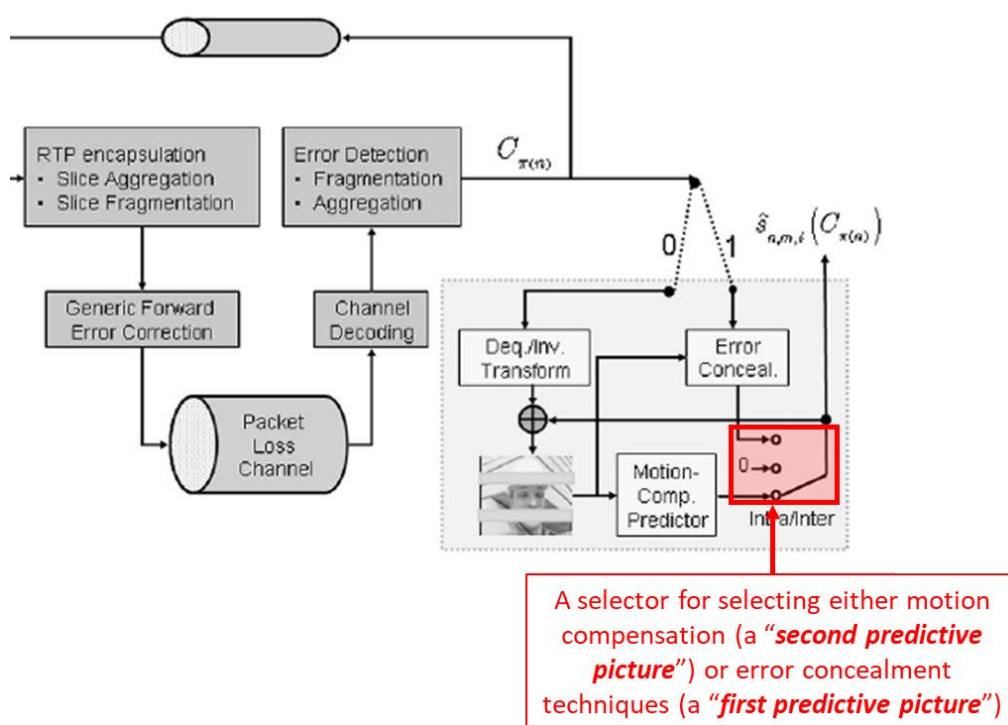
[6.15.DEC] a selector to select either the first predictive picture or the second predictive picture and supply the predictive picture thus selected to the combiner; and

166. Mualla discloses that its error concealment techniques can be deployed “[w]hen an error is detected,” and that during this period, the “decoding process is stopped.” APPLE-1005, 265. From at least this disclosure, a POSITA would have recognized and found obvious that tradition motion compensation (producing a “*second predictive picture*”) would execute until an error was detected by the decoder

in the bitstream, at which point the error concealment techniques of the Mualla-Shirani-Saito combination would be used to generate replacement motion vector and video data (a “*first predictive picture*”). APPLE-1005, 265.

167. A POSITA would have recognized or found obvious that switching between these two methods of decoding (“*select[ing] either the first predictive picture or the second predictive picture*”) would be effectuated by a switching component, such as a “*selector*.” Indeed, Girod (cited by Mualla) corroborates selecting between two different decoding modes in response to detected errors, as “an erroneous bit stream cannot be gracefully decoded by an ‘off-the-shelf’ video decoder build [sic] for error-free transmission.” APPLE-1008, 4. Girod explains that, in the case of errors, “[s]pecial provisions for error detection, resynchronization, and concealment are required.” *Id.* Stockhammer⁴ also corroborates the use of a “selector” to switch between traditional motion compensation and error concealment. APPLE-1009, FIG. 6.

⁴ Although Stockhammer’s teachings are within the general knowledge of a POSITA, a POSITA would have additionally combined Stockhammer into the Mualla-Shirani-Saito combination for the reasons discussed above. *See above*, §VI.A-E.



APPLE-1009, FIG. 6 (annotated and color added).

168. Moreover, Mualla uses a “*selector*” to control inter or intra coding. APPLE-1005, 72, FIG. 3.1. Using a selector to switch between normal decoding and error concealment “would have been a natural extension of techniques disclosed within Mualla.”

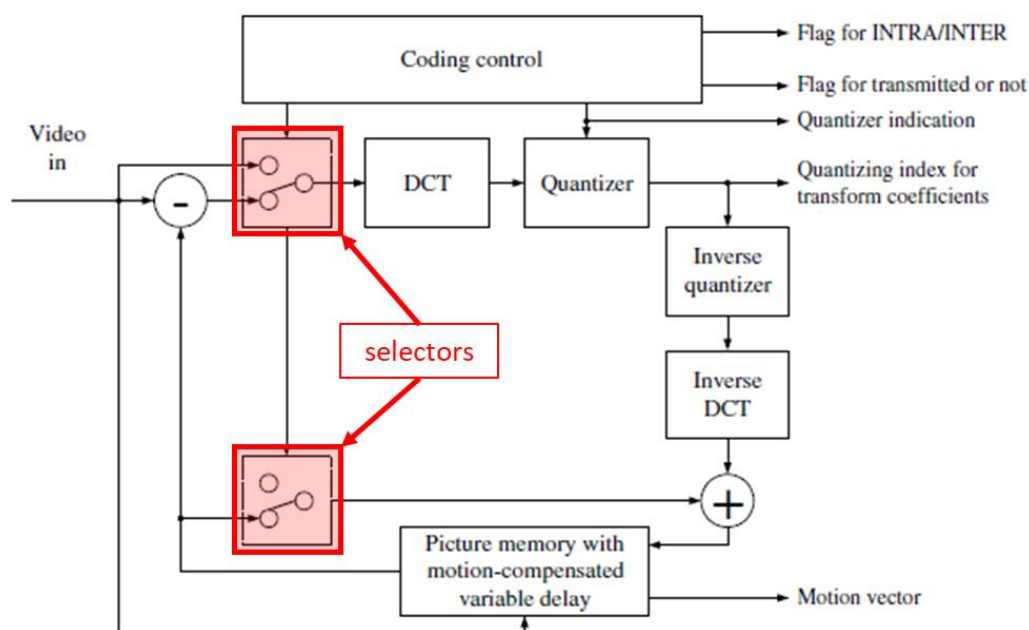


Figure 3.1: H.263 video encoder

APPLE-1005, FIG. 3.1 (annotated and color added).

[6.16.DEC] a decoding controller to receive decoding control data for decoding control from the parameter data and control the selector to switch the predictive picture to be supplied to the combiner between the first and second predictive pictures according to the decoding control data.

169. As explained above in [6.15.DEC], the Mualla-Shirani-Saito combination would have switched, via a “selector” or equivalent component, between conventional motion compensation and error concealment, depending on the presence of errors in the bitstream. *See above*, [6.15.DEC]. Additionally, Mualla also discloses that these errors can be detected from “syntax and semantic violations,” the “header information” being one source of this data (**“decoding control data for decoding control from the parameter data”**). APPLE-1005, 231-232. Additionally, Mualla’s H.263 video

encoder includes a “coding control” component (“*a decoding controller*”) that is “responsible for varying several parameters to control the rate or the quality of the coded video.” APPLE-1005, 72, 75, FIG. 3.1. Examples of functions that are controlled by the coding control component are “INTER/INTRA mode decision at the picture or MB level, the update pattern of the forced INTRA refresh, the TRANSMIT=SKIP decision at the MB level, and the QP and its change at the picture, GOB, or MB level.” APPLE-1005, 75. Illustrated below is Mualla’s example H.263 encoder with a “coding control” component that controls operations of the local decoder (the bottom switch).

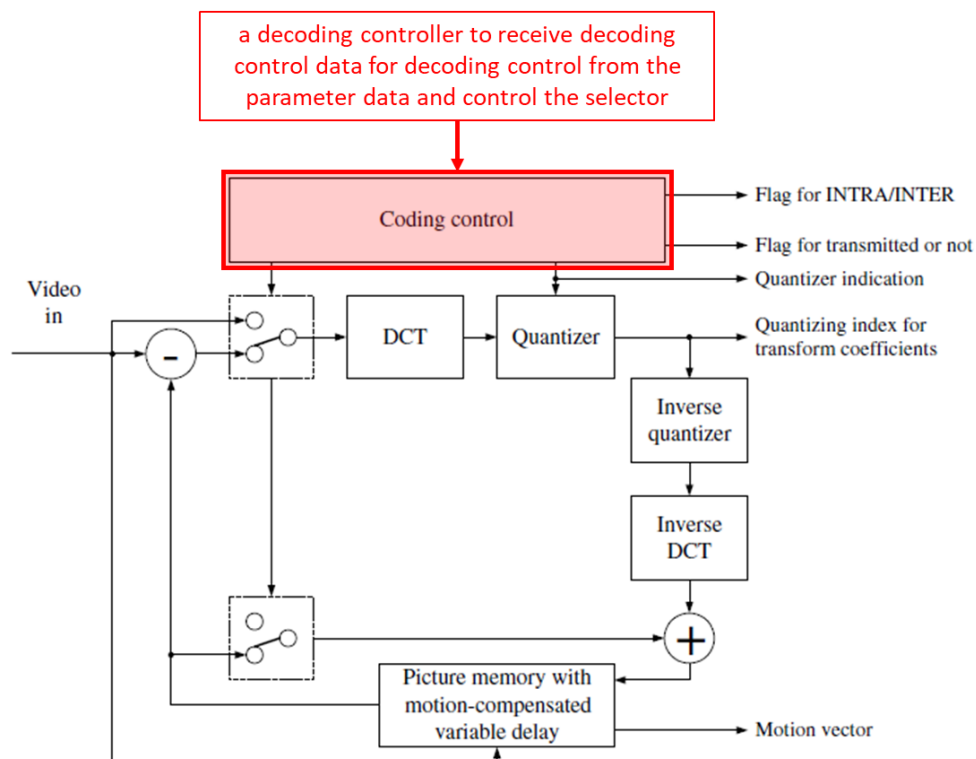
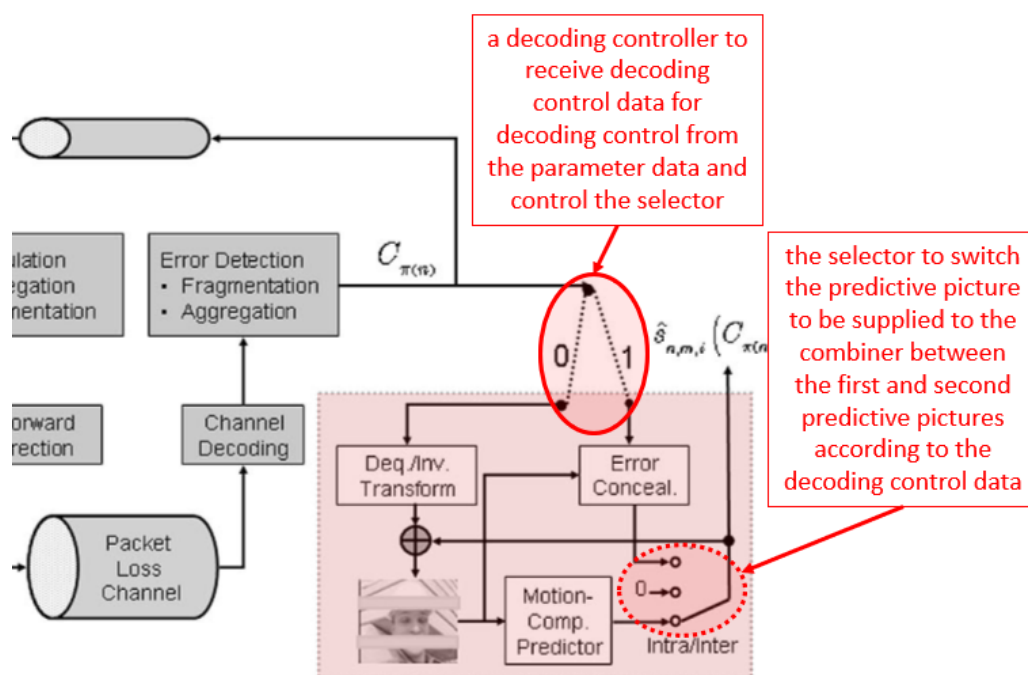


Figure 3.1: H.263 video encoder

APPLE-1005, FIG. 3.1 (annotated and color added).

170. A POSITA would have recognized or found obvious that Mualla's decoder would have implemented an analogous coding control component (“*a decoding controller*”) would have “*receive[d] decoding control data for decoding control from the parameter data*” and subsequently, in response to a detected error, “*control[ed] the selector to switch the predictive picture to be supplied to the combiner between the first and second predictive pictures according to the decoding control data.*” Indeed, this function is consistent with the operations of the coding controller described by Mualla, and Mualla's coding controller must necessarily process syntax data (“*decoding control data for decoding control from the parameter data*”) at least because it must make decisions regarding ‘inter’ or ‘intra’ prediction.

171. Additionally, as illustrated in Stockhammer's Figure 6 (reproduced below) and as discussed in [6.15.DEC], above, it was known that an H.264-based decoder can implement a *decoding controller* that determines whether an error has been detected (either binary 0 or 1) and controls a *selector* to switch between the outputs of the “error concealer” (the “*first predictive picture*”) or the output of the conventional “motion compensated predictor” (the “*second predictive picture*”) APPLE-1009, FIG. 6.



APPLE-1009, FIG. 6 (annotated and color added).

[7.pre] A non-transitory computer readable device having stored thereon a computer program comprising a set of instructions when executed by a computer to implement a method for moving-picture decoding, the program comprising:

172. Mualla discloses “software-based video codecs” (“*non-transitory computer readable device*”) that utilize various “algorithms” (“*a computer program comprising a set of instructions*”). APPLE-1005, 71, 182, 265, 299. For example, Mualla provides an example of a specific software implementation of H.263 called “Telenor” (citing to a “H.263 TMN software codec” as reference [144]) (“*a method for moving-picture decoding*”). APPLE-1005, 265, 299.

173. Moreover, the use of algorithms in implementing codecs was well-known before the Critical Date. Indeed, both Shirani and Stockhammer corroborate the use of “algorithms” and “software” in implementing H.263 and H.264 codecs. APPLE-1006, 1 (“many of the video compression algorithms (e.g., H.263)”); APPLE-1009, 1, 5 (“in the standardization of H.264/AVC for the development of the reference software”).

[7.1.DEC]-[8.3], [10.pre]-[10.13.DEC]

174. These limitations are obvious as explained above for the corresponding limitations listed in the following table.

Claim	Corresponding Claim
[10.pre]	[6.pre]
[7.1.DEC], [10.1.DEC]	[6.1.DEC]
[7.2.COD], [10.2.COD]	[6.2.COD]
[7.3.COD], [10.3.COD]	[6.3.COD]
[7.4.COD], [10.4.COD]	[6.4.COD]
[7.5.COD], [10.5.COD]	[6.5.COD]
[7.6.COD], [10.6.COD]	[6.6.COD]
[7.7.COD], [10.7.COD]	[6.7.COD]
[7.8.DEC], [8.pre], [10.8.DEC]	[6.8.DEC]
[7.9.DEC], [10.9.DEC]	[6.9.DEC]
[7.10.DEC], [10.10.DEC]	[6.10.DEC]
[7.11.DEC], [10.11.DEC]	[6.11.DEC]

[7.12.DEC], [10.12.DEC]	[6.12.DEC]
[8.1]	[6.14.DEC]
[8.2]	[6.15.DEC]
[8.3]	[6.16.DEC]
[10.13.DEC]	[6.13.DEC]

2. “Moving picture coding” claims 1-5, 9

[1.pre], [4.pre], [9.pre]

175. Mualla teaches extensive details of an H.263-based video codec system, which implements ***coding apparatus, method, and media*** for decoding ***moving pictures*** (e.g., “video”). APPLE-1005, 23-26, 31, 36, 51-52, 61-63, 227-228, 241-242, 265. For example, as discussed in §VI.A, above, Mualla’s Figure 9.1 and accompanying description disclose a “typical video communication system” which includes a “source encoder” (“***coding apparatus, method, and media***”). APPLE-1005, Figure 9.1 (reproduced below), 227-228. Further details of Mualla’s “source encoder” are illustrated and described with reference to Figures 2.3, 1.1, and 2.9 of Mualla, as explained in §VI.A, above. To facilitate understanding, I provide aggregated views of the relation between these different figures of Mualla are shown in Diagrams A and B discussed in §VI.A, above, which are reproduced again below.

176. Additionally, as discussed above in [7.pre], “*non-transitory computer readable device*” is both disclosed by Mualla and further would have been an obvious implementation choice to a POSITA. *See above* [7.pre].

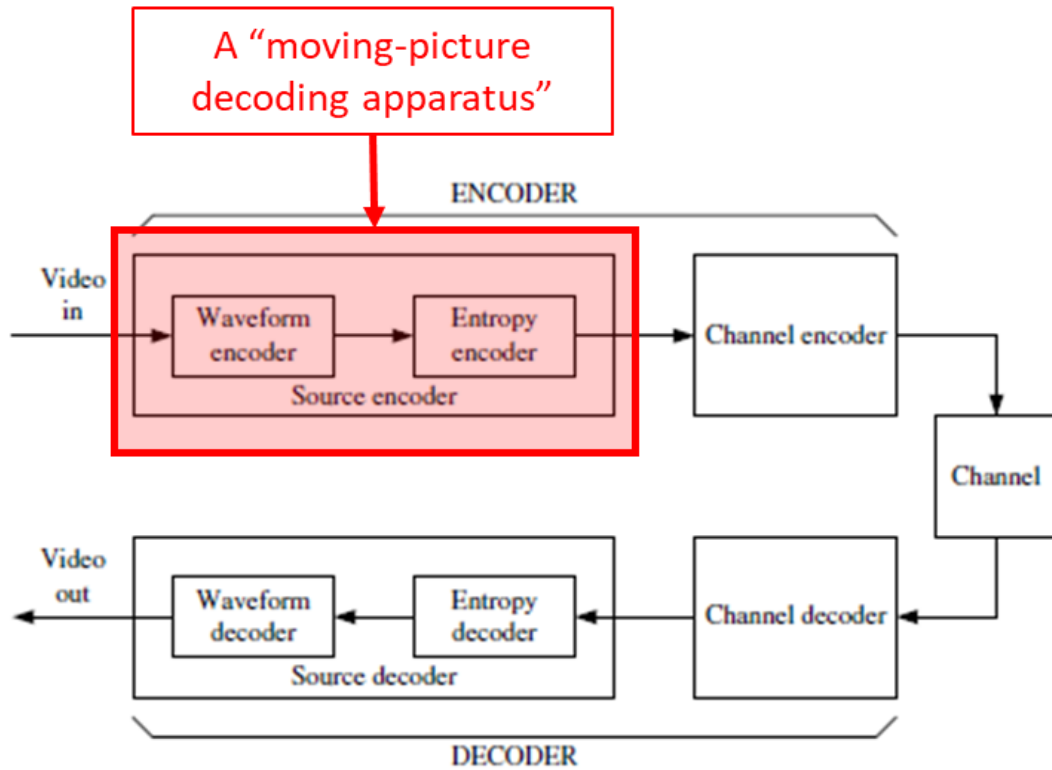


Figure 9.1: Typical video communication system

APPLE-1005, FIG. 9.1 (annotated and color added).

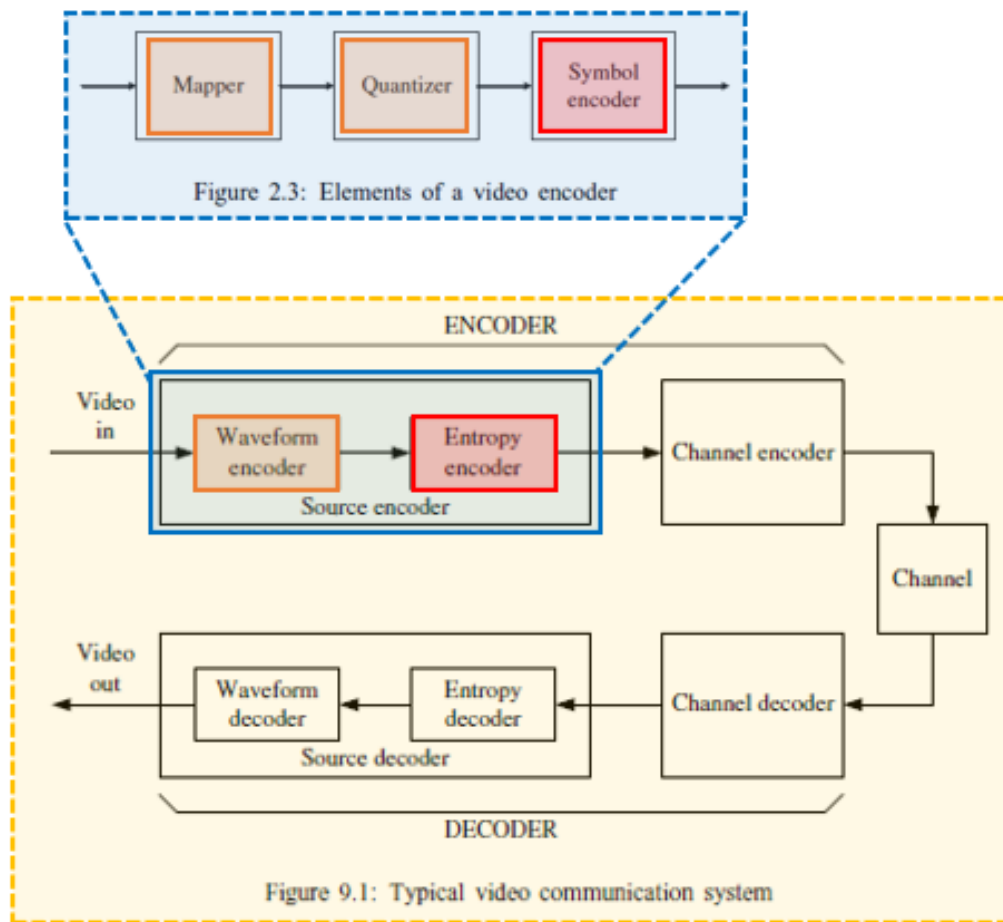


Diagram A (showing the relation between Mualla's Figures 9.1 and 2.3)

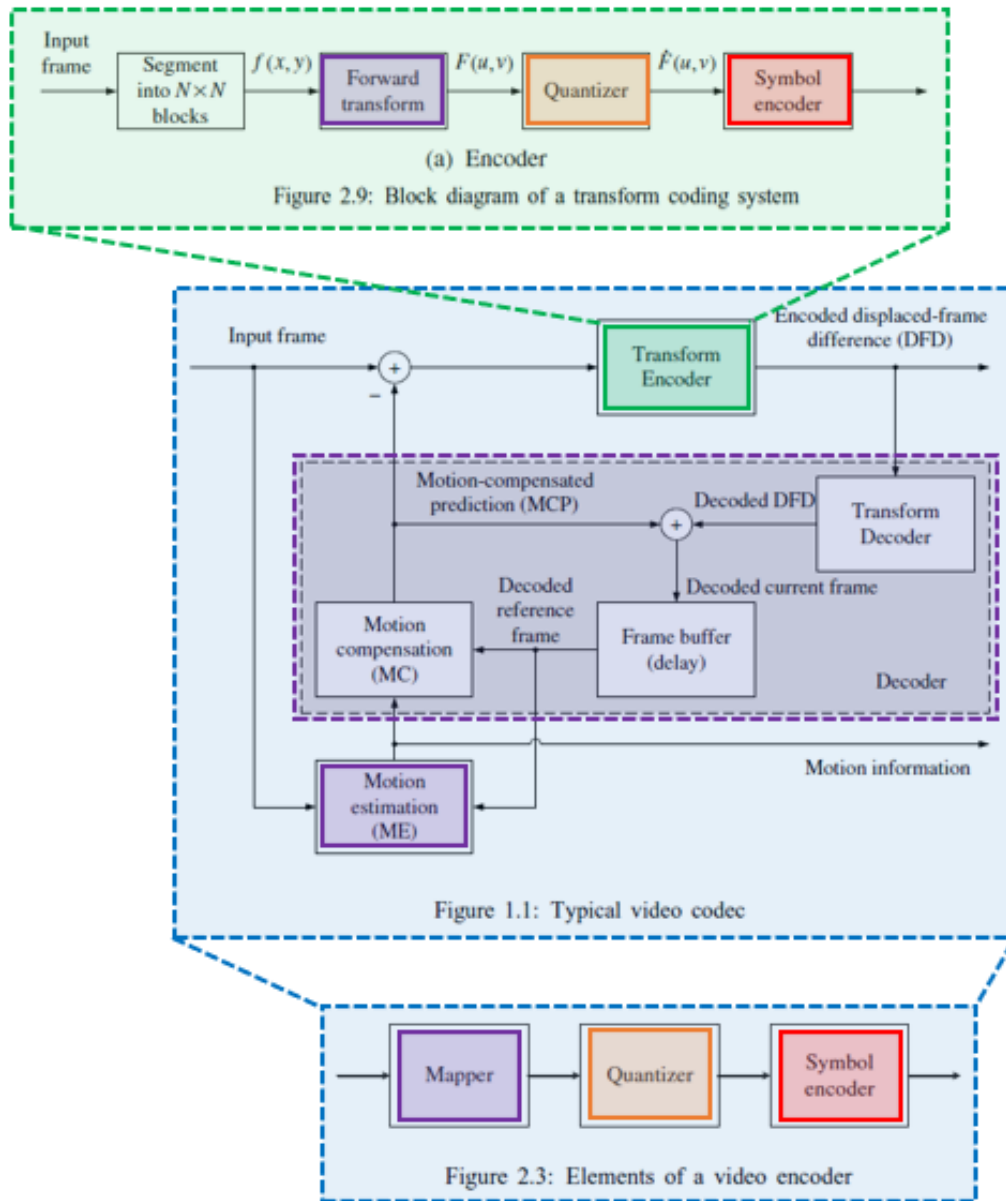


Diagram B (showing the relation between Mualla’s Figures 2.3, 1.1, and 2.9)

[1.8.COD], [2.3], [4.8.COD], [5.3], [9.6.COD]

177. Mualla’s “typical video codec” illustrates a component (“*a first subtractor*”) that subtracts the “[m]otion-compensated prediction (MCP)” (“*the first predictive picture*”) from an “[i]nput frame” (“*the picture to be coded*”) to produce,

after transform encoding, an “[e]ncoded displaced-frame difference (DFD)” (“*a first residual picture*”). APPLE-1005, 23-26, FIG. 1.1.

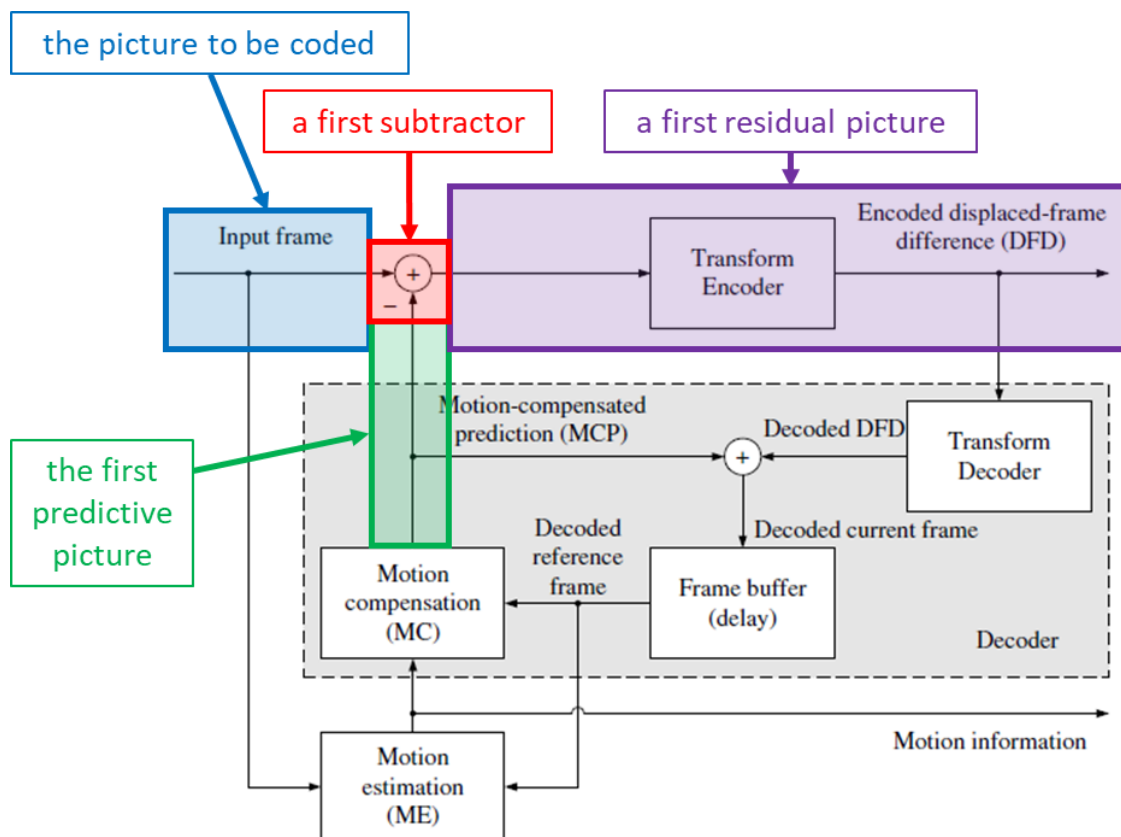


Figure 1.1: Typical video codec

APPLE-1005, FIG. 1.1 (annotated and color added).

3. Remaining limitations of Claims 1, 3-4, and 9

178. These limitations are obvious as explained above for the corresponding limitations listed in the following table.

Claim	Corresponding Claim
[1.1.COD], [4.1.COD], [9.1.COD]	[6.3.COD]
[1.2.COD], [4.2.COD], [9.2.COD]	[6.4.COD]

[1.3.COD], [4.3.COD], [9.3.COD]	[6.5.COD]
[1.4.COD], [1.5.COD], [4.4.COD], [4.5.COD], [9.4.COD]	[6.6.COD]
[1.6.COD], [4.6.COD], [9.5.COD]	[6.7.COD]
[1.7.COD], [4.7.COD]	[6.3.COD]
[1.9.COD], [1.10.COD], [3.2], [4.9.COD], [4.10.COD], [4.14.COD], [9.7.COD], [9.8.COD]	[6.2.COD]
[1.11.DEC], [4.11.DEC], [9.9.DEC]	[6.9.DEC]
[1.12.DEC], [4.12.DEC], [9.10.DEC]	[6.10.DEC]
[3.1], [4.13.COD]	[6.8.DEC]
[2.1], [5.1]	[6.2.COD]
[2.2], [5.2]	[6.14.DEC]
[2.4], [5.4]	[6.15.DEC]
[5.5]	[6.16.DEC]

VII. Ground 2B – Claims 1-10 are Obvious under 35 U.S.C. § 103 based on Mualla, Shirani, Saito, and Shimizu

A. Analysis

1. Claim 6

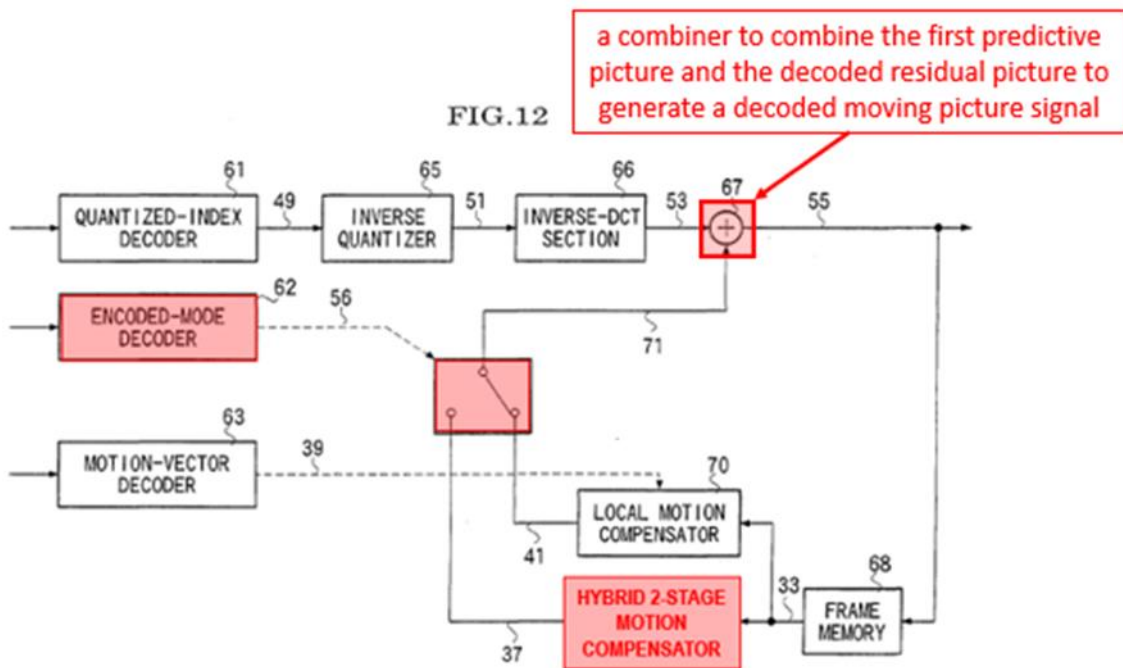
[6.pre]-[6.14.DEC]

179. Each of these elements are rendered obvious for the same reasons as discussed in their respective sections in Grounds 1A/1B above, supplemented with the additional remarks below. *Above*, VII.A.[6.pre]-[6.14.DEC]. Specifically, as explained in section VI.G, above, in the combination of Mualla, Shirani, Saito, and Shimizu, the

only change to Mualla's encoder and decoder is to add (i) a 2-stage hybrid motion compensated predictor using Poisson approximation techniques (as taught by Mualla-Shirani-Saito) and (ii) a selector/switch that selects between this 2-stage hybrid motion compensated predictor and Mualla's conventional motion estimator/compensator. As such, the basic operations of Mualla's encoder and decoder with respect to claim elements [6.pre]-[6.14.DEC] would remain unchanged in the Mualla-Shirani-Saito-Shimizu system operating in an error-free environment, with supplemental details of certain claim elements described below.

180. For [6.8.DEC], as explained in section VII.A, Mualla discloses both "border motion vector data" (motion vectors of neighboring blocks around the block to be encoded/decoded) and as explained in section VI.A, Mualla also discloses conventional "motion vector data" (motion vector of the block to be encoded/decoded). *Above*, VII.A.[6.8.DEC].

181. For [6.12.DEC], as explained in VI.A and VII.A, Mualla discloses a combiner that is implemented both in the encoder (APPLE-1005, Fig. 1.1) and in the decoder. APPLE-1005, 27, 76, FIG. 10.8; *Above* VII.A.[6.6.11.DEC]. Further, Shimizu provides an example of a combiner implemented in the decoder. APPLE-1024, Fig. 12, [0036] ("difference picture 53 and predicted picture 43 [output of switch 71 as shown in Fig. 11] are added to each other by adder 67 so that local decoded picture 55 is generated").

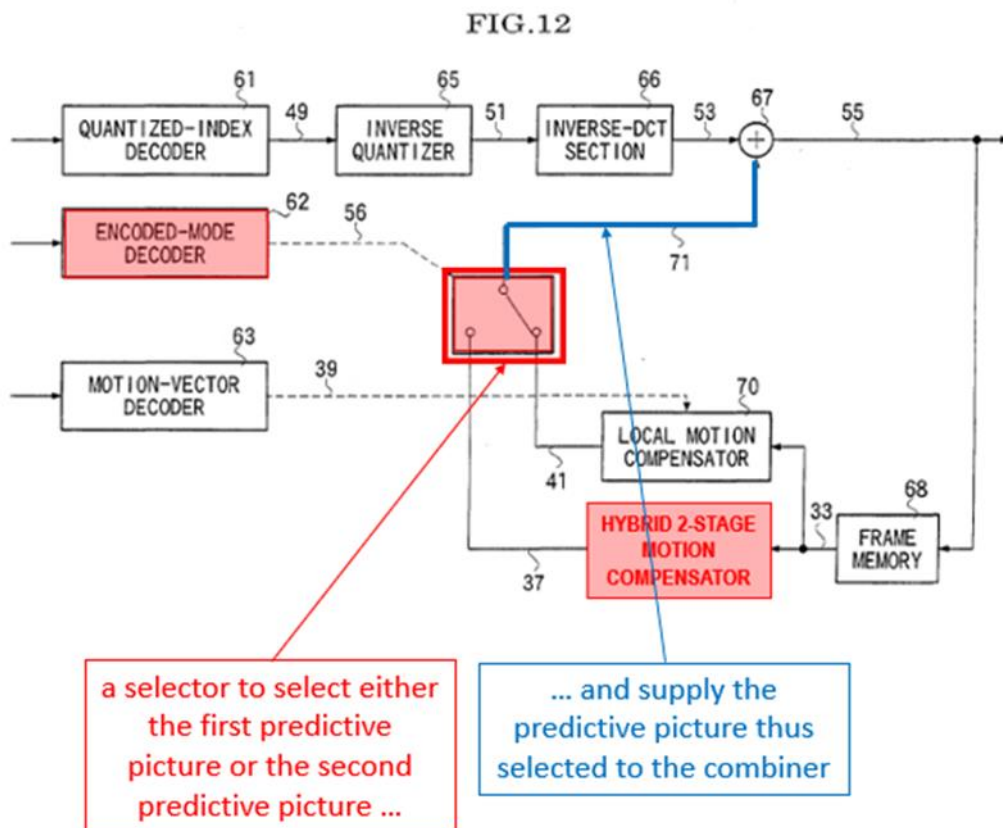


APPLE-1024, FIG. 12 (annotated and color added, modified to show the Mualla-Shirani-Saito hybrid 2-stage motion compensator implemented as the alternative motion compensator).

[6.15.DEC] a selector to select either the first predictive picture or the second predictive picture and supply the predictive picture thus selected to the combiner; and

182. Shimizu discloses that “encoded mode information 56 activates switch 71” (“a selector to select either the first predictive picture or the second predictive picture ...”) so that one of two motion compensation pictures is selected and provided to adder 67 (“... and supply the predictive picture thus selected to the combiner”). APPLE-1024, ¶¶[0034]-[0036], FIG. 12. In particular, the decoder’s switch 71 is controlled by encoded mode-choice information 56 which is received from

the encoded mode encoder 58 of the encoder (which communicates with the decoder's encoded mode decoder 62). *Id.*, ¶¶[0030]-[0033], FIG. 11.

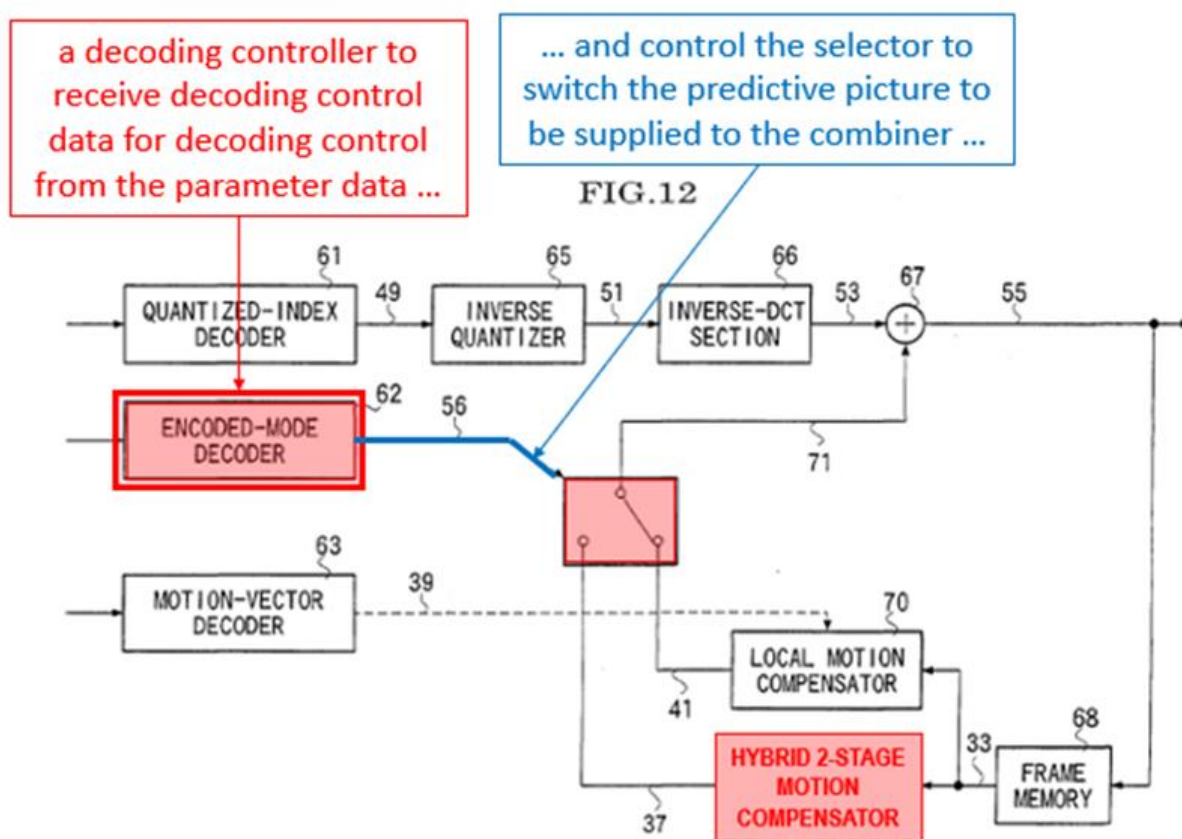


APPLE-1024, FIG. 12 (annotated and color added, modified to show the Mualla-Shirani-Saito hybrid 2-stage motion compensator implemented as the alternative motion compensator).

[6.16.DEC] a decoding controller to receive decoding control data for decoding control from the parameter data and control the selector to switch the predictive picture to be supplied to the combiner between the first and second predictive pictures according to the decoding control data.

183. As discussed above in 6.15.DEC, Shimizu discloses an “encoded-mode decoder 62” (“**a decoding controller**”) within the decoder that “decodes encoded-

mode choice information 56” (“... *to receive decoding control data for decoding control from the parameter data ...*”) that activates switch 71. APPLE-1024, ¶¶[0034]-[0036], FIG. 12. As discussed above in 6.15.DEC, switch 71 causes the selection of one of two motion compensation pictures, and in the combination of Mualla-Shirani-Saito-Shimizu, would have switched the mode of decoding between conventional motion compensation and the Mualla-Shirani-Saito two-stage hybrid motion compensated prediction (“... *and control the selector to switch the predictive picture to be supplied to the combiner between the first and second predictive pictures according to the de-coding control data*”). APPLE-1005, 247; APPLE-1024, ¶¶[0034]-[0036], FIG. 12.



APPLE-1024, FIG. 12 (annotated and color added, modified to show the Mualla-Shirani-Saito hybrid 2-stage motion compensator implemented as the alternative motion compensator).

2. Remaining claims 1-5, 7-10

184. Each of these claims are rendered obvious for the same reasons as discussed in Grounds 1A/1B above, in view of the additional disclosure of Shimizu discussed above with respect to elements [6.15.DEC]-[6.16.DEC]. *Above*, VII.A.

VIII. Additional Remarks

185. I currently hold the opinions set expressed in this declaration. But my analysis may continue, and I may acquire additional information and/or attain supplemental insights that may result in added observations.

APPENDIX A

LISTING OF CLAIMS

The claims of the Challenged Patents are shown below with a numeric mapping for ease of reference:

Claim 1	
[1.pre]	A moving-picture coding apparatus comprising:
[1.1.COD]	a predictive encoder to produce and encode a residual picture that is a residual signal between a picture to be coded that is an input moving-picture video signal to be subjected to coding and a predictive picture produced from a reference picture that is a local decoded video signal for each of a plurality of rectangular zones, each composed of a specific number of pixels, into which a video area of the moving-picture video signal is divided;
[1.2.COD]	a zone-border motion estimator to obtain a boundary condition of each of a plurality of borders between the rectangular zones and another plurality of rectangular zones adjacent to the rectangular zones,
[1.3.COD]	find a border, of the reference picture, having a boundary condition that matches the boundary condition, by motion-vector search in the reference picture,
[1.4.COD]	and generate border motion-vector data that is data on a motion vector from a border of the rectangular zone in the picture to be coded to the border of the reference picture thus found; and
[1.5.COD]	a zone-border motion compensator to define a boundary condition of a border that corresponds to the border motion vector data, from the reference picture based on the border motion-vector data,
[1.6.COD]	and generate an estimated video signal in each rectangular zone in the picture to be coded, that satisfies Poisson's Equation, thus producing a first predictive picture,
[1.7.COD]	wherein the predictive encoder produces the residual picture with the first predictive picture as the predictive picture and encodes the residual picture;
[1.8.COD]	said predictive encoder including a first subtractor to produce a first residual picture from a difference between the picture to be coded and the first predictive picture;
[1.9.COD]	an orthogonal transformer to perform orthogonal transform to the first residual picture, thus generating orthogonal-transform coefficients data;
[1.10.COD]	a quantizer to perform quantization to the orthogonal transform coefficients data based on a specific quantization parameter, thus generating post-quantization data;
[1.11.DEC]	an inverse-quantizer to perform inverse-quantization to the post-quantization data based on a specific quantization parameter, thus generating post-inverse-quantization data; and

[1.12.DEC]	an inverse-orthogonal transformer to perform inverse-orthogonal transform to the post-inverse-quantization data, thus producing a decoded residual picture.
Claim 2	
[2.1]	The moving-picture coding apparatus according to claim 1 wherein the predictive encoder further includes: a motion estimator to perform motion-vector search in the reference picture by block matching for each rectangular zone in the picture to be coded, thus generating motion vector data that indicates a matched rectangular zone in the reference picture;
[2.2]	a motion compensator to find a corresponding rectangular zone in the reference picture based on the motion-vector data, thus producing a second predictive picture;
[2.3]	a second subtractor to produce a second residual picture that is a difference between the second predictive picture and the picture to be coded; and
[2.4]	a residual determiner to compare the first predictive picture and the second predictive picture based on specific criteria, thus selecting the predictive picture having a smaller data amount.
Claim 3	
[3.1]	The moving-picture coding apparatus according to claim 1 wherein the predictive encoder includes an entropy encoder to perform entropy encoding, at least, to the post-quantization data and the border motion-vector data, thus generating coded bitstreams,
[3.2]	wherein the moving-picture coding apparatus comprises a multiplexer to multiplex the coded bitstreams based on a specific syntax structure.
Claim 4	
[4.pre]	A non-transitory computer readable device having stored thereon a computer program comprising a set of instructions when executed by a computer to implement a method for moving-picture coding, the program comprising:
[4.1.COD]	a predictive encoding program code to produce and encode a residual picture that is a residual signal between a picture to be coded that is an input moving-picture video signal to be subjected to coding and a predictive picture produced from a reference picture that is a local decoded video signal for each of a plurality of rectangular zones, each composed of a specific number of pixels, into which a video area of the moving-picture video signal is divided;
[4.2.COD]	a zone-border motion estimation program code to obtain a boundary condition of each of a plurality of borders between the rectangular zones and another plurality of rectangular zones adjacent to the rectangular zones,
[4.3.COD]	find a border, of the reference picture, having a boundary condition that matches the boundary condition, by motion-vector search in the reference picture,

[4.4.COD]	and generate border motion-vector data that is data on a motion vector from a border of the rectangular zone in the picture to be coded to the border of the reference picture thus found; and
[4.5.COD]	a zone-border motion compensation program code to define a boundary condition of a border that corresponds to the border motion vector data, from the reference picture based on the border motion-vector data,
[4.6.COD]	and generate an estimated video signal in each rectangular zone in the picture to be coded, that satisfies Poisson's Equation, thus producing a first predictive picture,
[4.7.COD]	wherein the predictive encoding program code produces the residual picture with the first predictive picture as the predictive picture and encodes the residual picture;
[4.8.COD]	said predictive encoding program code including a first subtraction program code to produce a first residual picture from a difference between the picture to be coded and the first predictive picture;
[4.9.COD]	an orthogonal transform program code to perform orthogonal transform to the first residual picture, thus generating orthogonal-transform coefficients data;
[4.10.COD]	a quantization program code to perform quantization to the orthogonal-transform coefficients data based on a specific quantization parameter, thus generating post-quantization data;
[4.11.DEC]	an inverse-quantization program code to perform inverse-quantization to the post-quantization data based on a specific quantization parameter, thus generating post-inverse-quantization data;
[4.12.DEC]	an inverse-orthogonal transform program code to perform inverse-orthogonal transform to the post-inverse-quantization data, thus producing a decoded residual picture; and
[4.13.COD]	an entropy coding program code to perform entropy coding, at least, to the post-quantization data and the border motion-vector data, thus generating coded bit strings,
[4.14.COD]	wherein the moving-picture coding program further comprises multiplex program code to multiplex the coded bit strings based on a specific syntax structure, thus generating a coded bitstream.
Claim 5	
[5.1]	The moving-picture coding program code according to claim 4 wherein the predictive encoding program code further includes: a motion estimation program code to perform motion-vector search in the reference picture by block matching for each rectangular zone in the picture to be coded, thus generating motion-vector data that indicates a matched rectangular zone in the reference picture;
[5.2]	a motion compensation program code to find a corresponding rectangular zone in the reference picture based on the motion-vector data, thus producing a second predictive picture;

[5.3]	a second subtraction program code to produce a second residual picture that is a difference between the second predictive picture and the picture to be coded; and
[5.4]	a selection program code to compare the first predictive picture and the second predictive picture based on specific criteria, thus selecting the predictive picture having a smaller data amount,
[5.5]	wherein the moving-picture coding program code further comprises a coding control program code to perform control to supply the selected residual picture and a predictive picture corresponding to the residual picture to the predictive encoding program code.
Claim 6	
[6.pre]	A moving-picture decoding apparatus comprising:
[6.1.DEC]	a demultiplexer to demultiplex coded data from an input signal based on a specific syntax structure,
[6.2.COD]	the input signal being obtained by multiplexing a coded bitstream obtained by predictive coding, border motion-vector data and post-quantization data obtained by quantization in the predictive coding,
[6.3.COD]	the coded bitstream obtained by producing and encoding a residual picture that is a residual signal between a picture to be coded that is an input moving-picture video signal to be subjected to coding and a predictive picture produced from a reference picture that is a local decoded video signal for each of a plurality of rectangular zones, each composed of a specific number of pixels, into which a video area of the moving-picture video signal is divided,
[6.4.COD]	obtaining a boundary condition of each of a plurality of borders between the rectangular zones and another plurality of rectangular zones adjacent to the rectangular zones,
[6.5.COD]	finding a border, of the reference picture, having a boundary condition that matches the boundary condition, by motion-vector search in the reference picture,
[6.6.COD]	and generating the border motion-vector data that is data on a motion vector from a border of the rectangular zone in the picture to be coded to the border of the reference picture thus found, defining a boundary condition of a border that corresponds to the border motion vector data, from the reference picture based on the border motion vector data,
[6.7.COD]	and generating an estimated video signal in each rectangular zone in the picture to be coded, that satisfies Poisson's Equation, thus producing the predictive picture;
[6.8.DEC]	an entropy decoder to perform entropy decoding to the data thus demultiplexed to generate, at least, motion-vector data, the post-quantization data, the border motion-vector data and parameter data required for constructing a specific syntax structure;

[6.9.DEC]	an inverse-quantizer to perform inverse-quantization to the post-quantization data to generate post-quantization orthogonal transform coefficients data;
[6.10.DEC]	an inverse-orthogonal transformer to perform inverse-orthogonal transform to the post-quantization orthogonal transform coefficients data to produce a decoded residual picture of one video area;
[6.11.DEC]	a zone-border motion compensator to define a boundary condition of a border that corresponds to the border motion vector data, from the reference picture based on the border motion-vector data, and generate an estimated video signal in each rectangular zone in the picture to be coded, that satisfies Poisson's Equation, thus producing a first predictive picture;
[6.12.DEC]	a combiner to combine the first predictive picture and the decoded residual picture to generate a decoded moving picture signal;
[6.13.DEC]	a memory to store the decoded moving-picture signal for at least one picture as a reference picture;
[6.14.DEC]	a motion compensator to specify a corresponding rectangular zone in the reference picture based on the motion vector data, thus generating a second predictive picture;
[6.15.DEC]	a selector to select either the first predictive picture or the second predictive picture and supply the predictive picture thus selected to the combiner; and
[6.16.DEC]	a decoding controller to receive decoding control data for decoding control from the parameter data and control the selector to switch the predictive picture to be supplied to the combiner between the first and second predictive pictures according to the decoding control data.
Claim 7	
[7.pre]	A non-transitory computer readable device having stored thereon a computer program comprising a set of instructions when executed by a computer to implement a method for moving-picture decoding, the program comprising:
[7.1.DEC]	a demultiplex program code to demultiplex coded data from an input signal based on a specific syntax structure,
[7.2.COD]	the input signal being obtained by multiplexing a coded bitstream obtained by predictive coding, border motion vector data and post-quantization data obtained by quantization in the predictive coding,
[7.3.COD]	the coded bitstream obtained by producing and encoding a residual picture that is a residual signal between a picture to be coded that is an input moving-picture video signal to be subjected to coding, and a predictive picture produced from a reference picture that is a local decoded video signal for each of a plurality of rectangular zones, each composed of a specific number of pixels, into which a video area of the moving-picture video signal is divided,
[7.4.COD]	obtaining a boundary condition of each of a plurality of borders between the rectangular zones and another plurality of rectangular zones adjacent to the rectangular zones,

[7.5.COD]	finding a border, of the reference picture, having a boundary condition that matches the boundary condition, by motion-vector search in the reference picture,
[7.6.COD]	and generating the border motion-vector data that is data on a motion vector from a border of the rectangular zone in the picture to be coded to the border of the reference picture thus found, defining a boundary condition of a border that corresponds to the border motion vector data, from the reference picture based on the border motion vector data,
[7.7.COD]	and generating an estimated video signal in each rectangular zone in the picture to be coded, that satisfies Poisson's Equation, thus producing the predictive picture;
[7.8.DEC]	an entropy decoding program code to perform entropy decoding to the data thus demultiplexed to generate, at least, the post-quantization data, the border motion-vector data and parameter data required for constructing a specific syntax structure;
[7.9.DEC]	an inverse-quantization program code to perform inverse-quantization to the post-quantization data to generate post-quantization orthogonal transform coefficients data;
[7.10.DEC]	an inverse-orthogonal transform program code to perform inverse-orthogonal transform to the post-quantization orthogonal transform coefficients data to produce a decoded residual picture of one video area;
[7.11.DEC]	a zone-border motion compensation program code to define a boundary condition of a border that corresponds to the border motion vector data, from the reference picture based on the border motion-vector data, and generate an estimated video signal in each rectangular zone in the picture to be coded, that satisfies Poisson's Equation, thus producing a first predictive picture; and
[7.12.DEC]	a combine program code to combine the first predictive picture and the decoded residual picture to generate a decoded moving-picture signal, the decoded moving-picture signal for at least one picture being stored as a reference picture.
Claim 8	
[8.pre]	The moving-picture decoding program according to claim 7 wherein the entropy decoding program code further generates motion-vector data, the program further comprises:
[8.1]	a motion compensation program code to specify a corresponding rectangular zone in the reference picture based on the motion-vector data, thus generating a second predictive picture;
[8.2]	a selection program code to select either the first predictive picture or the second predictive picture and supply the predictive picture thus selected to the combiner; and
[8.3]	a decoding controlling program code to receive decoding control data for decoding control from the parameter data and control the selector to switch

	the predictive picture to be supplied to the combiner between the first and second predictive pictures according to the decoding control data.
Claim 9	
[9.pre]	A moving-picture coding method to be implemented in a moving-picture coding apparatus comprising the steps of:
[9.1.COD]	producing and encoding a residual picture that is a residual signal between a picture to be coded that is an input moving-picture video signal to be subjected to coding and a predictive picture produced from a reference picture that is a local decoded video signal for each of a plurality of rectangular zones, each composed of a specific number of pixels, into which a video area of the moving-picture video signal is divided;
[9.2.COD]	obtaining a boundary condition of each of a plurality of borders between the rectangular zones and another plurality of rectangular zones adjacent to the rectangular zones
[9.3.COD]	finding a border, of the reference picture, having a boundary condition that matches the boundary condition, by motion-vector search in the reference picture,
[9.4.COD]	and generating border motion-vector data that is data on a motion vector from a border of the rectangular zone in the picture to be coded to the border of the reference picture thus found; defining a boundary condition of a border that corresponds to the border motion vector data, from the reference picture based on the border motion-vector data,
[9.5.COD]	and generating an estimated video signal in each rectangular zone in the picture to be coded, that satisfies Poisson's Equation, thus producing a first predictive picture;
[9.6.COD]	producing a first residual picture from a difference between the picture to be coded and the first predictive picture;
[9.7.COD]	performing orthogonal transform to the first residual picture, thus generating orthogonal-transform coefficients data;
[9.8.COD]	performing quantization to the orthogonal-transform coefficients data based on a specific quantization parameter, thus generating post-quantization data;
[9.9.DEC]	performing inverse-quantization to the post-quantization data based on a specific quantization parameter, thus generating post-inverse-quantization data; and
[9.10.DEC]	performing inverse-orthogonal transform to the post-inverse quantization data, thus producing a decoded residual picture.
Claim 10	
[10.pre]	A moving-picture decoding method to be implemented in a moving-picture coding apparatus comprising the steps of:
[10.1.DEC]	demultiplexing coded data from an input signal based on a specific syntax structure,

[10.2.COD]	the input signal being obtained by multiplexing a coded bitstream obtained by predictive coding, border motion-vector data and post-quantization data obtained by quantization in the predictive coding,
[10.3.COD]	the coded bitstream obtained by producing and encoding a residual picture that is a residual signal between a picture to be coded that is an input moving-picture video signal to be subjected to coding, and a predictive picture produced from a reference picture that is a local decoded video signal for each of a plurality of rectangular zones, each composed of a specific number of pixels, into which a video area of the moving-picture video signal is divided,
[10.4.COD]	obtaining a boundary condition of each of a plurality of borders between the rectangular zones and another plurality of rectangular zones adjacent to the rectangular zones,
[10.5.COD]	finding a border, of the reference picture, having a boundary condition that matches the boundary condition, by motion-vector search in the reference picture,
[10.6.COD]	and generating the border motion-vector data that is data on a motion vector from a border of the rectangular zone in the picture to be coded to the border of the reference picture thus found, defining a boundary condition of a border that corresponds to the border motion vector data, from the reference picture based on the border motion-vector data,
[10.7.COD]	and generating an estimated video signal in each rectangular zone in the picture to be coded, that satisfies Poisson's Equation, thus producing the predictive picture;
[10.8.DEC]	performing entropy decoding to the data thus demultiplexed to generate, at least, the post-quantization data, the border motion-vector data and parameter data required for constructing a specific syntax structure;
[10.9.DEC]	performing inverse-quantization to the post-quantization data to generate post-quantization orthogonal transform coefficients data;
[10.10.DEC]	performing inverse-orthogonal transform to the post-quantization orthogonal transform coefficients data to produce a decoded residual picture of one video area;
[10.11.DEC]	defining a boundary condition of a border that corresponds to the border motion vector data, from the reference picture based on the border motion-vector data, and generate an estimated video signal in each rectangular zone in the picture to be coded, that satisfies Poisson's Equation, thus producing a first predictive picture;
[10.12.DEC]	combining the first predictive picture and the decoded residual picture to generate a decoded moving-picture signal; and
[10.13.DEC]	storing the decoded moving-picture signal for at least one picture as a reference picture.

APPENDIX B

UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE PATENT TRIAL AND APPEAL BOARD

Samsung Electronics Co. Ltd. and Samsung Electronics America, Inc.
"Samsung"
Petitioners

v.

Advanced Coding Technologies, LLC
"ACT"
Patent Owner

INTER PARTES REVIEW OF U.S. PATENT NO. 8,090,025

DECLARATION OF DR. CLIFFORD READER

I declare that all statements made in this declaration on 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.

Date: 11/8/24,

By: 

Clifford Reader, Ph.D.

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I, Clifford Reader, Ph.D., do hereby declare:

1. I am making this declaration at the request of Samsung in the matter of *INTER PARTES* REVIEW OF U.S. PATENT NO. 8,090,025, “the ’025 Patent.”

2. I am being compensated for my work in this matter at my standard hourly rate of \$750 for consulting services. My compensation in no way depends on the outcome of this proceeding or the content of my testimony.

3. In preparing this Declaration, I considered the following materials:
- (a) U.S. Patent No. 8,090,025 (“the ’025 Patent”) (Exhibit SAMSUNG-1001)
 - (b) The Prosecution History of the ’025 Patent (Exhibit SAMSUNG-1002)
 - (c) Al-Mualla, et al., “Video Coding for Mobile Communications: Efficiency, Complexity and Resilience,” Elsevier, 2002 (Exhibit SAMSUNG-1005)
 - (d) S. Shirani, et al., “A Concealment Method for Video Communications in an Error-Prone Environment,” in *IEEE Journal on Selected Areas in Communications*, vol. 18, no. 6, pp. 1122-1128, June 2000 (Exhibit SAMSUNG-1006)
 - (e) N. Saito, et al., “The Polyharmonic Local Sine Transform: A New Tool for Local Image Analysis and Synthesis without Edge Effect,” *Applied and Computational Harmonic Analysis*, vol. 20, pp. 41-73, 2006 (Exhibit SAMSUNG-1007)

- (f) B. Girod, et al., “Feedback-Based Error Control for Mobile Video Transmission,” in Proceedings of the IEEE, vol. 87, no. 10, pp. 1707-1723, Oct. 1999 (Exhibit SAMSUNG-1008)
- (g) T. Stockhammer, et al., “H.264/AVC in Wireless Environments,” in IEEE Trans. on Circuits and Systems for Video Tech., vol. 13, no. 7, July 2003 (Exhibit SAMSUNG-1009)
- (h) Perez, et al., “Poisson Image Editing,” ACM, ACM Transactions on Graphics (TOG), vol. 22, Issue 3, Jul. 2003, pp. 313-318 (Exhibit SAMSUNG-1010)
- (i) Wexler, et al., “Space-Time Video Completion,” In Proc. IEEE Comput. Soc. Conf. Computer Vision and Pattern Recognition, 2004, pp. 120 –127 (Exhibit SAMSUNG-1011)
- (j) Raskar, et al., “Image Fusion for Context Enhancement and Video Surrealism,” Proceedings of the 3rd Symposium on Non-Photorealistic Animation and Rendering, 2004, pp. 85-152 (Exhibit SAMSUNG-1012)
- (k) Sun, et al., “Poisson Matting,” ACM Transactions on Graphics (Tog), Special Issue: Proceedings of the 2004 Siggraph Conference Session: Interacting With Images, vol. 23, Issue 3, 2004, pp. 315-321 (Exhibit SAMSUNG-1013)
- (l) U.S. Patent No. 7,636,128 B2 to Sun, et al. (Sun-128) (Exhibit SAMSUNG-1014)

- (m) Fattal, et al., “Gradient Domain High Dynamic Range Compression,” In Proceedings of ACM SIGGRAPH, 2002, 249–256 (Exhibit SAMSUNG-1015)
- (n) ITU-T Rec. H.263 (01/2005) (“the H.263 standard”) (Exhibit SAMSUNG-1016)
- (o) M. Wada, “Selective Recovery of Video Packet Loss Using Error Concealment,” IEEE Journal on Selected Areas of Communication, vol. 7, pp. 807–814, June 1989 (Exhibit SAMSUNG-1017)
- (p) ITU-T Rec. H.263 (02/1998) (Exhibit SAMSUNG-1021)
- (q) List, et al., “Adaptive Deblocking Filter,” IEEE Journal on Circuits and Systems for Video Technology, vol. 13, pp. 614-619, July 200 (Exhibit SAMSUNG-1022)

I. Professional Background

A. Summary

5. I am a digital media consultant providing technical, business development and intellectual property consulting services in the areas of digital media including digital imaging, digital video, digital audio and digital speech. Applications include consumer audio and video transmission and storage; video, audio and speech compression; real-time video processing and display; digital speech processing; image/video/audio systems architecture; and image/video/audio chip architecture. I have held this position since 2001 and have consulted for over 80 clients.

B. Education

6. I received my Doctoral degree in 1974 from the University of Sussex, England. My thesis was titled "Orthogonal Transform Coding of Still and Moving Pictures." The research for my thesis was performed in residence at the Image Processing Institute, University of Southern California, Los Angeles.

7. I received my B. Eng. Degree with Honors in 1970 from the University of Liverpool, England, in the field of electronics.

C. Work Experience

8. From 1970 to 1973 I performed my graduate research in video compression. I was one of the first to perform a type of image coding (adaptive block

transform coding) and the first to apply this type of coding to video. This is described in my thesis and summarized in an SPIE paper. SAMSUNG-1022. These techniques underlie the audiovisual coding standards known as MPEG (Moving Picture Experts Group), H.26x, and virtually all other video compression schemes today.

9. From 1975 to 1981 I studied, designed and developed systems for military imaging systems including real-time image and video reconnaissance systems and battlefield management systems.

10. In the early 1980s I taught classes at Santa Clara University, California in digital signal processing and digital image processing.

11. From 1982 to 1989 I architected and led hardware and software engineering teams in the design of systems for real-time imaging for military, medical and earth resources applications.

12. From 1990 to 2001 I architected and led hardware and software engineering teams in the design of semiconductor chips and systems for real-time imaging in digital consumer audio/video applications, including videoconferencing (with speech coding), broadcast TV and DVD.

D. Standardization

13. In 1990 I became an accredited delegate to the Moving Picture Experts Group – MPEG. I, and my team contributed to the technical work for all three parts

of the standard – Systems, Video and Audio – and I participated in the management of the MPEG committee.

14. I was Head of Delegation (HoD) to MPEG for the United States in 1991-1992, during which time the MPEG1 standard was completed and the MPEG2 standard was successfully positioned as the global standard for digital video broadcasting and recording (DVD). I was the Editor in Chief of the MPEG1 standard. I personally reviewed and edited all three parts of the standard in detail, and wrote much of the informative annex for the MPEG1 standard. I participated in the technical and management work for development of the MPEG2 standard.

15. I chaired the implementation subcommittee that analyzed MPEG1 Audio (Levels I & II aka MUSICAM; Level III aka mp3), Dolby AC3 and other proposed audio compression algorithms including legacy algorithms for complexity and cost of implementation.

16. I was a co-founder of the MPEG4 standard and chaired the subcommittee from inception for 2-1/2 years, beginning in 1993, following which I chaired the MPEG4 Requirements subcommittee for a further 2 years. These subcommittees established many of the fundamental principles of the MPEG4 standard, including object-based coding, software-based implementation, and development of the bitstream as a syntactic language. *E.g.* MPEG4 focused on audiovisual low bitrate coding, including low bitrate speech coding.

17. The MPEG4 standard in ISO and the H.263 standard in ITU-T were developed collaboratively, with the H.263 Rapporteur and I synchronizing meetings and establishing profiles in each standard that are precisely compatible.

18. I was instrumental in establishing the work on Advanced Audio Coding (AAC).

19. I initiated the work in Synthetic-Natural Hybrid Coding (SNHC), and personally contributed to the work on compression of 3D graphics in the area of error resilient coding.

20. In the early 2000s, I was an invited expert to the Joint Video Team (JVT) established by ISO and ITU to develop the H.264 standard (also denoted MPEG4 Pt. 10, AVC). I was also invited to become an officer of the China National Standards committee AVS, in which I chair the Intellectual Property Rights Subgroup.

21. I have closely followed the developments of the H.265 and H.266 standards.

E. Intellectual Property Rights

22. In 1993 I was hired by CableLabs to be the technical expert for establishing the MPEG Patent Pool (Now MPEGLA). In the course of creating a list of essential IP to practice the standard, I reviewed approximately 10,000 abstracts and 1,000 patents. This is summarized in a chapter of the MPEG book by Mitchell et al. SAMSUNG-1023.

23. Multiple companies have hire me to assist in developing portfolios of their standards-essential patents.

24. In 2002 I was hired by 10 companies to evaluate the standards essential patent environment for the nascent H.264 standard.

25. In 2003 I was hired to evaluate the standards essential patent environment for the nascent national China AVS standards.

26. In 2013 I was hired to evaluate the standards essential patent environment for the nascent AV1 standard.

27. In 2017 I was hired to evaluate the standards essential patent environment for the H.265/HEVC standard.

28. I am the Co-Director of the China AVS Patent Pool Administration. I lead the negotiations for sub-licensing of the AVS standards. In 2022 I played a leading role in the adoption of the AVS3 video standard by DVB.

29. I have performed expert consulting and expert witness work for patent holders and defendants in patent licensing negotiations and litigation.

F. Curriculum Vitae

30. Additional information concerning my professional publications and presentations in the field of digital video and cases in which I have served as an expert are set forth in my current Curriculum Vitae, a copy of which is attached as Exhibit A.

This Curriculum Vitae lists many publications authored or co-authored by me; and lists the cases in which I have testified via depositions and trials.

II. Digital Video Technologies

31. Below I describe the state of digital video coding as of the '025 Patent's earliest claimed priority date (April 17, 2006), and summarize the development of technologies underlying the features and methods recited in claims 1-2.

A. Analog Video

32. Like film, video comprises a rapid sequence of still images that the human vision system integrates into a perception of motion. The “moving images” are often called video frames and video pictures.

33. All-electronic television¹ was invented by Philo Farnsworth in the late 1920s. Farnsworth developed the technique of raster scanning images and produced cameras and CRTs (cathode ray tubes) that could synchronously acquire and reproduce moving images.

34. All-electronic television service was introduced by the BBC in England in November 1936. Broadcasting of television programs continued until interrupted by the Second World War. Television service began in the U.S. in July 1941. These services provided only black-and-white video until 1953, when the NTSC standard in

¹ Electro-mechanical television systems were also introduced.

the U.S. was revised to include color. Analog broadcasting continued in the U.S. for almost seventy years. Full-power analog television broadcasting ceased in 2009 under order from the FCC.

B. Digital Video

35. Digitization of analog signals in general was introduced in the late 1940s with the name “pulse code modulation” (PCM). Fundamental sampling theory showed that a bandwidth-limited analog signal could be sampled at twice the rate of the highest frequency in the band, and still be perfectly reconstructed from such samples. The sample amplitudes could be represented by the value of a number, *e.g.*, a decimal value or a binary value. In the case of image or video data, it has been widespread practice to represent this value by an unsigned 8-bit integer. Analog TV signals that scanned a video frame were digitized into two-dimensional arrays of digital picture elements, known as “pels” or “pixels.” Digital video, like analog video (and film) comprises a rapid sequence of frames.

36. PCM was followed in 1952 by the invention at Bell Labs of differential pulse code modulation, (DPCM), which was immediately applied to video. Because the correlation between pixels in typical scenes was high, it was efficient to code the pixels by successively predicting each pixel from the preceding pixel or pixels. AT&T demonstrated its Picturephone in 1964 at the World’s Fair. Subsequently, commercial Picturephone service was introduced in 1970, using DPCM coding.

37. Digital video was introduced in the professional television studio environment with the CCIR 601 standard that was developed in the early 1980s and published in 1982 (now known as the ITU-R BT.601 standard). The standard covered PCM data formats for the NTSC and PAL video standards and facilitated the development of modern production and post-production studios, involving non-linear editing, digital switchers, and mixers, as well as digital special effects.

38. Digital video in its raw format is highly redundant. Each video frame comprises a regular, rectangular array of pixels. The density of the pixel array is chosen such as to portray the highest spatial resolution enabled by a particular video system. Historically, the earliest systems portrayed 400-500 lines of resolution. The so-called HDTV systems introduced in the 1990s doubled the number of lines to 1000 lines, and the recent so-called 4K systems double the number of lines again to 2000 lines. The imminent next generation of so-called 8K systems will further double the number of lines to 4000 lines, which will approximate the resolution of a 35mm film system.

39. Historically the frame rate was 30 frames per second, but one of the HDTV formats doubled this to 60 frames per second.

40. Transmission or storage of raw digital video data requires huge volumes of data and very fast data rates. Transmitting standard definition color TV with a format of 720x486 pixels and 30 frames/s would require over 250Mbits/s. HDTV would

require approximately 5 times as much data and so-called 4K TV (UHDTV) at 60 frames/s would require approximately 40 times as much data.

41. Within a given scene being imaged by a video system, the content is very likely not to contain the highest level of detail except in a few, small areas. While a prescribed density of pixels may accurately describe such high detail areas, that density of pixels is overkill for the rest of the scene to a greater or lesser degree. So the typical digital video frame is spatially redundant. For example, if the video scene contains the sky, or a uniformly painted wall, adjacent pixels will have almost identical intensity and color.

42. The frame rate of the video is established to smoothly portray the fastest motion the system is designed to support. But such motion may occur only a fraction of the time, and may occur only over a portion of a frame spatially. So the typical video sequence of frames is temporally redundant. For example, sportscasters sitting at a desk demonstrate little motion over only a portion of the scene, but when they cut away to basketball, the action is frenetic and may be scene-wide. In the former case the pixel values will be almost identical from one frame to the next over most of the frame.

C. Video Coding

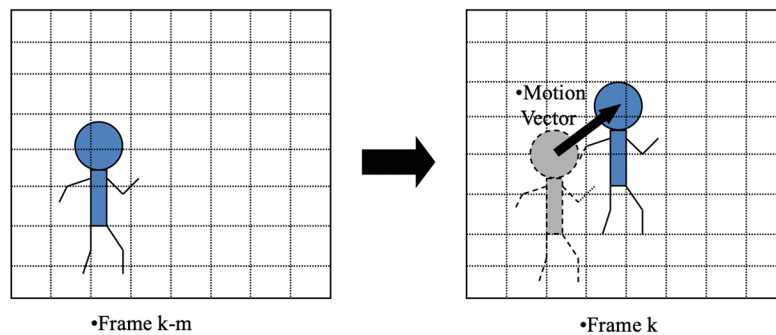
43. Video coding, also known as video compression is the art of removing the spatial and temporal redundancy to enable storage or transmission of digital video data with vastly fewer bits, while preserving the quality of the raw video data to the maximum

extent possible. Expressed another way, video coding is the art of representing the information in a video sequence with the least data (i.e., the fewest bits) and the highest reconstructed quality.

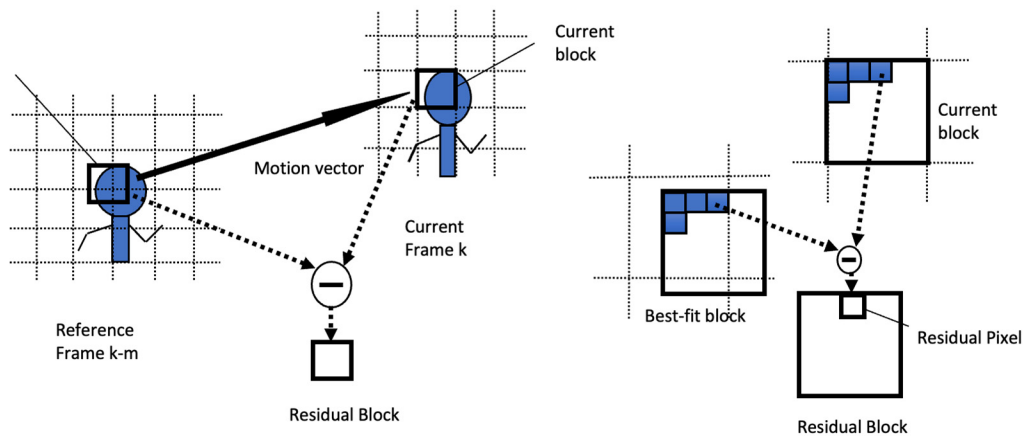
44. Video coding is not performed by a single algorithm, rather it comprises a set of video coding tools, each designed to tackle a particular aspect of reducing the redundancy of raw video data. Some video tools tackle the spatial redundancy, while other tools tackle the temporal redundancy. In each case, the tools attempt to identify and extract the visual information perceived by the human vision system. This information is then encoded into a video bitstream.

45. The fundamental research for video coding was performed in the 1960s and 1970s. By the end of the 1970s, a so-called hybrid architecture had been developed that remains today as the foundation for almost all video coding standards. Temporal redundancy is removed using block-based motion compensation. This is based on a model of motion in which objects within a scene generally do not change, but rather move from one location in the scene to another. On a block basis, this model works well. The following figures I assembled illustrate the point:

- **Model: Motion consists of translation in the viewing plane.**



46. Thus for each block in a current frame, a search is made to find a best match to the block in a “reference” frame that has already been coded. The best-matched block is used as a prediction for the current block. The difference between the pixel values of the current block and the pixel values of the prediction block is called the residual data. The location of the best match block in the reference frame relative to the location of the current block is called a motion vector. The residual data block and the motion vector are coded, and typically comprise a small fraction of the amount of data needed to code the current block alone. The following figures I assembled illustrate the point:



47. For blocks that cannot be temporally predicted efficiently, spatial prediction within the same frame is applied. In both cases the blocks of residual data may still contain spatial redundancy within the block. This redundancy is reduced using transform coding techniques.

48. The nature of video data is highly variable, both spatially and temporally. Some video sequences contain high levels of spatial detail. Such detail may span across the whole video frame or may be confined to local areas of the video frame. Some video sequences contain high degrees of movement that also may span across the whole video frame, such as when a camera is panning rapidly across a scene, or may be localized within the video frame. Video coding is performed in a highly adaptive way, by breaking each video frame into small blocks and adapting the spatial and temporal coding to the characteristics of the data on a local basis.

49. The temporal and spatial information is entropy coded to efficiently represent it and is then formatted into a bitstream.

50. The adaptive coding of video results in a highly variable instantaneous bitrate – it is obvious the volume of data produced when a ball is snapped in a football game is vastly higher than that produced during a time-out. As a result, the entropy coded bitstream at the encoder is buffered in order to smooth out at least some of the variation in data rate before transmission or storage and there is a corresponding buffer at the input to the decoder.

51. Video coding in particular has been characterized by the difficulty and cost involved in implementing coding algorithms for use in mass-market consumer applications. The volume of video data is very large, and the requirement for presenting video data that has been transmitted or retrieved from storage in real-time has been very challenging. As a consequence, while researchers in the field have conceived of sophisticated mathematical algorithms and procedures for video coding for decades, practical implementation has had to wait for semiconductor technology to pass certain thresholds.

D. Video Coding Standards

1. Background

52. Two international bodies are responsible for audiovisual standards – the ITU-T and ISO/IEC. Throughout the last three decades, these bodies have collaborated to develop generations of standards, most frequently publishing identical texts under their own standardization programs.

53. In general, the standardization process has followed the practice of beginning with a requirements gathering stage, leading to a call for proposals and evaluation stage, and then a development stage. In the development stage, the draft standard, and complementary reference software, are iterated from one meeting to the next. Owing to the highly variable nature of video data, the experts propose techniques to develop a particular coding tool and perform experiments using the reference software and selected test sequences to determine whether or not, and under what circumstances, a proposed technique improves the draft coding standard. Frequently, a technique brings improvement under specific, limited circumstances, so it is common practice for a tool to be switched on and off for local regions of the video sequence (spatially and/or temporally), or for parameters of a coding tool to be locally adjusted. In this sense, the development of a standard and attendant adoption of coding tools is an ad hoc process based upon empirical evidence.

54. The structure of standards for audiovisual coding has comprised an audio/speech coding part, video coding part, and a “systems” part. The audio/speech and video parts establish standards normatively specifying precise formats for coded bitstreams dedicated exclusively to audio/speech and video respectively. These may be called elementary bitstreams. For audiovisual applications such as broadcast television, these elementary bitstreams are combined into a single bitstream by the system part.

2. The MPEG1 Standards

55. The MPEG committee established requirements for the MPEG1 standard and called for proposals in 1989. Many of the resulting proposals were based on the preceding work for the H.261 videoconferencing standard, indeed, MPEG1 may be viewed as an extension of that standard. But for MPEG1, the requirements were focused on a digital replacement for the analog VCR, and included trick play modes such fast-forward, fast rewind and reverse play. Multiple responses to the call proposed groups of pictures as a mechanism to meet these requirements. During the ensuing development of the standard, the Group Of Pictures (GOP) data structure was defined.

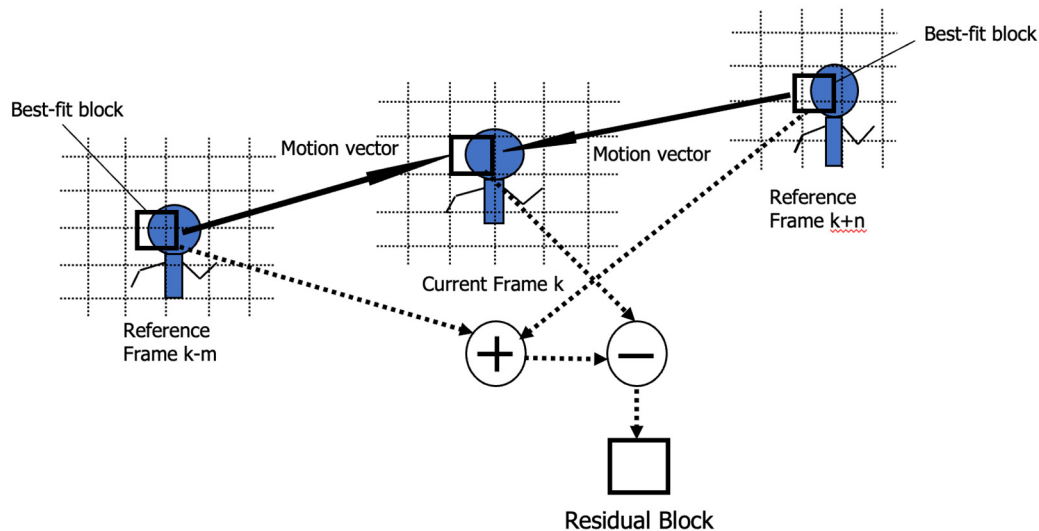
2.1.71 group of pictures [video]: A series of one or more coded pictures intended to assist random access. The group of pictures is one of the layers in the coding syntax defined in this part of ISO/IEC 11172.

SAMSUNG-1015, 6.

The group of pictures must contain an I-picture, may contain P-pictures and B-pictures and can be any length greater than or equal to one I-picture. SAMSUNG-1015, 15-16. In MPEG1, the coding order and display order of the pictures of the GOP can be different from each other. *Id.*

56. The MPEG1 standard, which is incorporated by reference in this declaration in full, introduced a highly efficient method of temporal coding called bi-directional prediction. This was subsequently adopted by the MPEG2 standard. In this method, multiple video frames are buffered prior to encoding and the coded data for multiple frames are buffered before decoding. Temporal coding is used first to predict

and code the blocks in a future frame that typically may be two or three frames ahead in the sequence of buffered frames. This is called a “P-frame.” Then the blocks in an intervening frame are coded by searching for matching blocks in a previous frame and a future frame. This is called a “B-frame.” The corresponding pixel values in the best match blocks are averaged and the averaged block is used to predict the block in the intervening frame. The resultant residual block and the two corresponding motion vectors are coded.



57. The prediction of P-frames by successive forward prediction and B-frames by prediction from adjacent I-frames and P-frames is illustrated in Figure D.2 of the MPEG1 Standard, shown below. It can be seen that intra-coded frame I2 is not predicted from another frame; P-frames P5, P8 and P11 are forward-predicted from I-frames or other P-frames, and pairs of frames I2, P5, P8 and P11 are used to predict the corresponding interstitial B-frames.

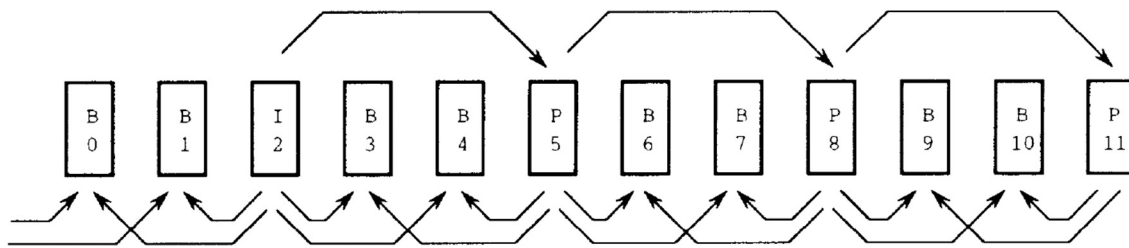


Figure D.2 -- Dependency relationship between I, B, and P-pictures

Figure D.2 illustrates a number of pictures in display order. The arrows show the dependency relationship of the predictive and bidirectionally predictive coded pictures.

SAMSUNG-1015, 54.

58. The number of interstitial B-frames is determined by an encoder and is application-specific. It has been found empirically that two B-frames is optimum for natural video sequences, typified by broadcast television and movies recorded on DVD. It is common practice to have a constant number of B-frames, as shown in the above figures.

59. The MPEG1 standard was technically completed in 1991, and published by the standards setting organization in 1993. *E.g.*, SAMSUNG-1015. By this time, GOP structure was well defined and understood.

3. The MPEG2 Standard

60. The MPEG committee established requirements for the MPEG2 standard and called for proposals in 1991. The requirements were focused first on digital television broadcasting and recording of standard definition video (*e.g.*, NTSC, PAL) at full resolution. As such, MPEG2 comprises an extension of MPEG1 to include coding

of interlaced video. The MPEG2 standard also includes optional coding tools for scalable video coding. *E.g.*, SAMSUNG-1028; SAMSUNG-1016.

61. The MPEG2 standard, officially ISO/IEC 13818-2, which is incorporated by reference in this declaration in full, was technically completed in 1994, and rapidly became massively successful in the global marketplace as the standard for digital television broadcasting and digital video recording – DVD. *E.g.*, SAMSUNG-1028, SAMSUNG-1016.

E. The H.263 Standard

62. H.263 is a standard developed by ITU-T for videoconferencing applications. The work commenced in 1993, leading to three versions of the standard in 1996, 1998 and 2001. The first version is an evolution of the earlier H.261 standard. The second version, which is incorporated by reference in this declaration in full, included a number of optional annexes that are relevant to the current matter. See, *e.g.*, SAMSUNG-1020.

For example, SAMSUNG-1021, Annex F Advanced Prediction Mode (incorporated by reference in full in this declaration) specifies overlapped block motion compensation – OBMC – in clause F.3:

Each pixel in an 8 * 8 luminance prediction block is a weighted sum of three prediction values, divided by 8 (with rounding). In order to obtain the three prediction values, three motion vectors are used: the motion vector of the current luminance block, and two out of four "remote" vectors:

- the motion vector of the block at the left or right side of the current luminance block;
- the motion vector of the block above or below the current luminance block.

For each pixel, the remote motion vectors of the blocks at the two nearest block borders are used. This means that for the upper half of the block the motion vector corresponding to the block above the current block is used, while for the lower half of the block the motion vector corresponding to the block below the current block is used (see Figure F.3). Similarly, for the left half of the block the motion vector corresponding to the block at the left side of the current block is used, while for the right half of the block the motion vector corresponding to the block at the right side of the current block is used (see Figure F.4).

2	1	1	1	1	1	1	2
2	2	1	1	1	1	2	2
2	2	1	1	1	1	2	2
2	2	1	1	1	1	2	2
2	2	1	1	1	1	2	2
2	2	1	1	1	1	2	2
2	2	1	1	1	1	2	2
2	1	1	1	1	1	1	2

Figure F.4/H.263 – Weighting values, H_2 , for prediction with motion vectors of the luminance blocks to the left or right of current luminance block

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63. SAMSUNG-1021, Annex J Deblocking Filter Mode (incorporated by reference in full in this declaration) specifies in clause J.3 a one-dimensional filter applied across horizontal and vertical block edges:

The filter operations are performed across 8×8 block edges at the encoder as well as on the decoder side. The reconstructed image data (the sum of the prediction and reconstructed prediction error) are clipped to the range of 0 to 255 as described in 6.3.2. Then the filtering is applied, which alters the picture that is to be stored in the picture store for future prediction. The filtering operations include an additional clipping to ensure that resulting

pixel values stay in the range 0...255. No filtering is performed across a picture edge, and when the Independent Segment Decoding mode is in use, no filtering is performed across slice edges when the Slice Structured mode is in use (see Annexes K and R) or across the top boundary of GOBs having GOB headers present when the Slice Structured mode is not in use (see Annex R). Chrominance as well as luminance data are filtered.

When the mode described in this annex is used together with the Improved PB-frames mode of Annex M, the backward prediction of the B-macroblock is based on the reconstructed P-macroblock (named PREC in G.5) after the clipping operation but before the deblocking edge filter operations. The forward prediction of the B-macroblock is based on the filtered version of the previous decoded picture (the same picture data that are used for prediction of the P-macroblock).

The deblocking filter operates using a set of four (clipped) pixel values on a horizontal or vertical line of the reconstructed picture, denoted as A, B, C and D, of which A and B belong to one block called block1 and C and D belong to a neighbouring block called block2 which is to the right of or below block1. Figure J.1 shows examples for the position of these pixels.

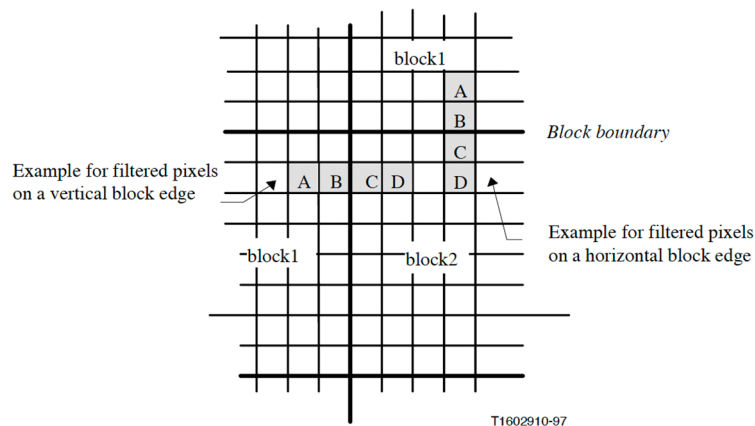


Figure J.1/H.263 – Examples of positions of filtered pixels

64. SAMSUNG-1021, Annex N Reference Picture Selection mode (incorporated by reference in full in this declaration) specifies a mechanism for error recovery in which on a picture or subpicture basis, a decoder that experiences a loss of data may fill in the resultant “hole” in the picture. It may be able to fill in the hole by use of a different reference picture than one which is lost. While such a “patch” might not be perfect, it might subjectively conceal the error – which would be fleeting. Alternatively, it may signal the encoder to transmit the data needed to fill the hole.

F. The H.264 Standard

65. H.264 is a standard jointly developed by ITU-T for videoconferencing applications and ISO for consumer video applications. (The ISO designation is 14496-10, i.e., MPEG4 Part 10 also known as AVC – Advanced Video Codec, SAMSUNG-1027.) The work commenced in 1998 in the ITU-T workgroup VCEG (Video Coding Experts Group), with MPEG joining in December 2001 to form the Joint Video Team – JVT. The first version was published in May 2003. Scalable Video Coding (SVC) was included from version 3 in November 2007 (ITU-T Rec. H.264 (11/2007), SAMSUNG-1009, which is incorporated by reference in this declaration in full.

66. H.264/AVC provides a significant improvement in video coding performance over MPEG2 and is still the most widely used video coding standard worldwide. Notably it is used for High Definition Television broadcasting (HDTV).

67. For example, clause 8.7 Deblocking Filter Process (which is incorporated in this declaration in full) discloses a one-dimensional filter applied across horizontal and vertical block edges that is a significant advance over the H.263 deblocking filter:

A conditional filtering shall be applied to all 4x4 block edges of a picture, except edges at the boundary of the picture and any edges for which the deblocking filter process is disabled by `disable_deblocking_filter_idc`, as specified below. This filtering process shall be performed on a macroblock basis, with all macroblocks in a picture processed in order of increasing macroblock addresses. Prior to the operation of the deblocking filter process for each macroblock, the deblocked samples of the macroblock or macroblock pair above (if any) and the macroblock or macroblock pair to the left (if any) of the current macroblock shall be available. The deblocking filter process is invoked for the luma and chroma components separately. For each macroblock, vertical edges are filtered first, from left to right, and then horizontal edges are filtered from top to bottom. The luma deblocking filter process is performed on four 16-sample edges and the deblocking filter process for each chroma components is performed on two 8-sample edges, for the horizontal direction as shown on the left side of Figure 8 9 and for the vertical direction as shown on the right side of Figure 8 9. Sample values above and to the left of the current macroblock that may have already been modified by the deblocking filter process operation on previous macroblocks shall be used as input to the deblocking filter process on the current macroblock and may be further modified during the filtering of the current macroblock. Sample values modified during filtering of vertical edges are used as input for the filtering of the horizontal edges for the same macroblock.

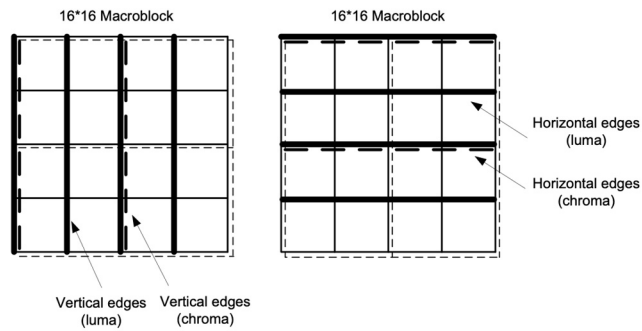


Figure 8-9 – Boundaries in a macroblock to be filtered (luma boundaries shown with solid lines and chroma boundaries shown with dashed lines)

ITU T Rec. H.264 (05/2003) – Prepublished version p. 156

68. A complete description can be found in List P, Joch A, Lainema J, Bjøntegaard G, Karczewicz M, Adaptive deblocking filter, IEEE Trans. on CSVT, vol. 13, pp. 614–619, July 2003, which is incorporated in this declaration by reference in full.

III. Relevant Legal Standards

69. I have been asked to provide my opinions as to whether claims 1-10 of the '025 Patent would have been obvious to a person of ordinary skill in the art as of the earliest claimed priority date of the '025 patent (April 17, 2006) (“Critical Date”).

70. I am an engineer by training and profession. The opinions I express in this declaration involve the application of my technical knowledge and experience to the evaluation of certain prior art with respect to the '025 Patent. In addition, I understand that the following legal principles apply.

71. It is my understanding that, in determining whether claims of the '025 patent are obvious in this proceeding, the claim terms are generally given their ordinary and customary meaning as understood by a person of ordinary skill in the relevant art.

A person of ordinary skill in the art would read the claim terms in the context of the entire patent specification in which they appear, as well as the prosecution history of the patent.

72. It is my understanding that a claim is unpatentable under 35 U.S.C. § 103 if the claimed subject matter as a whole would have been obvious to a person of ordinary skill in the art at the time of the alleged invention. I also understand that an obviousness analysis takes into account the scope and content of the prior art, the differences between the claimed subject matter and the prior art, and the level of ordinary skill in the art at the time of the invention.

73. In determining the scope and content of the prior art, it is my understanding that a reference is considered relevant prior art if it falls within the field of the inventor's endeavor. In addition, a reference is prior art if it is reasonably pertinent to the particular problem with which the inventor was involved. A reference is reasonably pertinent if it logically would have commended itself to an inventor's attention in considering his problem. If a reference relates to the same problem as the claimed invention, that supports use of the reference as prior art in an obviousness analysis.

74. To assess the differences between prior art and the claimed subject matter, it is my understanding that 35 U.S.C. § 103 requires the claimed invention to be considered as a whole. This "as a whole" assessment involves showing that one of

ordinary skill in the art at the time of invention, confronted by the same problems as the inventor and with no knowledge of the claimed invention, would have selected the elements from the prior art and combined them in the claimed manner.

75. It is my further understanding that several rationales may be applied for combining references or modifying a reference to show obviousness of claimed subject matter. These rationales include: combining prior art elements according to known methods to yield predictable results; simple substitution of one known element for another to obtain predictable results; a predictable use of prior art elements according to their established functions; applying a known technique to a known device (method or product) ready for improvement to yield predictable results; choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success; and some teaching, suggestion, or motivation in the prior art that would have led one of ordinary skill to modify a prior art reference or to combine prior art teachings to arrive at the claimed invention.

IV. Person of Ordinary Skill in the Art

76. It is my understanding that when interpreting the claims of the '025 patent I must do so based on the perspective of one of ordinary skill in the art at the time of the alleged invention ("POSITA"). For purposes of my analysis in this declaration, I have taken the earliest claimed priority date of the '025 patent (April 17, 2006) as the date of the alleged invention ("Critical Date"). I understand that the factors considered

in determining the ordinary level of skill in a field of art include the level of education and experience of persons working in the field; the types of problems encountered in the field; the teachings of the prior art, and the sophistication of the technology at the time of the alleged invention. I understand that a POSITA is not a specific real individual, but rather is a hypothetical individual having the qualities reflected by the factors above. I understand that a POSITA would also have knowledge from the teachings of the prior art, including the art cited below.

77. Taking these factors into consideration, it is my opinion that one of ordinary skill in the art in the field of digital video coding as of the Critical Date, would have had at least a bachelor's degree in computer science, computer engineering, electrical engineering, or a related field, and at least two years of industry experience in digital video processing, or a related field. Additional graduate education could substitute for professional experience, or additional professional experience could substitute for formal education.

78. I have possessed the qualifications of a POSITA since the Critical Date of the '025 patent, and long before.

V. Overview of the Subject Patent US8090025

A. Overview

79. The '025 Patent is directed to “a moving-picture coding apparatus, method and program, and a moving-picture decoding apparatus, method and program

that, without a smoothing procedure, can produce a predictive picture maintaining continuity of a video signal.” SAMSUNG-1001, 2:30-38. In addition to known video coding and decoding techniques, the ’025 Patent discloses a “controller” (117a and 313a) and a “switch” (102/103 and 701) for selecting between “ordinary” motion estimation/compensation and “zone-border” motion estimation/compensation.” SAMSUNG-1001, 25:21-42, 26:24-48, 28:21-39, FIGS. 5 (showing an encoder) and 7 (showing a decoder). The ’025 Patent discloses that these two modes of motion compensation are “adaptively switched based on the data amount, thus producing high-quality decoded videos with a fewer code amount overall.” SAMSUNG-1001, 28:21-39.

80. The “ordinary” motion estimation/compensation is performed by a “motion estimator” (502) and a “motion compensator” (503 and 702) which the ’025 Patent describes in detail in its FIG. 13 description (produced below). SAMSUNG-1001, 10:4-39, 21:63-22:14, 28:21-39, FIGS. 5, 7, 13.

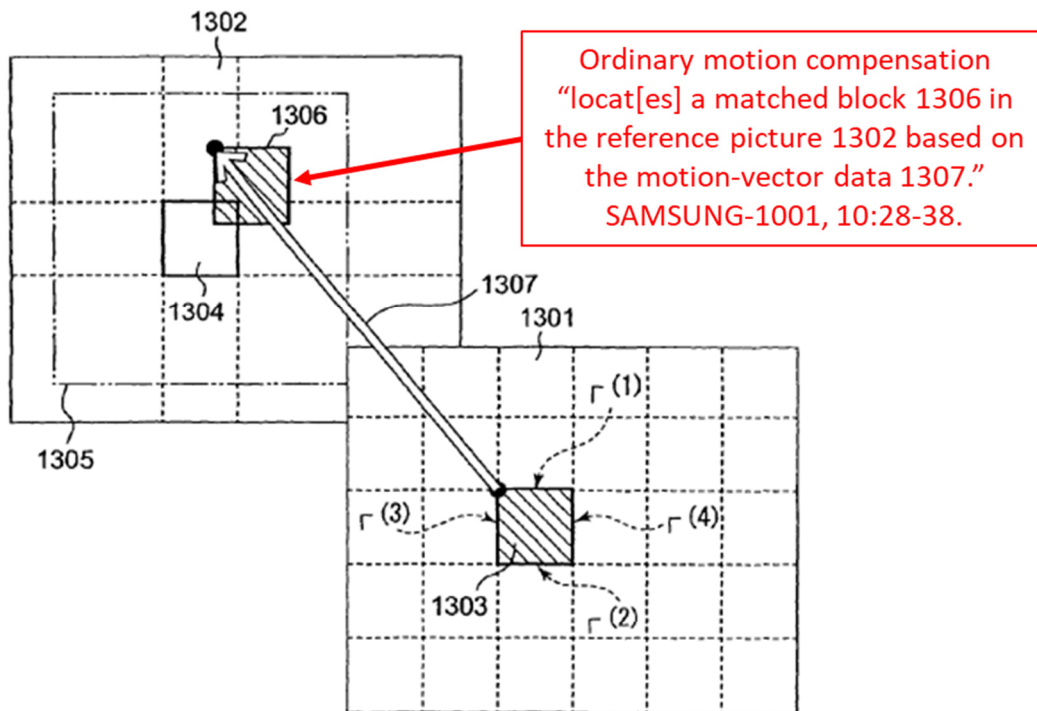


FIG. 13

SAMSUNG-1001, FIG. 13 (annotated).

81. The “zone-border” motion estimation/compensation includes two steps, described in FIGS. 14-17. SAMSUNG-1001, 10:39-12:20. In the first step, as shown in FIGS. 14 and 15, “motion-vector search is performed on block borders.” SAMSUNG-1001, 10:39-45. Block borders are associated with a “boundary condition” which is “a gradient of a video signal on a block border.” SAMSUNG-1001, 10:46-56. The zone-border motion estimator then “obtains border gradient data that is a boundary condition of a block border in a picture to be coded” and then selects the “closest gradient to the gradient of an original signal on the block border.”

SAMSUNG-1001, 10:57-65, FIGS. 14-15. This process is shown below in FIGS. 14-15. Next, in the second step as shown in FIGS. 16 and 17, "Poisson's Equation is then applied based on the gradient data of the video signal thus defined to generate a predictive signal in block which is then applied to a predictive block 1606a." SAMSUNG-1001, 11:20-34.

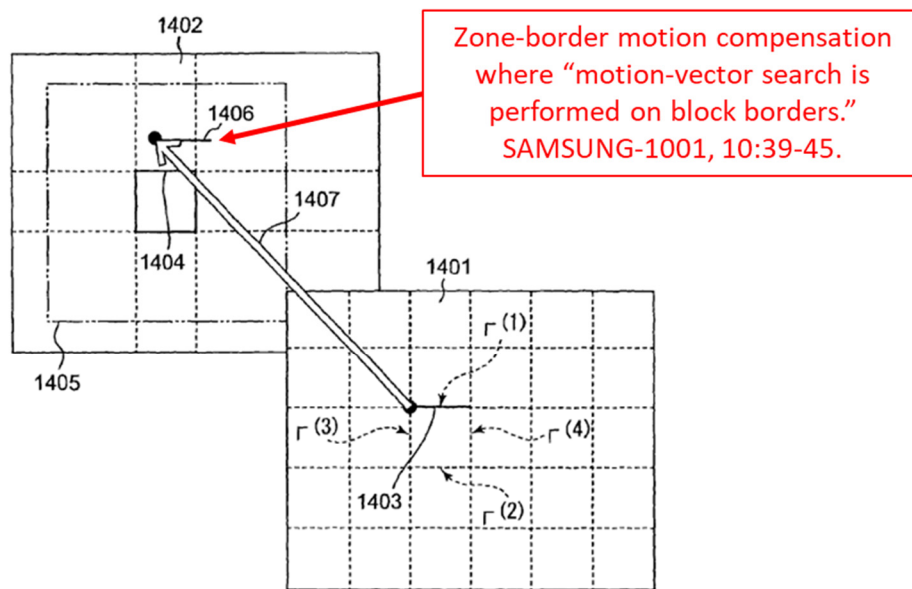


FIG. 14

SAMSUNG-1001, FIG. 14 (annotated).

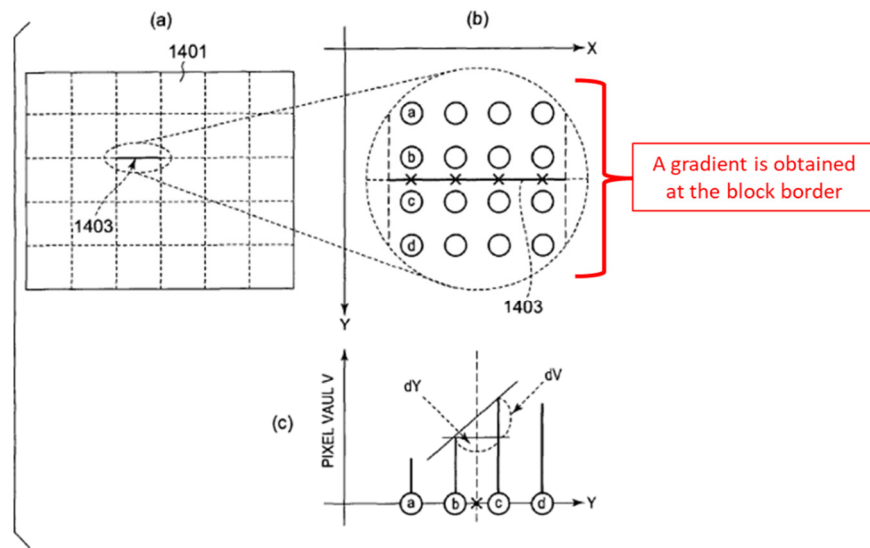


FIG. 15

SAMSUNG-1001, FIG. 15 (annotated).

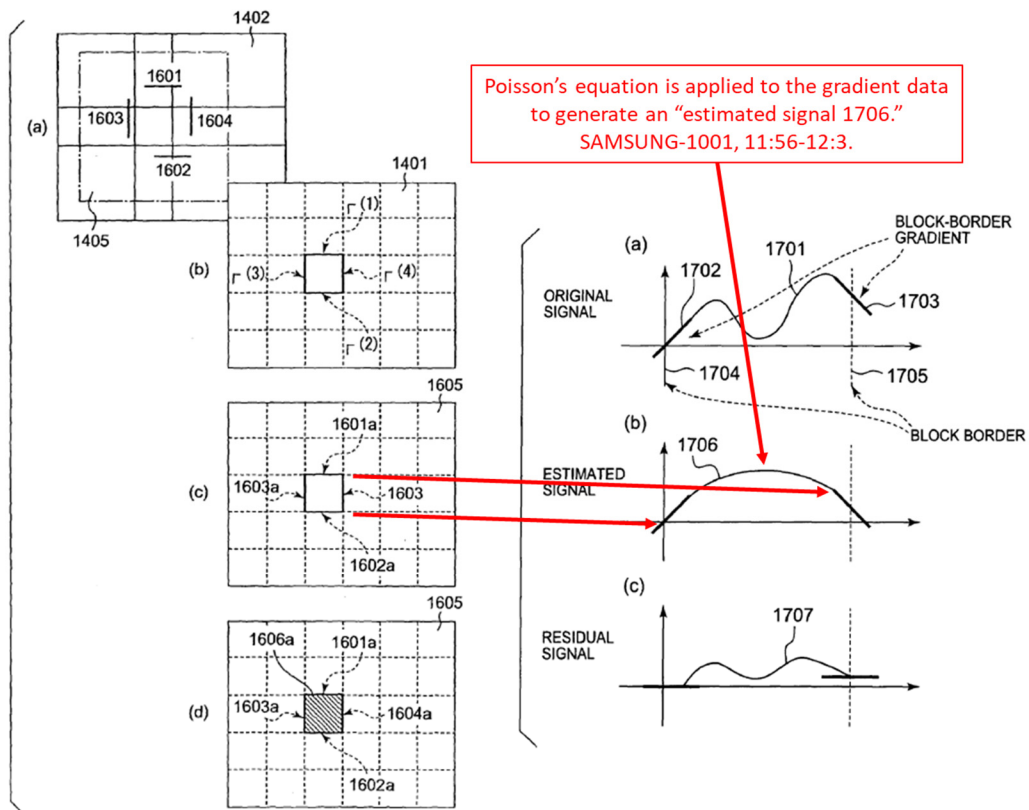


FIG. 16

FIG. 17

SAMSUNG 1001, FIGS. 16-17 (annotated).

B. Prosecution History of the '025 Patent

82. Application Serial No. 11/787,623 (“the ’025 application”) that issued as the ’025 Patent was filed on April 17, 2007, claiming priority to Japanese Application Nos. 2007-093162 and 2006-112995 filed on March 30, 2007, and April 17, 2006, respectively. SAMSUNG-1001, Cover. On September 28, 2011, without issuing any previous prior art rejections, the Examiner issued a notice of allowability and an Examiner’s amendment. SAMSUNG-1002, 34-52. The Applicant paid the issue fee on November 30, 2011. SAMSUNG-1002, 23-27. The ’025 application issued as the ’025 Patent on January 3, 2012. SAMSUNG-1001, Cover. In sum, the examiner allowed the application over prior art references that are substantially different from those relied upon in this petition. Indeed, during prosecution, there is no indication that the examiner considered Mualla, Shirani, Saito, or Stockhammer, which render the challenged claims obvious, as discussed below. *See generally*, SAMSUNG-1002.

VI. Summary of ’025 Prior Art

83. The following pieces of prior art render obvious the alleged invention of the ’025 patent in the combinations addressed further below (Grounds 1A/1B).

A. Overview of Mualla (and Mualla and Stockhammer in Ground 1B)

84. Mualla is a treatise on “fundamentals and standards of video source coding” and addresses “areas of coding efficiency, computational complexity, and error

resilience in a single volume.” SAMSUNG-1005, 9-10. Structurally, Chapters 1 and 2 of Mualla provide “an introduction to video coding” by describing “some of the fundamentals of video source coding.” SAMSUNG-1005, 10, 31-64. Chapter 3 of Mualla provides a “brief introduction to video coding standards” such as “H.263 (and its extensions H.263+ and H.263++).” SAMSUNG-1005, 10, 65-111. Chapters 4 and 7 of Mualla provide details of “motion estimation (ME)” and “motion compensation (MC).” SAMSUNG-1005, 10-11, 115-146, 181-195. Chapters 9 and 10 of Mualla describe techniques for “error resilience” in video coding systems. SAMSUNG-1005, 11, 225-279.

85. Given its comprehensive nature, Mualla presents different details of encoders/decoders in different figures, depending on what is being explained, but these figures are substantively cumulative to an overall teaching of video coding systems. To facilitate understanding, aggregated views of the relation between different figures of Mualla are shown in Diagrams A and B, below.

86. Diagram A (below) illustrates the relation between Figures 9.1 and 2.3 of Mualla. In Figure 9.1 (annotated in yellow, below) Mualla provides an illustration of a “typical video communication system.” SAMSUNG-1005, Figure 9.1, 227-228. The system includes a “source encoder” designed to “compress the input video” (annotated in blue, below). SAMSUNG-1005, Figure 9.1, 228. The source encoder of Figure 9.1 “consists of a *waveform encoder* and an *entropy encoder*” (annotated in orange and red,

respectively, in Figure 9.1, below). SAMSUNG-1005, 228. Further details of the source encoder (annotated in blue) of Figure 9.1 are shown in Figure 2.3, With reference to Figure 2.3, Mualla explains that the waveform encoder of Figure 9.1 “corresponds to the *mapper* and *quantizer* blocks” of Figure 2.3 (annotated in orange, below), whereas “the entropy encoder” of Figure 9.1 “corresponds to the *symbol encoder* block” of Figure 2.3 (annotated in red, below). SAMSUNG-1005, Figures 9.1, 2.3, 228.

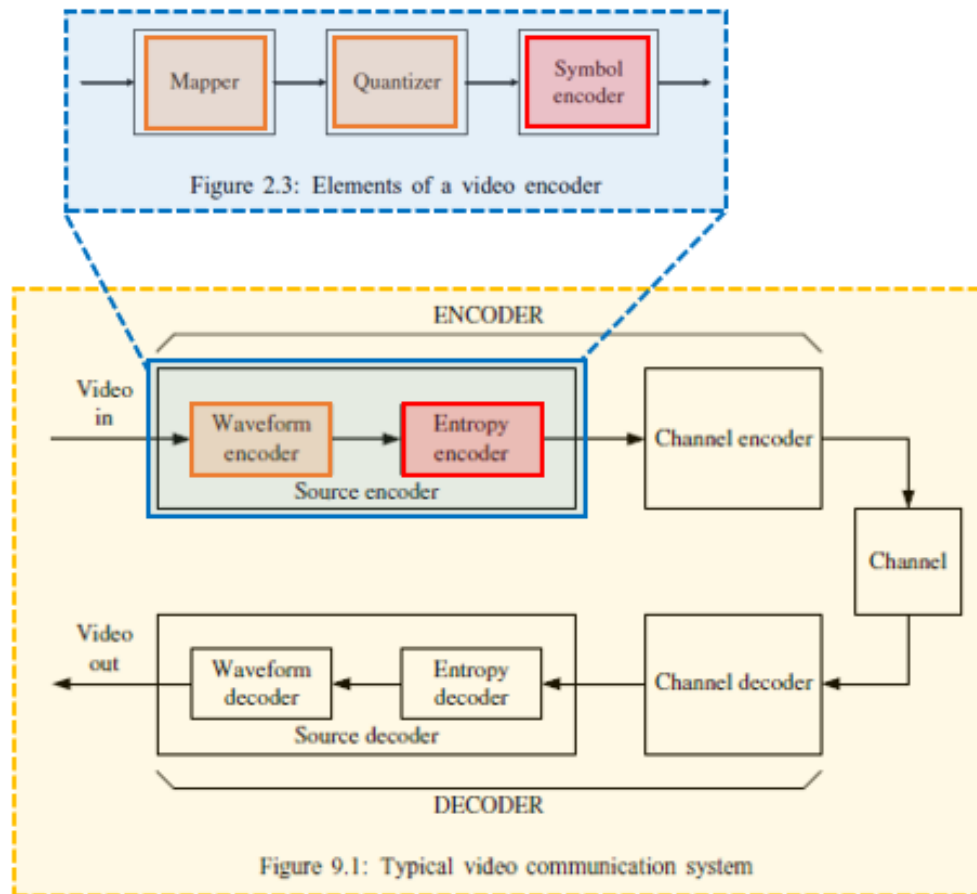


Diagram A (showing the relation between Mualla’s Figures 9.1 and 2.3).

87. Mualla explains that the “mapper” in Figure 2.3 “is designed to reduce **statistical redundancy** and make the data more amenable to compression in later

stages.” SAMSUNG-1005, 40. Mualla describes two types of statistical redundancy, namely “**spatial** (*intraframe*) and **temporal** (*interframe*) correlations between neighboring pels.” *Id.*

88. Mualla discloses that **spatial** (*intraframe*) redundancy is reduced by “intraframe coding” which can be implemented by “**transform coding**.” SAMSUNG-1005, 50-51. Mualla also discloses that **temporal** (*interframe*) redundancy can be reduced by “interframe coding” which can be implemented by “**motion estimation (ME)**” and “**motion compensation (MC)**.” SAMSUNG-1005, 60-61. Mualla provides further details of these techniques in Figures 1.1 and 2.9, described next.

89. Diagram B (below) illustrates the relation between Figure 2.3 (annotated in blue in Diagram A, above) and Figures 1.1 and 2.9 of Mualla. In particular, Figure 2.9 discloses details of transform coding (to reduce spatial redundancy) while Figure 1.1 discloses details of motion estimation and motion compensation (to reduce temporal redundancy). Beginning with Figure 1.1, Mualla describes a “typical video codec” which includes a “motion estimation (ME) block” (annotated in purple, below) and a “motion compensation (MC) block” (annotated in purple, below, which is included as part of a local “decoder” implemented at the encoder) which are designed to reduce temporal redundancy. SAMSUNG-1005, 26. Figure 1.1 also illustrates a “transform encoder” block (annotated in green, below). SAMSUNG-1005, Figure 1.1. Further details of the “transform encoder” are provided in Figure 2.9 (annotated in green, below), which

includes a “forward transform” (annotated in purple, below) designed “to decorrelate the pels of the input block” (reduce spatial redundancy). SAMSUNG-1005, 51-52.

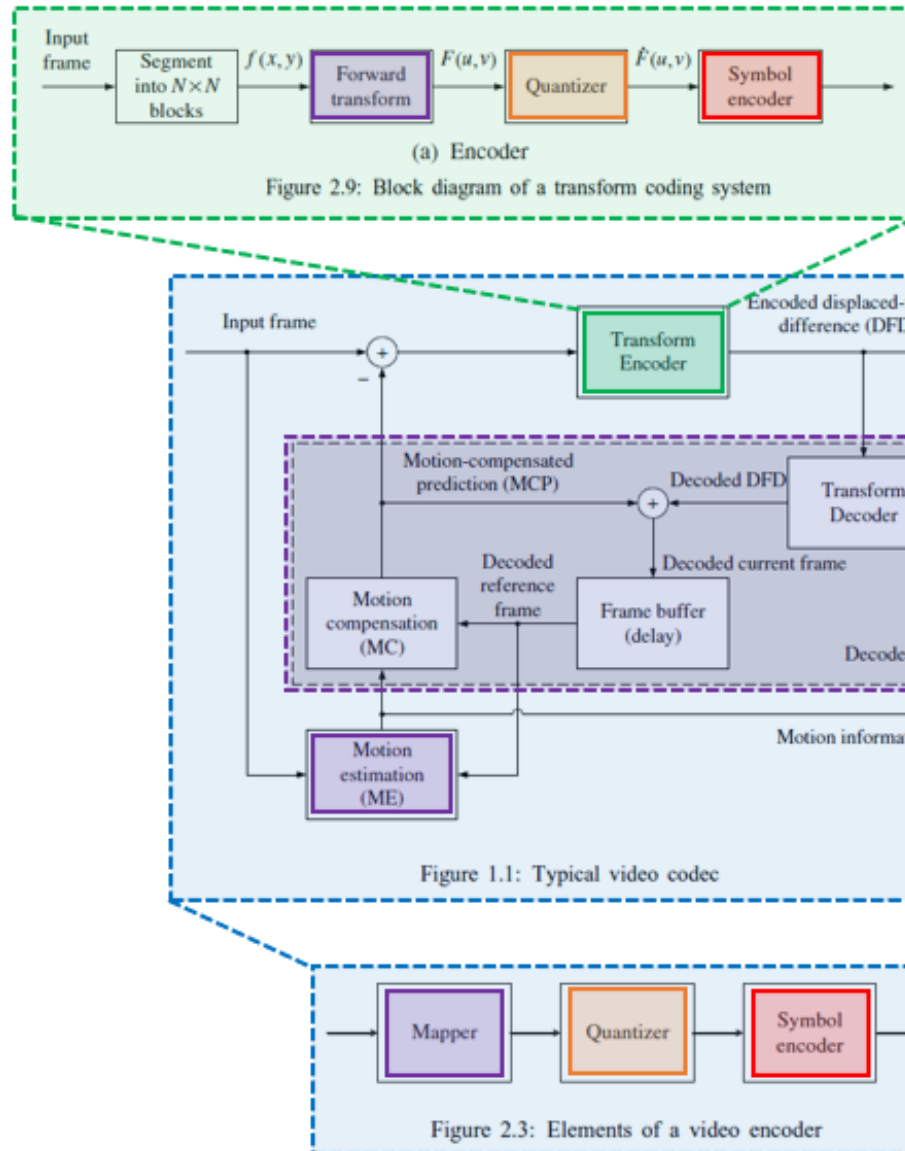


Diagram B (showing the relation between Mualla’s Figures 2.3, 1.1, and 2.9).

90. With this background of typical video coding systems, Mualla describes the specific “picture coding structure” of the “H.263 standard.” SAMSUNG-1005, 71-73. Mualla explains that “[t]he input video consists of a sequence of pictures (or

frames)” and “[e]ach picture is divided into *groups of blocks* (GOBs)” where “[e]ach GOB is divided into *macroblocks* (MBs)” and each MB “consists of 16×16 samples of *Y*” (which Mualla refers to as 16x16 pixel elements or “pels” as shown in Figure 3.2). SAMSUNG-1005, 71. Mualla’s Figure 3.2 illustrates the H.263 picture structure for a QCIF picture frame (reproduced below).

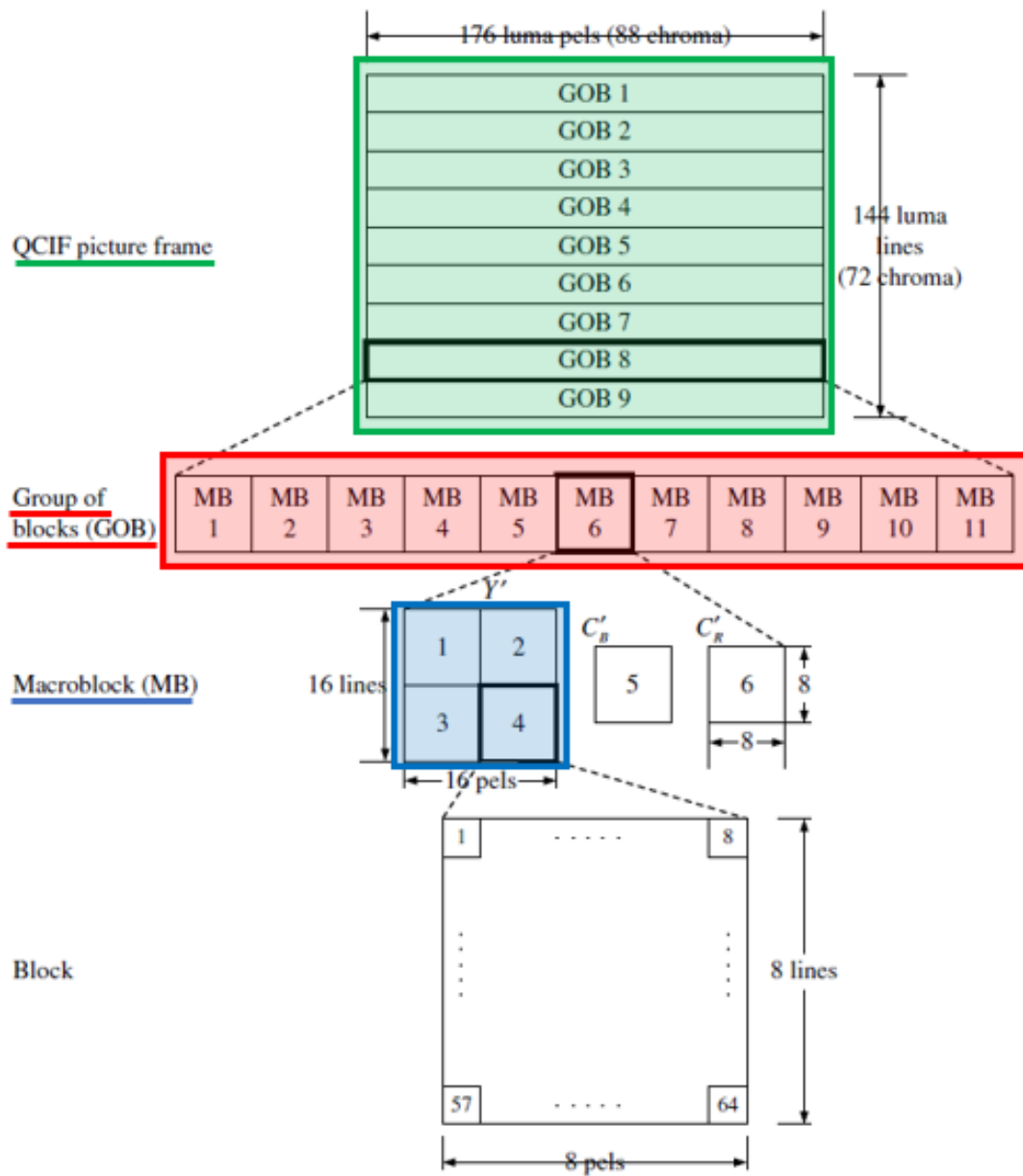


Figure 3.2: H.263 picture structure for a QCIF frame

SAMSUNG-1005, Figure 3.2 (annotated and color added).

91. When the input video is encoded, Mualla explains that in each picture frame, “GOBs are coded from top to bottom in increasing number” and “[w]ithin each GOB, the MBs are coded from left to right (and from top to bottom if the GOB

contains more than one row of MBs) in increasing number.” SAMSUNG-1005, 71, Figure 3.2.

92. Referring back to Figure 1.1 (reproduced below), in order to encode an “input frame” of video (also referred to as the “current frame”), Mualla discloses that the encoder: (i) uses “motion estimation (ME)” and “motion compensation (MC)” to generate “a prediction of the current frame” (SAMSUNG-1005, 26, Figure 1.1), and (ii) subtracts the “prediction” of the current frame from the current frame “to produce an error signal known as the displaced-frame difference (DFD)” which is then encoded using the “transform encoder” (SAMSUNG-1005, 26-27, Figure 1.1).

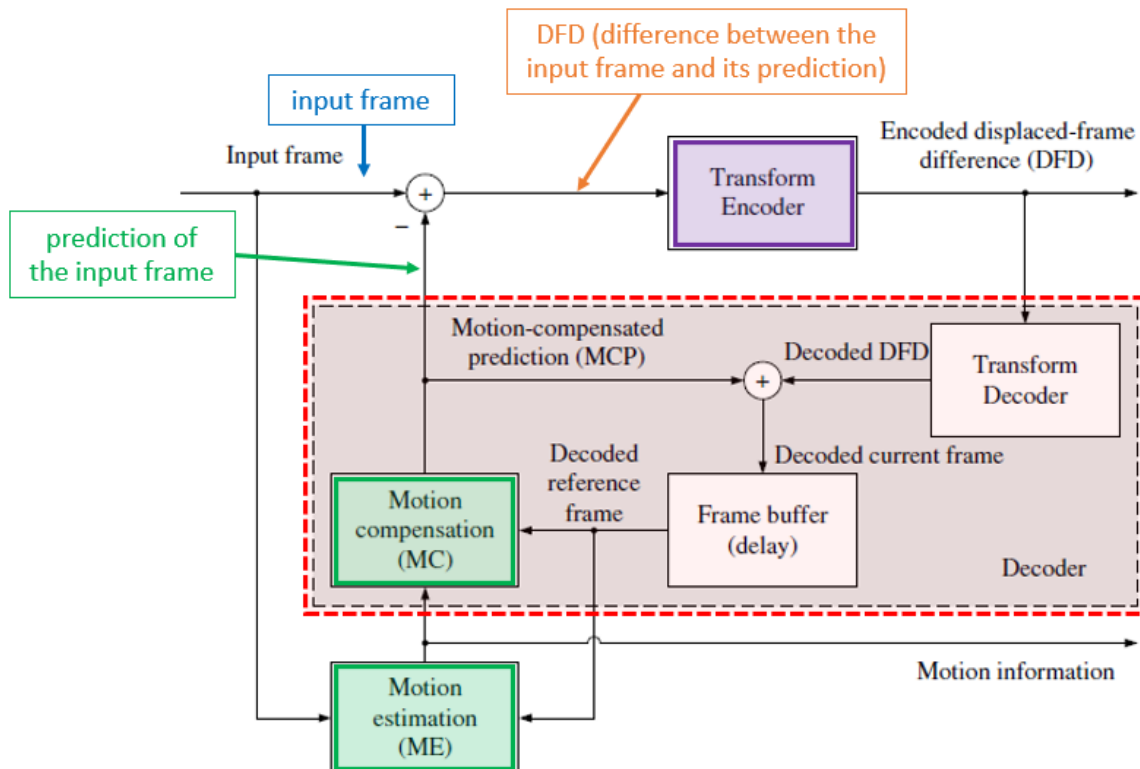


Figure 1.1: Typical video codec

SAMSUNG-1005, Figure 1.1 (annotated and color added)

93. Mualla provides further details of these two operations, which are summarized below.

(i) Generating the “prediction” of the current frame

94. As shown in Figure 1.1 (reproduced again below), for a given input frame (annotated in blue, below, also referred to as the “current frame”), Mualla describes generating the “prediction” of the current frame (annotated in green) by using a “motion compensation (MC) block” (annotated in green) which uses “motion information” estimated by a “motion estimation (ME) block” (also annotated in green). SAMSUNG-1005, 26, *see also* 61, Figure 1.1.

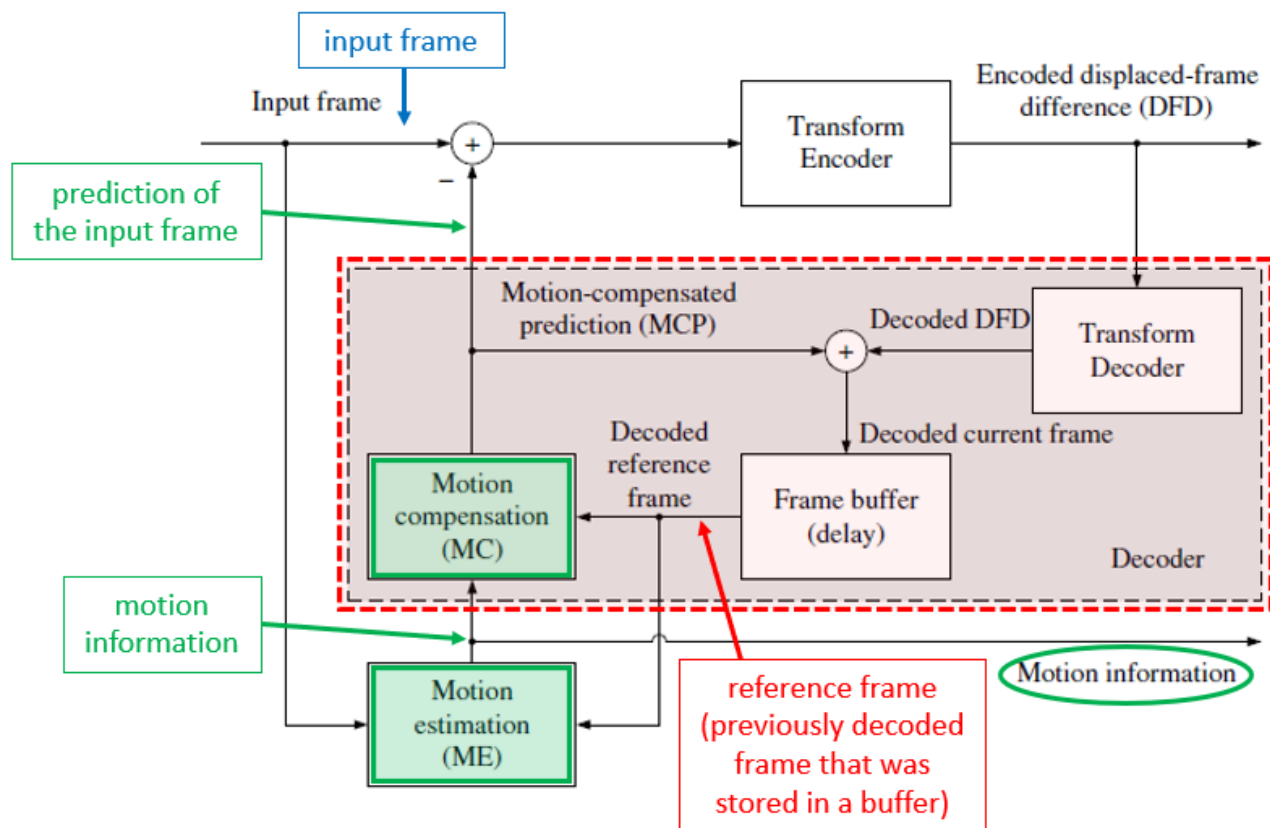


Figure 1.1: Typical video codec

SAMSUNG-1005, Figure 1.1 (annotated and color added)

95. The encoder’s “motion estimation (ME) block” produces “motion information” which is an estimate of “the movement that occurred between the current frame and a reference frame (usually a previously decoded frame that was stored in a frame buffer)” (annotated in red in Figure 1.1, above). SAMSUNG-1005, 26, *see also* 61. Mualla explains that “[t]he most commonly used ME method is the block-matching motion estimation (BMME) algorithm” in which the “motion of each block” is estimated “by searching for the best-match block in the reference frame.” SAMSUNG-1005, 62. The motion of the current block is then “represented by a motion vector,

which is the displacement between the block and its best-match block in the reference frame.” *Id.* Mualla provides an example of motion estimation in Figure 2.16 (reproduced below). Mualla further explains that the BMME technique is supported by the H.263 standard, in which “the encoder estimates one motion vector per MB [(macroblock)].” SAMSUNG-1005, 73-74.

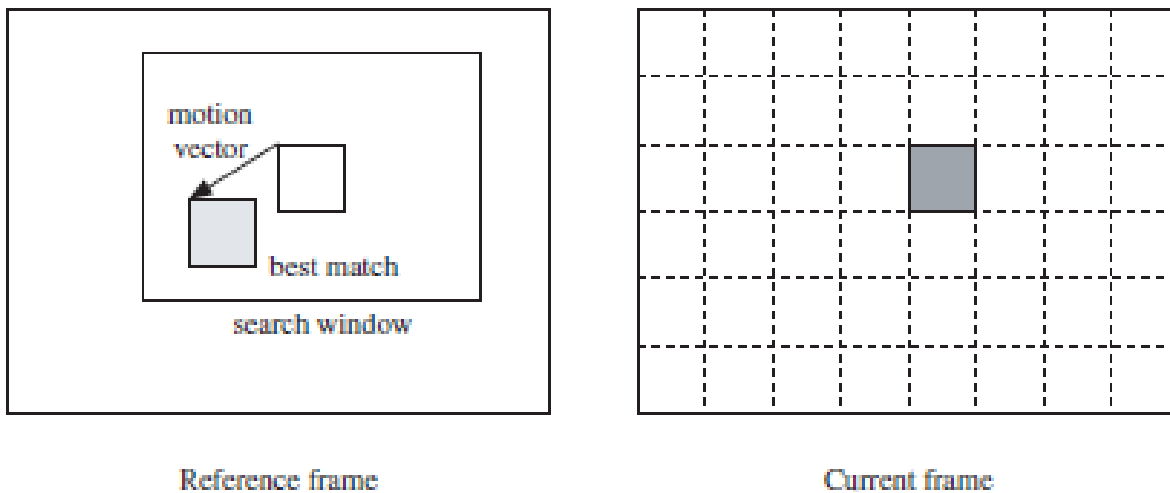


Figure 2.16: Block-matching motion estimation

SAMSUNG-1006, Figure 2.16.

96. Once the motion estimation (ME) process has estimated a motion vector, the encoder then performs “motion compensation (MC)” in which the motion information is utilized “to move the contents of the reference frame to provide a better prediction of the current frame.” SAMSUNG-1005, 61. Mualla refers to the resulting prediction (annotated in green in Figure 1.1, above) as the “the motion-compensated prediction (MCP) or the displaced-frame (DF).” *Id.*

97. As shown in Figure 1.1 (above), the video encoder implements motion compensation (MC) by using a local “decoder” (annotated in red, below) that locally decodes a frame, stores the decoded frame in the local frame buffer, and generates the prediction of the current frame based on the previously decoded and stored frame. SAMSUNG-1005, 4, Figure 1.1. Thus, the “decoder” shown in Figure 1.1 is a local decoder that is implemented in the encoder, which replicates decoding operations implemented at a remote decoder in the receiver.

98. In addition to supplying the estimated motion vector to the motion compensation (MC) block, the motion vector is also encoded and output from the encoder (see the “motion information” circled in the lower-right-hand corner of Figure 1.1, above). SAMSUNG-1005, Figure 1.1. In particular, in the H.263 standard, Mualla explains that for each macroblock, “[t]he estimated motion vector $MV = (MV_x, MV_y)$ is predictively coded” which means that “the motion vector difference $MVD = MV - MVP$ is encoded instead of the motion vector itself.” SAMSUNG-1005, 74. The “MVP” is defined as the “motion vector predictor” which is “the median of three candidate predictors, which are the motion vectors of three surrounding macroblocks.” SAMSUNG-1005, 74, Figure 3.3(a). The motion vector difference (MVD) is then “entropy coded” and the encoded MVD is output from the encoder as encoded motion information. SAMSUNG-1005, 74.

(ii) Encoding the DFD

99. Once a prediction of the current frame has been generated in step (i) using ME and MC, as described above, Mualla explains that “the prediction is then subtracted from the current frame to produce an error signal known as the displaced-frame difference (DFD)” (annotated in orange, below) which is then encoded using a “transform encoder” to produce an “encoded ... DFD” (annotated in purple, below) which is output from the encoder. SAMSUNG-1005, Figure 1.1 (reproduced again below).

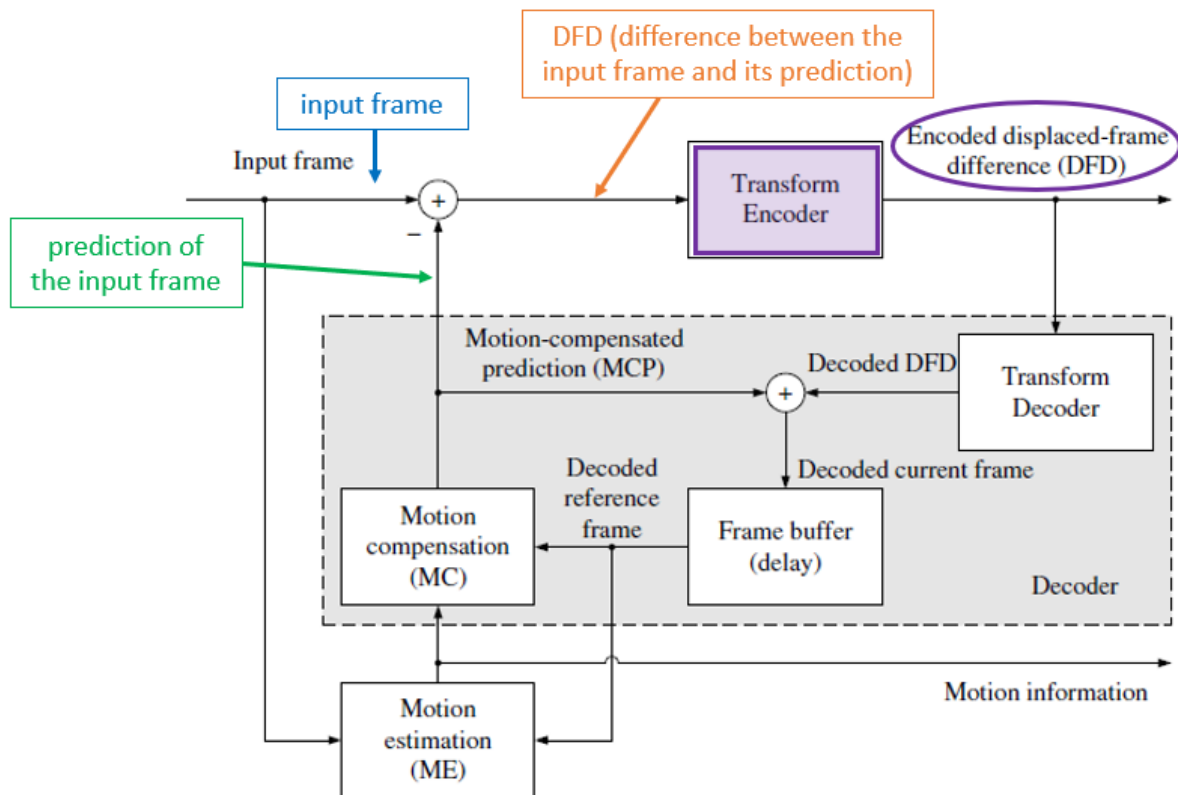


Figure 1.1: Typical video codec

SAMSUNG-1005, Figure 1.1 (annotated and color added).

100. Mualla describes details of the “transform encoder” (annotated in purple, above) in Figure 2.9 (reproduced below), in which “the input frame is first **segmented** into $N \times N$ blocks” (annotated in orange, below), and then “a unitary¹⁶ space-frequency **transform** [(annotated in green, below)] is applied to each block to produce an $N \times N$ block of transform (spectral) coefficients that are then suitably **quantized** [(annotated in blue, below)] and and **coded** [(annotated in red, below)].” SAMSUNG-1005, 51-52.

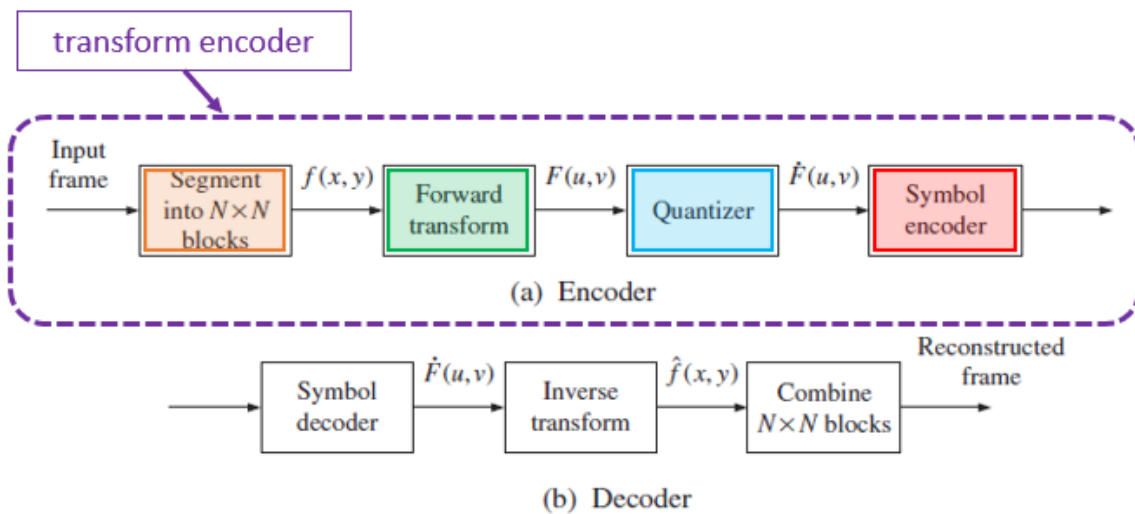


Figure 2.9: Block diagram of a transform coding system

SAMSUNG-1005, Figure 2.9 (annotated and color added).

101. Thus, Mualla discloses that the encoder outputs both the encoded DFD (circled in purple in Figure 1.1, above) and the encoded motion information (circled in green in Figure 1.1, above). SAMSUNG-1005, 26, 52, Figure 1.1.

102. Referring back to Figure 9.1, Mualla explains that “[a]t the decoder, the reverse operations are performed to obtain the output video.” SAMSUNG-1005, 228. Figure 9.1.

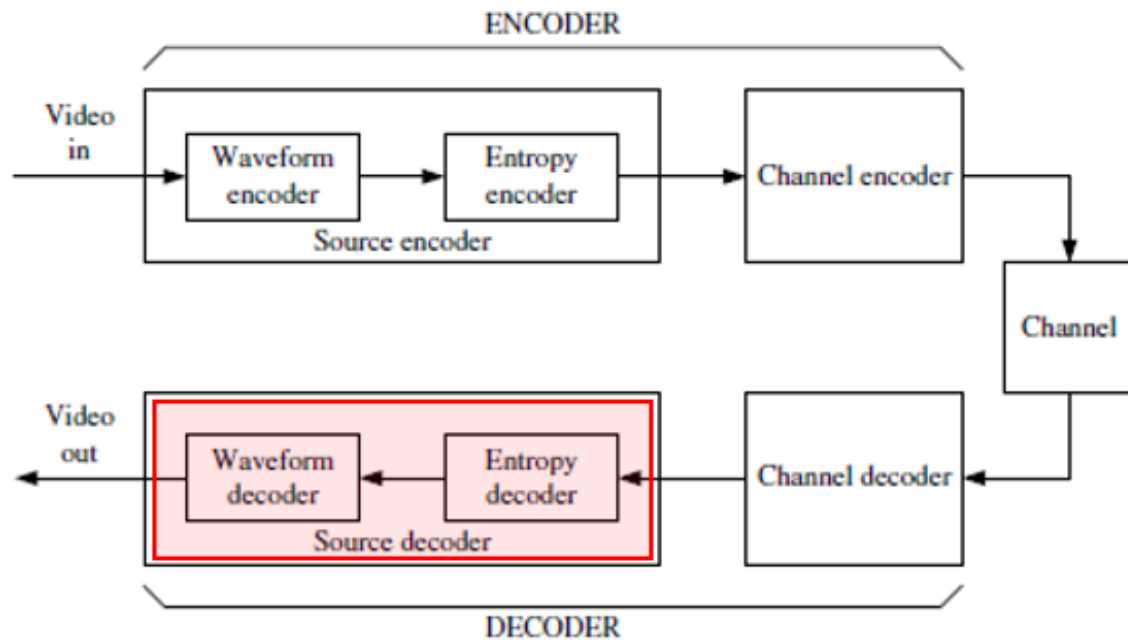


Figure 9.1: Typical video communication system

SAMSUNG-1005, Figure 9.1 (color added).

103. In the specific context of an H.263 system, Mualla discloses that these reverse operations are performed by a “decoding process” that includes (i) “motion vector decoding” in which “for each transmitted inter MB, the decoder calculates the same motion vector predictor MVP used at the encoder and adds it to the decoded motion vector difference MVD to obtain the decoded motion vector MV,” (ii) “motion compensation” in which “[t]he decoded motion vector is used to compensate” the macroblock, (iii) “inverse quantization” for “reconstructing an approximation of the original coefficient,” (iv) “inverse transform” in which “[t]he reconstructed block of coefficients is processed by a separable 2-D 8x8 inverse DCT,” and (v) “reconstruction

of blocks” in which “the reconstructed block is formed by summing the motion-compensated prediction and the result of the inverse DCT.” SAMSUNG-1005, 76.

Error Resilience Techniques

104. In addition to the conventional video coding and decoding operations discussed above, Mualla further describes, in Chapters 9 and 10, techniques for “error resilience” in video coding, including “error detection and error control techniques” applicable to the H.263 standard. SAMSUNG-1005, 11, 227-251. Mualla explains that “when transmitted over a mobile channel, compressed video can suffer severe degradation and the use of error-resilience techniques is vital.” SAMSUNG-1005, 25. In particular, Mualla explains that “[w]hen transmitted over a mobile channel, video can be affected by a number of loss mechanisms, like multipath fading, shadowing, and co-channel interference.” SAMSUNG-1005, 205. Furthermore, “the higher the compression, the more sensitive the bitstream is to errors, since in this case each bit represents a larger amount of decoded video.” SAMSUNG-1005, 227. Therefore, in addition to the compression techniques described above, Mualla also discloses modifying the decoder (and encoder) to implement techniques for detecting and recovering from errors that occur during transmission of the compressed bitsream.

105. To implement error resilience, Mualla describes a system in which “[t]he decoder was modified to perform error detection by detecting syntax and semantic violations.” SAMSUNG-1005, 265. Mualla explains that “[w]hen an error is detected,

the decoding process is stopped” and “[a]ll macroblocks between the point where the error was detected and the synchronization point are marked as damaged macroblocks.”

Id. Mualla discloses recovering the damaged macroblocks by using an error control technique called “hybrid error concealment” which combines both “spatial techniques” and “temporal techniques” (examples of which are presented in Figures 9.7 and 9.8, reproduced below). SAMSUNG-1005, 242-246. In this hybrid technique, “temporal concealment is first used to get an initial estimate of the damaged block” and “this initial estimate is then refined using spatial concealment.” SAMSUNG-1005, 246.

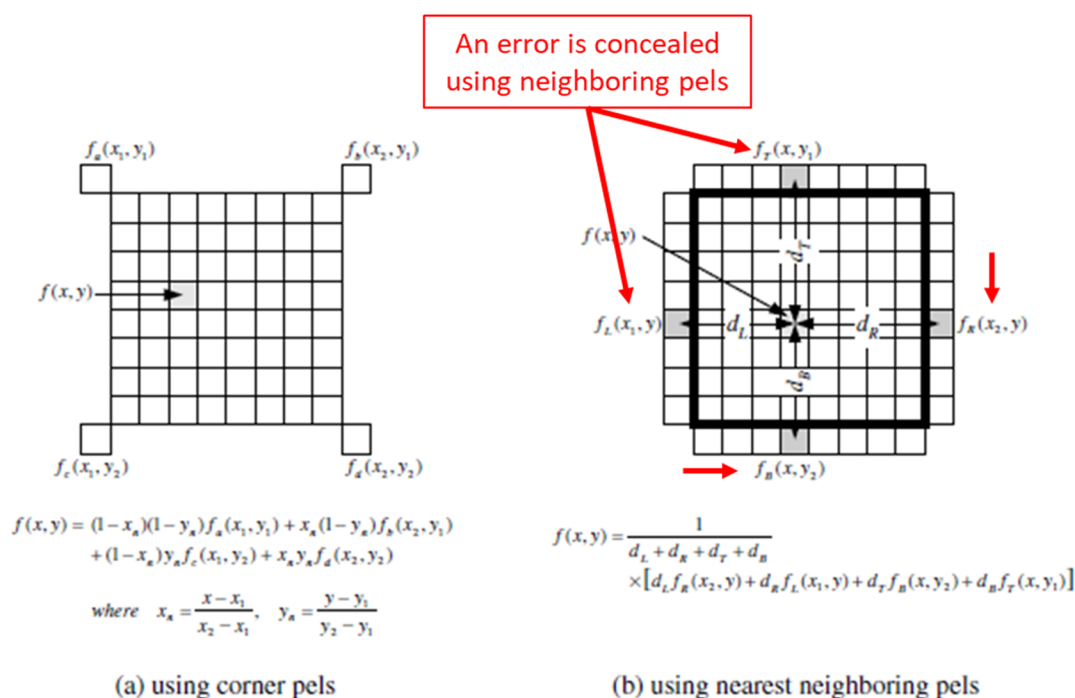


Figure 9.7: Error concealment using spatial interpolation

SAMSUNG-1005, FIG. 9.7 (annotated).

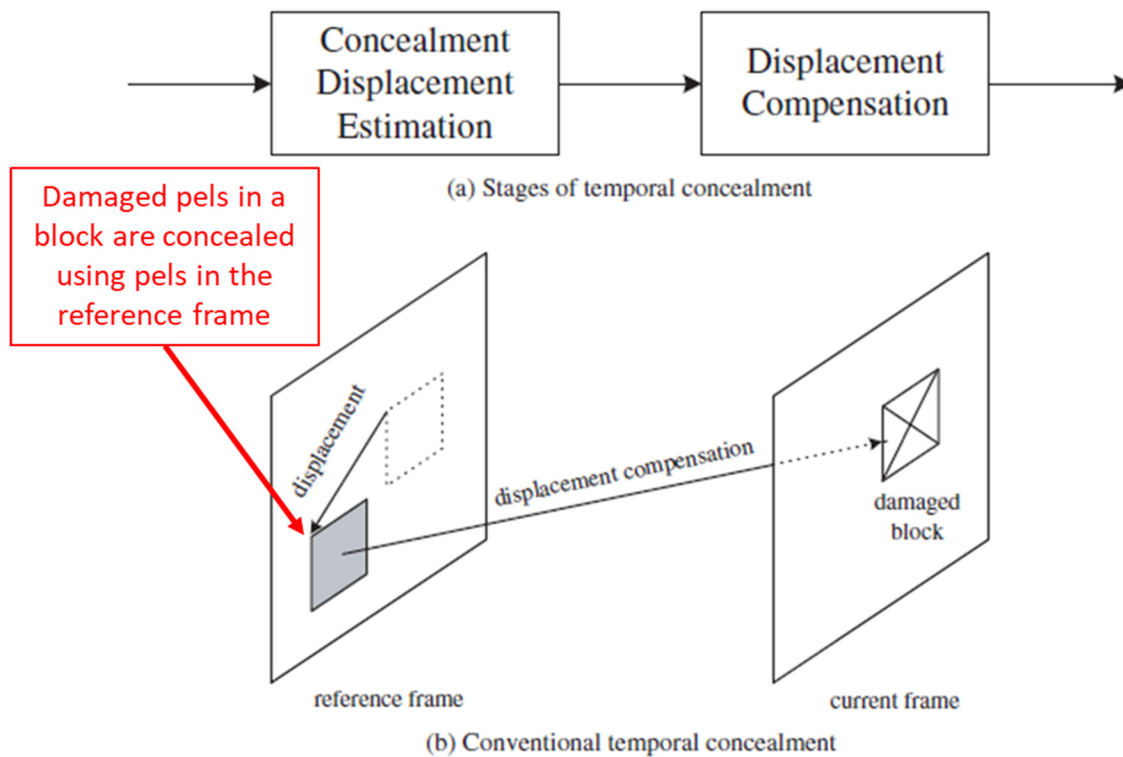


Figure 9.8: Temporal error concealment

SAMSUNG-1005, FIG. 9.8 (annotated).

106. Furthermore, although Mualla describes details of error resilience (including *error detection* to detect errors and subsequent *error concealment* to recover from those errors) at the decoder, Mualla also teaches performing *error concealment* at the **encoder**. SAMSUNG-1005, 246-250. For example, Mualla discloses that “the encoder and decoder cooperate to minimize the effects of transmission errors” and in particular “coding efficiency can also be improved by performing error concealment in the encoder so that both encoder and decoder use the same reference frames for prediction.” SAMSUNG-1005, 249. To implement error concealment at the encoder, Mualla describes “interactive techniques” in which “the decoder uses a feedback

channel to inform the encoder about which parts of the transmitted video have been received in error” and “[b]ased on this feedback information, the encoder adjusts its operation to combat the effects of such errors.” SAMSUNG-1005, 224. Mualla explains that “[w]hen feedback information is received, the encoder can reconstruct the error propagation process” so that “the encoder can track the error propagation.” SAMSUNG-1005, 247.

107. In describing such interactive techniques, Mualla cites to numerous corroborating references that teach additional details of implementing “interactive” error concealment where the same error concealment technique is performed at both the **encoder and decoder**. SAMSUNG-1005, 246-250. For example, Girod (SAMSUNG-1008, cited as reference 201 in Mualla) teaches “error tracking” techniques for H.263-based systems in which the decoder performs “reporting of the temporal and spatial location of MB’s that could not be decoded successfully and had to be concealed” and “[b]ased on the information of an NACK, the encoder can reconstruct the resulting error distribution in the current frame.” SAMSUNG-1008, 7. Girod explains that, in order to perform error tracking, “the coder has to know the decoder’s concealment technique” and that error tracking “does not require any modifications of the bit stream syntax of the motion-compensated hybrid coder” and “is therefore fully compatible with standards such as ... H.263.” SAMSUNG-1008, 9. As another example, Wada (SAMSUNG-1017, cited as reference 203 in Mualla and also cited as

reference 50 in Girod) teaches both a “procedure at the receiver” and “a procedure at the transmitter” for error resilience. SAMSUNG-1017, 1-2. At the **receiver**, Wada teaches that (1) “Packet loss is detected,” (2) “Damaged picture block(s) is (are) specified,” (3) “Notice of packet loss with the address(es) of damaged picture block(s) is sent back to the transmitter,” (4) “Error concealment is carried out over damaged picture block(s),” and then (5) “Decoding is continued.” *Id.* At the **transmitter**, Wada describes a method in which (1) “Notice of packet loss is received with the address(es) of damaged picture block(s),” (2) “The **same error concealment as is performed at the receiver is carried out in the local-decoded frame stored**,” (3) “Local decoding is reexecuted from the point of the concealed block(s) up to the currently encoded block,” and then (4) “Encoding is normally continued.” SAMSUNG-1017, 2.

108. Therefore, in view of the teachings of Mualla (and the references cited by Mualla which reflect knowledge in the art at the time of Mualla’s teachings), a POSITA would have understood or found obvious that (i) an H.263-based **decoder** performs *error detection* to detect errors and *error concealment* to recover from those errors, and (ii) an H.263-based **encoder** receives feedback from the decoder regarding errors that were detected, and performs the same *error concealment* to replicate those same errors in its local decoder so as to use the same reference frames for error prediction.

109. Furthermore, Stockhammer (SAMSUNG-1009, which cites both Girod and Wada as references 62 and 63, respectively, for teachings of error tracking in H.263

systems) provides illustrative diagrams for implementing feedback-based error detection and error correction in an H.264-based system. SAMSUNG-1009, 8, Fig. 6 (reproduced below). In particular, Fig. 6 of Stockhammer illustrates an encoder (on the left-hand side, annotated in blue) that implements a local “decoder” (annotated in red) to perform “video encoding” to generate “packets.” *Id.* The packets are transmitted over a “packet loss channel” in which packets are randomly lost during transmission. *Id.* At the remote decoder (on the right-hand side, annotated in red), Stockhammer explains that “[t]he decoder processes the received sequence of packets” such that “received packets are decoded as usual” whereas “for the lost packet, an error-concealment algorithm has to be invoked.” SAMSUNG-1009, 8.

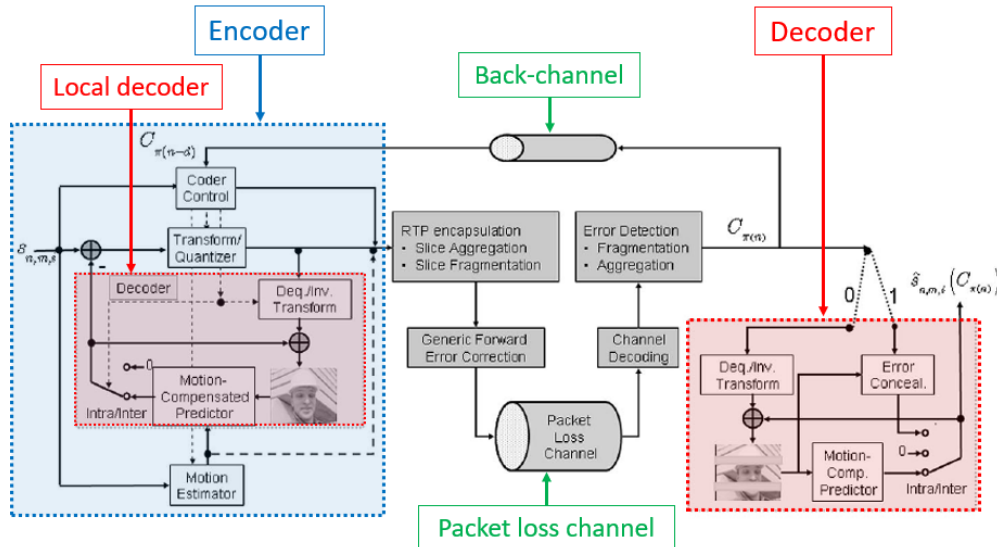


Fig. 6. H.264/AVC in IP-based packet-lossy environment with RTP encapsulation, generic forward error correction, delayed feedback information, and error concealment.

SAMSUNG-1009, FIG. 6 (annotated and color added).

110. Stockhammer also illustrates, in Fig. 6 above, and describes that a “back-channel from the decoder to the encoder is available [((shown in the upper part of Fig.

6))] which allows reporting ... of the observed channel behavior at the decoder to the encoder.” *Id.* Stockhammer provides further details of error resilience utilizing such “feedback” from the decoder to encoder, and specifically cites to Girod and Wada (as references 62 and 63, respectively) for teachings of “a simple yet powerful approach suitable for video codecs ... such as MPEG-2, H.261, or H.263 ... under the name *error tracking*.” SAMSUNG-1009, 11.

111. To the extent the implementation details of Stockhammer were not already understood to a POSITA with knowledge of error concealment techniques (e.g., from reviewing the disclosures of Mualla and Shirani), a POSITA reviewing the teachings of Stockhammer would have also been motivated to combine these same implementation details into the teachings of Mualla (e.g., thus creating the Mualla-Shirani-Saito-Stockhammer combination of Ground 1B). SAMSUNG-1009, 8-11. Indeed, although the techniques of Stockhammer were well understood, a POSITA would have naturally searched for specific implementation examples (e.g., Stockhammer’s FIG. 6 above) to refine the broader disclosure of Mualla.

112. To summarize, Mualla provides a self-contained teaching of video coding systems, including the concept of feedback-based error tracking in which **(i)** an H.263-based **decoder** performs *error detection* to detect errors and *error concealment* to recover from those errors, and **(ii)** an H.263-based **encoder** receives feedback from the decoder regarding errors that were detected, and performs the same *error concealment* to

replicate those same errors in its local decoder so as to use the same reference frames for error prediction. In particular, Mualla refers to (i) as a “post-processing” technique and refers to (ii) as an “interactive” technique, and Mualla explains that a “combination” of these two techniques can be employed in practical systems. SAMSUNG-1005, 251 (“It should be emphasized that the three categories of techniques are not mutually exclusive, and different combinations can be employed in practical systems”).

113. These teachings of Mualla are corroborated by Girod and Wada (both of which are cited in Mualla) and Stockhammer (which also cites to Girod and Wada) which provide additional details and diagrams for the same concepts disclosed in Mualla.

114. Therefore, in view of the teachings of Mualla (as corroborated by Girod, Wada, and Stockhammer), a POSITA would have understood or found obvious that feedback-based error resilience at both the encoder and decoder can be implemented by a system such as the one shown in Diagram C, below. SAMSUNG-1009, Fig. 6. In this diagram, Figure 6 of Stockhammer has been modified to show how error concealment would be implemented at the encoder, based on the teachings of Mualla. SAMSUNG-1009, Fig. 6. In particular, the modified portions of Stockhammer’s Fig. 6 are annotated and shaded in red in Diagram C. SAMSUNG-1009, Fig. 6. As shown, the modification simply amounts to replacing the encoder’s local “decoder” with an

analogous error concealment structure-enabled as already implemented in the remote decoder. SAMSUNG-1009, Fig. 6.

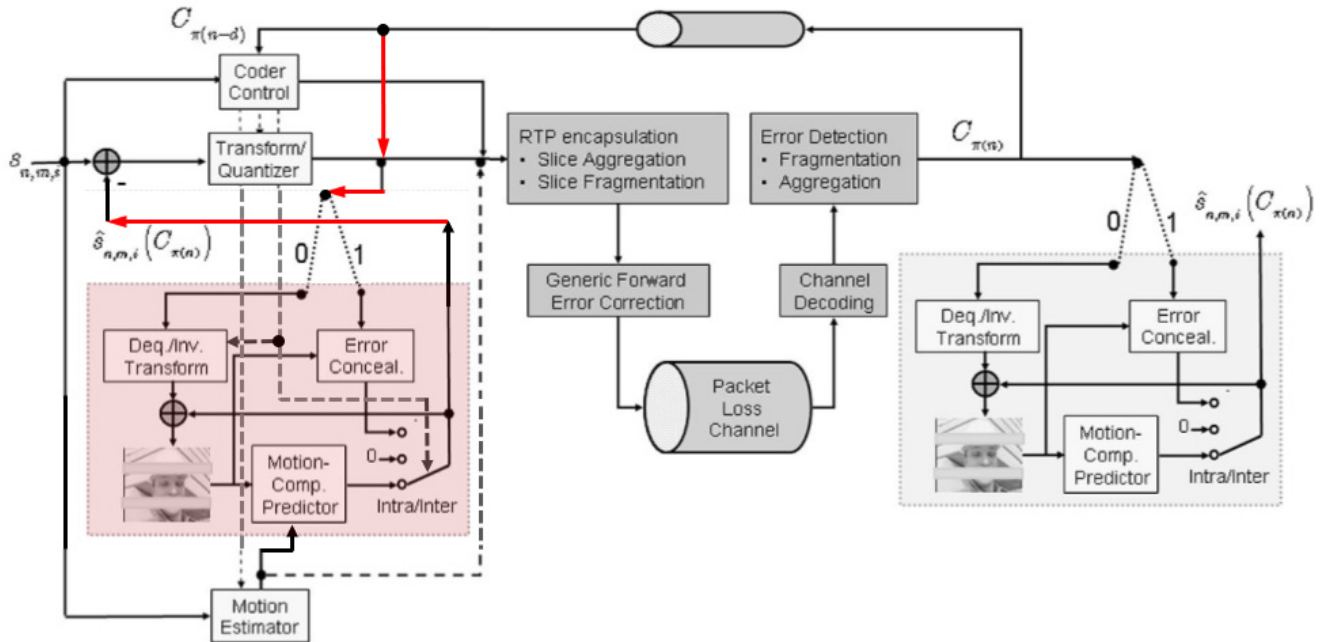


Diagram C (showing a video coding system with interactive error concealment).

115. Diagram D, below, illustrates a detailed view of the modified encoder of Diagram C. SAMSUNG-1009, Fig. 6. As discussed previously, the modified encoder implements a local decoder (shaded in red) that performs error concealment. SAMSUNG-1009, Fig. 6.

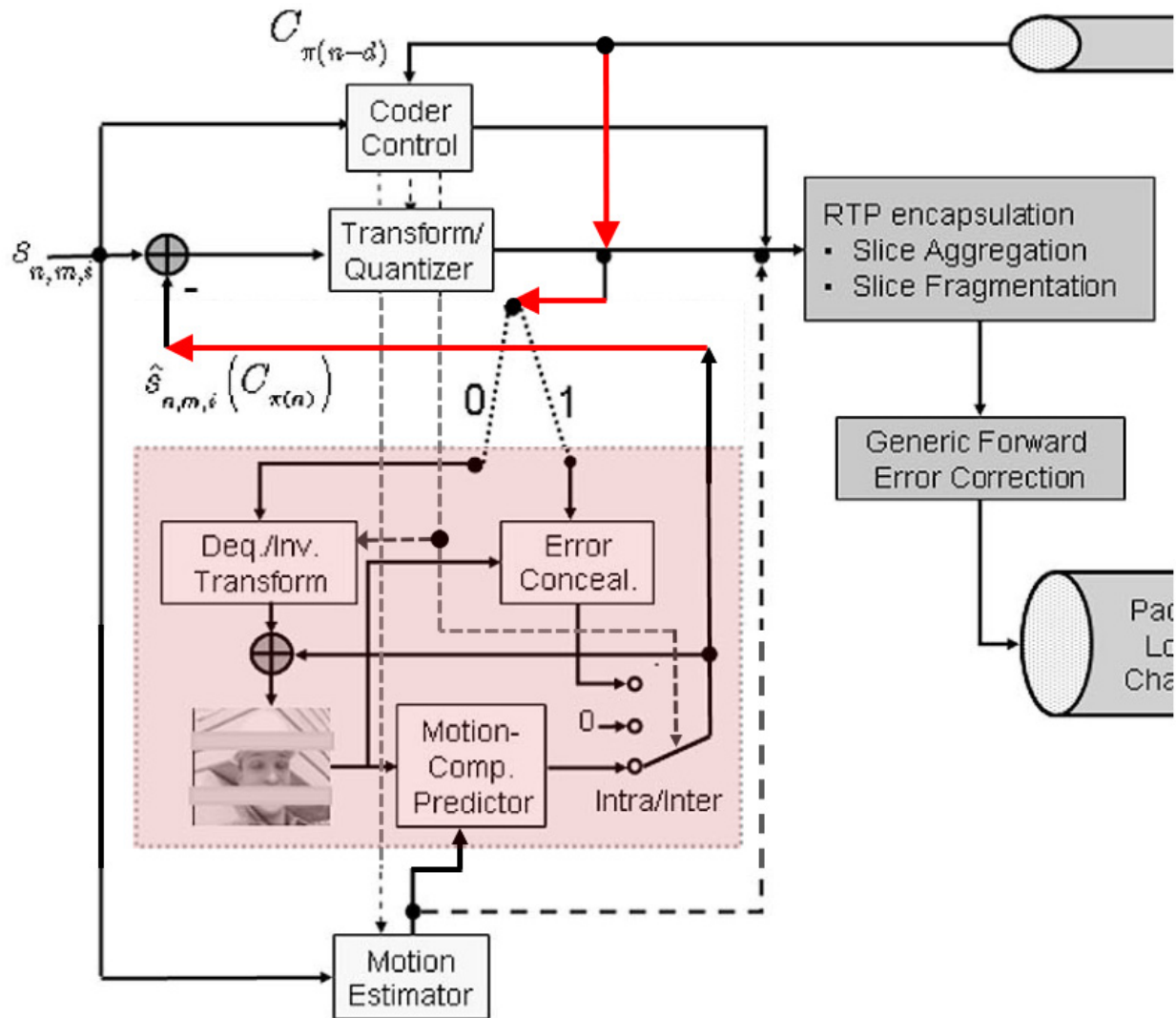


Diagram D (detailed view of the modified encoder of Diagram C).

116. The modified encoder receives feedback (annotated red line in the upper part of Diagram D) via the “back-channel” regarding blocks that were received in error at the remote decoder (not shown in Diagram D, refer to Diagram C). SAMSUNG-1009, 8, Fig. 6. Based on this feedback, a selector (the binary selector shown above the red shaded area in Diagram D) selects between “0” (if the feedback indicates that an error occurred in reception of the macroblock) or “1” (if the feedback indicates that no

error occurred in the macroblock). SAMSUNG-1009, 8, Fig. 6. If the feedback indicates that no error occurred (“0”), then the modified encoder performs the conventional steps of dequantization and inverse transform (upper-left-hand block in the red shaded area of Diagram D) with “motion compensated-predictor” (lower block in the red shaded area of Diagram D) and the second selector at the bottom-right-hand corner of the red shaded area is in the lower-most position. SAMSUNG-1009, 8, Fig. 6. Otherwise, if the feedback indicates that an error occurred (“1”), then the modified encoder performs “error concealment” (upper-right-hand block in the red shaded area of Diagram D) and the second selector at the bottom-right-hand corner of the red shaded area is in the upper-most position. SAMSUNG-1009, 8, Fig. 6.

117. Specifically, in the case of an error (“1”), POSITA would have understood or found obvious, based on the technique of “error tracking” as described in Mualla (as corroborated by Wada) that “the encoder can track the error propagation from the original occurrence up to the current frame” (SAMSUNG-1005, 247) by using a method in which “[t]he same error concealment as is performed at the receiver is carried out in the local-decoded frame stored” and then “[l]ocal decoding is reexecuted from the point of the concealed block(s) up to the currently encoded block” (SAMSUNG-1017, 2).

118. In both scenarios of the feedback indicating error and no error, the encoder’s local “decoder” generates a “reconstructed image” (i.e., the aggregate signal $\hat{s}_{n,m,i}(o, C_{\pi(n)})$) that labels the red annotated line on the left-hand side of Diagram D)

which is provided to a subtractor (left-hand side of Diagram D) which subtracts the reconstructed image from the input image (i.e., the input signal $s_{n,m,i}$). SAMSUNG-1009, Fig. 6. This is consistent with the teachings of Mualla for conventional encoding (SAMSUNG-1005, Figure 1.1, discussed above) where the encoder's local decoder generates a "prediction of the input frame" (the reconstructed image) is subtracted from the input frame (the input image).

119. Therefore, in view of the teachings of Mualla (as corroborated by Girod, Wada, and Stockhammer), a POSITA would have understood or found obvious that an error resilience technique (such as the "hybrid error concealment" technique described in Mualla) can be implemented at both the encoder and the decoder in a feedback-based video coding system.

B. Overview of Shirani

120. Shirani is cited in Mualla (as reference [199]) for teaching details of the "hybrid error concealment" technique that was described in Mualla. SAMSUNG-1005, 246. Specifically, Shirani teaches a "two-stage error-concealment method for block-based compressed video which was transmitted in an error-prone environment" in an H.263 video coding framework. SAMSUNG-1006, Abstract; 4. Shirani's "first stage" "obtain[s] an initial estimate of the missing block using information from the previous frame," which Shirani refers to as "temporal" concealment (consistent with Mualla). SAMSUNG-1005, 243-245; SAMSUNG-1006, 1-2. In Shirani's "second stage," "the

information around each missing block is used to refine the initial estimate,” which Shirani refers to as “spatial” concealment (consistent with Mualla). SAMSUNG-1005, 242-243; SAMSUNG-1006, 1-3.

121. For the “first stage,” Shirani describes a technique that utilizes motion vectors of “subblocks adjacent to the missing block” (in particular, subblocks that are “adjacent above and left” as well as “subblocks ... to the right and below of the missing block”) to derive an “initial estimate” of the missing block that has the smallest sum of “border errors.” SAMSUNG-1006, 3. Shirani illustrates an example of “subblocks adjacent to the missing block, i.e., $u1$, $u2$, $l1$, and $l2$ in Fig. 1(a)” (annotated in blue, below). SAMSUNG-1006, 3, FIG. 1(a) (reproduced below).

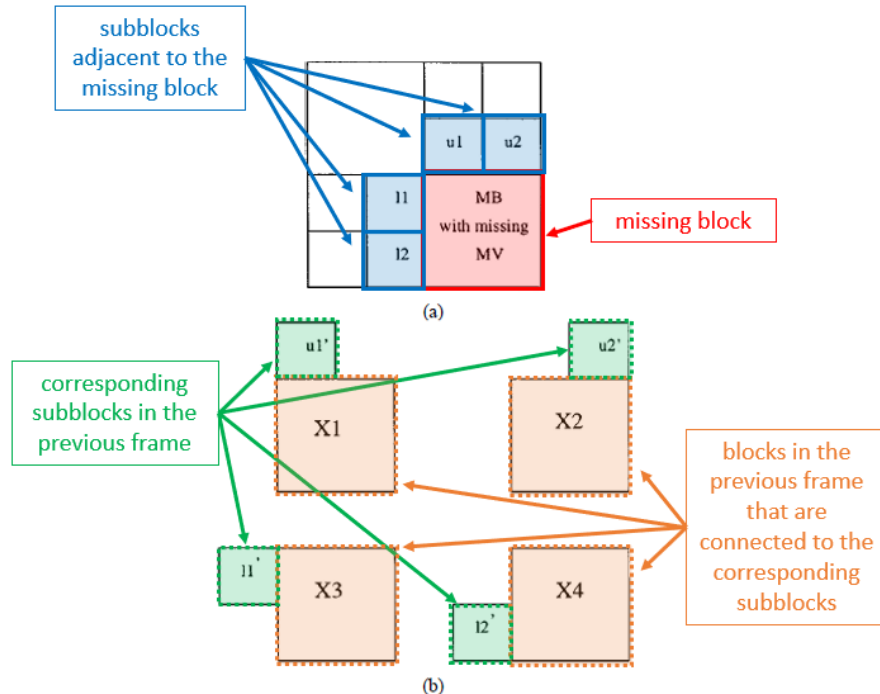


Fig. 1. (a) The four subblocks, (b) their corresponding subblocks in the previous frame, and the blocks connected to them.

SAMSUNG-1006, FIG. 1(a) (annotated and color added).

122. Once these adjacent subblocks ($u1$, $u2$, $l1$, and $l2$, annotated in blue, above) are identified, Shirani discloses that “for each of these subblocks, a corresponding subblock in the previous frame is determined” (denoted $u1'$, $u2'$, $l1'$, and $l2'$ at the bottom of FIG. 1(a) of Shirani, annotated in green, above). SAMSUNG-1006, 3. Then, “four blocks, namely X1, X2, X3, and X4 [annotated in orange in FIG. 1(a), above], which are connected to $u1'$, $u2'$, $l1'$, and $l2'$, and (respectively), are determined” and “a block from the above four blocks [(X1, X2, X3, and X4)] that minimizes the squared sums of border errors, between the estimated block and its adjacent above and left blocks, is selected.” SAMSUNG-1006, 3. This is accomplished by defining “border error[s]” in “terms of pixels,” including an error for the “bottom line pixels of the block to the top of the missing block” and an error for the “right column pixels of the block to the left of the missing block” and applying the same technique to define border errors for pixels adjacent to “the subblocks ... to the right and below of the missing block.” *Id.*

123. To estimate the motion of the adjacent subblocks ($u1$, $u2$, $l1$, and $l2$, annotated in blue, above), Shirani discloses that “computational overhead can be reduced if the search for displacement of each of the subblocks is restricted to a set of candidate motion vectors,” where the candidate motion vectors can include “the motion vectors of available neighboring blocks, the median of the motion vectors of available neighboring blocks, the average of the motion vectors of available neighboring

blocks.” SAMSUNG-1006, 3. Furthermore, although the above description focused on adjacent subblocks above and to the left of the missing block, Shirani also discloses that “the same method can be extended to include the subblocks of the blocks to the right and below of the missing block.” SAMSUNG-1006, 3.

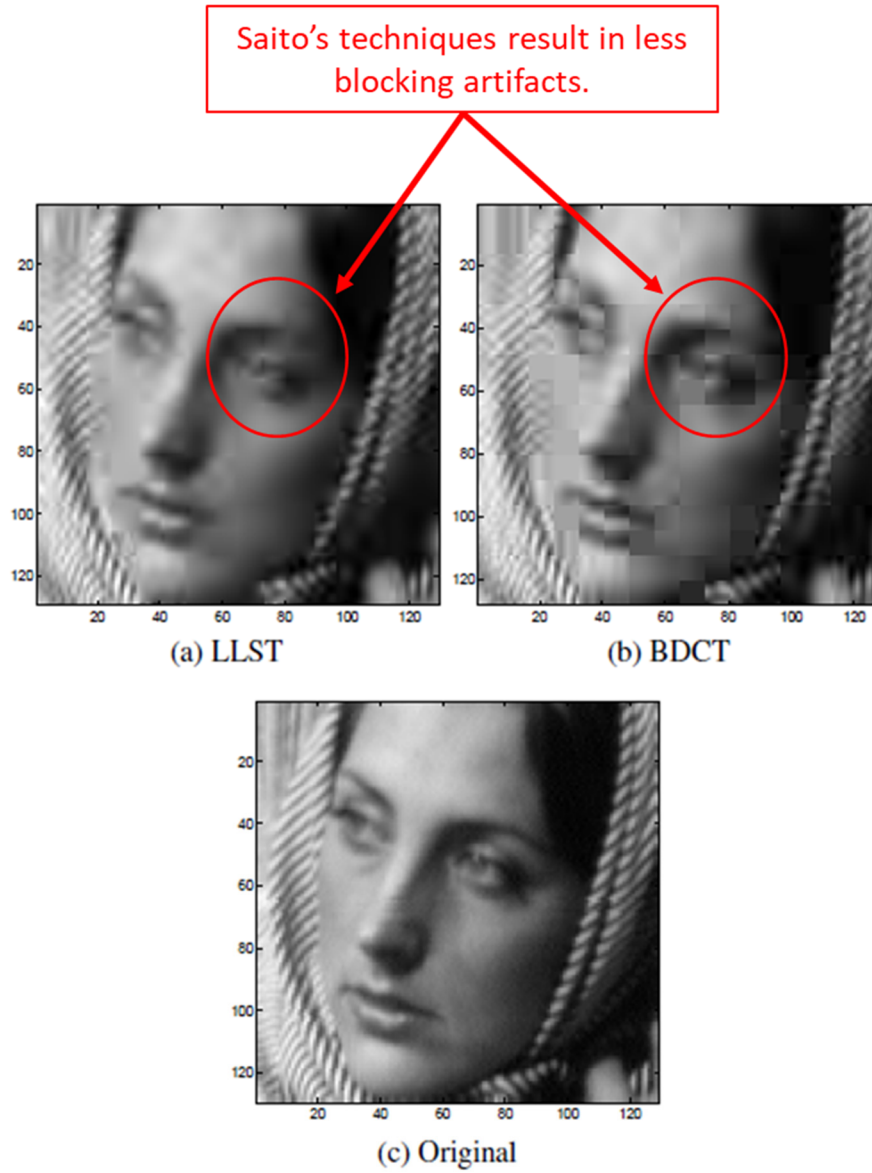
124. For the “second stage,” Shirani describes various techniques of “spatial error concealment” that can “refine the initial estimate” (obtained in the first stage, above) by utilizing “information around each missing block.” SAMSUNG-1006, 1, 3. As examples of “spatial error concealment,” Shirani describes techniques in which neighboring pixels around the missing block are used, to “refine the initial estimate” that was obtained in the first stage. SAMSUNG-1006, 1 (“each pixel in a damaged block is interpolated from the corresponding pixels in its four neighboring blocks”), 3 (“[i]n the second stage of our proposed error-concealment method, the information around each missing block is used to refine the initial estimate”).

C. Overview of Saito

125. Saito discloses “image approximation” using techniques that are based on solving Poisson’s equation. SAMSUNG-1007, 6, 27. Saito expresses an overarching goal of improving “the perceptual quality of these approximations” and a desire for a “perceptually correct metric” that can improve the “visual quality” of approximated images. SAMSUNG-1007, 18. Saito also discusses the relevance of “psychophysical

experiments” in selecting appropriate image approximation techniques that improve “visual fidelity” of reconstructed images. SAMSUNG-1007, 24.

126. To achieve these goals, Saito discloses a “polyharmonic local sine transform” (PHLST) and a “polyharmonic local cosine transform” (PHLCT) that both solve Poisson’s equation and are “effective for image approximation.” SAMSUNG-1007, 6, 27. Saito explains that “PHLST can represent smooth regions of an image very efficiently” and therefore “image approximation and compression are immediate and important applications of PHLST.” SAMSUNG-1007, 8-9. Saito further discloses “extensions and applications of PHLST” which include a version called “polyharmonic local cosine transform (PHLCT).” SAMSUNG-1005, 27. Saito explains that the PHLCT technique can “solve the ... Poisson equation with the Neumann boundary condition.” *Id.* Saito further explains that the PHLCT utilizes “the first order normal derivative of data at the boundary.” *Id.* In particular, Saito discloses that the solution to Poisson’s equation has “the same normal derivative at the boundary with the original function” by ensuring that “the residual function v_j ... clearly satisfies $\partial v_j / \partial v = 0$ on $\partial \Omega_j$.” SAMSUNG-1007, 27. Thus, Saito’s PHLCT technique ensures that the derivative of the estimated signal at a boundary of a block is equal to the derivative of the signal to be estimated at the boundary, thus ensuring smoothness of the estimated image across block boundaries with less “blocking artifacts”. SAMSUNG-1007, 27; *see also* 5, 58, Abstract, FIG. 11 (reproduced below).



SAMSUNG-1007, FIG. 11 (Cropped and annotated).

D. The combination of Mualla and Shirani (and the Combination of Mualla-Stockhammer and Shirani in Ground 1B²)

127. As discussed above, Mualla describes “hybrid error concealment” techniques for “error resilience” in video coding that implements both temporal and spatial concealment. SAMSUNG-1005, 241-246. Mualla specifically cites Shirani for details of this “hybrid error concealment” technique. SAMSUNG-1005, 241-246. Given Mualla’s explicit reference to Shirani, a POSITA would have naturally looked to Shirani and its “two-stage error concealment” technique for further details of how to implement “hybrid error concealment” as described in Mualla. SAMSUNG-1005, 246; SAMSUNG-1006, 1-6. A POSITA implementing the supplemental teachings of Shirani into the existing disclosure of Mualla would have created the Mualla-Shirani combination (and the Mualla-Stockhammer-Shirani combination in Ground 1B).

128. In particular, the hybrid error concealment techniques of the Mualla-Shirani combination perform error detection to detect whether errors exist in a frame (also referred to as a picture). SAMSUNG-1005, 241-246; SAMSUNG-1006, 2-4. If errors are detected in a frame/picture, a two-stage motion-compensated error

² Although my discussion in this section focuses on the combination of Mualla and Shirani, it is similarly applicable to the combination of Mualla-Stockhammer and Shirani in Ground 1B, with Stockhammer supplementing Mualla merely to provide illustrative details of implementing what a POSITA would have understood or found obvious to already be taught by Mualla’s error concealment disclosure.

concealment algorithm is applied to perform both temporal and spatial concealment to conceal the errors and generate a predicted frame. SAMSUNG-1005, 242-246; SAMSUNG-1006, 2-4. Otherwise, if no errors are detected, conventional motion compensation is applied. *Id.* Specifically, as discussed above, the two-stage (hybrid) error concealment algorithm of the Mualla-Shirani combination implements a “first stage” which applies “temporal” concealment and a “second stage” which applies “spatial” concealment. SAMSUNG-1005, 242-245; SAMSUNG-1006, 1-3.

129. Furthermore, in the combination of Mualla and Shirani, and in particular in Shirani’s “two-stage error concealment” technique, Shirani describes various alternatives for the “second stage” (in which “spatial” concealment is performed). As discussed above, as an example of the second stage, Shirani describes a spatial concealment technique in which “each pixel in a damaged block is interpolated from the corresponding pixels in its four neighboring blocks such that the total squared border error is minimized.” SAMSUNG-1006, 1.

130. Furthermore, as discussed above, the two-stage hybrid error concealment is implemented in both the encoder and the decoder (“interactive” error concealment), as taught by Mualla, so that the encoder and decoder can “cooperate to minimize the effects of transmission errors” and in particular so that “coding efficiency can also be improved by performing error concealment in the encoder so that both encoder and decoder use the same reference frames for prediction.” SAMSUNG-1005, 246-250.

131. As explained below in more detail, combining Mualla and Shirani would have been obvious at least because such a combination would have merely involved (1) combining prior art elements according to known methods to yield predictable results; and the (2) use of known techniques to improve similar devices in the same way. Indeed, Mualla describes a similar hybrid error concealment technique as Shirani, and the combination would have simply involved adding Shirani's teachings into the compatible teachings of Mualla, thus, for at least this reason, making the Mualla-Shirani combination predictable and foreseeable with a reasonable expectation of success. SAMSUNG-1005, 246; SAMSUNG-1006, 1-6. Moreover, because Mualla explicitly cites to Shirani's teachings when discussing its own techniques of hybrid error concealment, the use of Shirani's techniques in Mualla would have improved a similar device in the same way. SAMSUNG-1005, 246. Additionally, Mualla and Shirani implement their teachings in similar video coding standards (e.g., H.263). SAMSUNG-1005, 71-94, 231; SAMSUNG-1006, 4-5.

E. The combination of Mualla, Shirani, and Saito (and the Combination of Mualla-Stockhammer-Shirani and Saito in Ground 1B³)

132. As discussed above, the combination of Mualla and Shirani (and the combination of Mualla-Stockhammer and Shirani in Ground 1B) implements a two-stage (hybrid) error concealment technique. In particular, the second stage applies “spatial error-concealment” to “restore the missing blocks using the information in the current frame.” SAMSUNG-1006, 1; *see also* SAMSUNG-1005, 242 (explaining that spatial concealment techniques “conceal damaged pels in a frame using information from correctly received and/or previously concealed neighboring pels within the same frame”). Both Mualla and Shirani disclose that “spatial” concealment can be implemented using various techniques from the field of conventional image-processing, each with benefits and tradeoffs. SAMSUNG-1005, 242-243; SAMSUNG-1006, 1.

133. Therefore, as evidenced in the teachings of both Mualla and Shirani, a POSITA would have understood or found obvious that **image-processing** techniques

³ Although my discussion in this section focuses on the combination of Mualla-Shirani and Saito, it is similarly applicable to the combination of Mualla-Stockhammer-Shirani and Saito in Ground 1B, with Stockhammer supplementing Mualla merely to provide illustrative details of implementing what a POSITA would have understood or found obvious to already be taught by Mualla’s error concealment disclosure.

are a natural solution for implementing the **second-stage “spatial”** concealment of the Mualla-Shirani two-stage hybrid technique. It was well-known to use image-processing techniques to perform spatial concealment within an individual frame of a video. SAMSUNG-1011 (disclosing a hybrid-type “space-time video completion” techniques for “[c]orrection of missing/corrupted video frames” in which “classical spatial image completion and synthesis” is implemented for “spatial” correction within an individual video frame).

134. Furthermore, a POSITA would have understood or found obvious that image processing can be performed by techniques that involve solving Poisson’s equations. Numerous research papers and patents had, several years before the Critical Date, described techniques for image editing and image reconstruction that involved solving Poisson’s equation. SAMSUNG-1010 (disclosing “Poisson image editing” which is “based on solving Poisson equations” for “seamless editing of image regions”); SAMSUNG-1012 (disclosing techniques for “image reconstruction” by “solving the Poisson differential equation”); SAMSUNG-1013 and SAMSUNG-1014 (disclosing techniques for “natural image matting” by “solving Poisson equations”); SAMSUNG-1015 (disclosing a technique that “constructs a low dynamic range image by solving a Poisson equation”).

135. A POSITA would have understood or found obvious that image processing techniques involving Poisson’s equation are particularly effective in

addressing the same challenges and achieving the same goals emphasized by Mualla and Shirani for error concealment applications. For example, Mualla explains the fundamental importance of considering the “human visual system (HVS)” in video codec techniques. SAMSUNG-1005, 33, 36, 40, 52, 55, 59. Mualla explains that the “classical view of image the image coding problem” has a disadvantage because it “does not place enough emphasis on exploiting the properties of the HVS [human visual system]. Efforts to utilize models of the HVS and to use more representative coding entities (real objects) led to a new class of coding methods known as the second-generation coding methods.” SAMSUNG-1005, 59. Specifically, in the context of error resilience and error concealment, Mualla explains that a “decoder attempts to conceal the effects of errors by providing a **subjectively acceptable** approximation to the original data. This is achieved by exploiting the limitations of the **human visual system** and the high temporal and/or spatial correlation of video sequences.” SAMSUNG-1005, 242; 251. Indeed, Mualla measures the performance of different error concealment techniques by the “[s]**ubjective quality**” of error-concealment in a video frame, as viewed by the human visual system. SAMSUNG-1005, 265; 268 Figures 10.8, 10.10. In addition to these challenges of providing good subjective quality of error-concealed images for the human visual system, Mualla also explains a mathematical challenge in that “[e]rror concealment is an ill-posed problem since it **does not have a unique solution.**” SAMSUNG-1005, 242; 251. Like Mualla, Shirani also stresses the

fundamental importance of considering the “limitations of the **human visual system**” when designing an error concealment technique, as well as the benefits of using a technique that can achieve a “a **unique global solution.**” SAMSUNG-1006, 1, 4.

136. In view of Mualla and Shirani emphasizing a fundamental goal of improving the “subjective quality” of error concealment techniques for the “human visual system,” a POSITA would have understood that an image approximation technique based on **solving Poisson’s equation**, as taught by Saito (SAMSUNG-1007), is an effective way to achieve this goal. The Poisson equation has been used extensively in field of image processing and computer vision due to the specific benefits it provides for improving the perceptual quality of reconstructing images. SAMSUNG-1010 (disclosing “[t]he Poisson equation has been used extensively in computer vision” because “it is well known to psychologists [Land and McCann 1971] that slow gradients of intensity, which are suppressed by the Laplacian operator, can be superimposed on an image with barely noticeable effect. Conversely, the second-order variations extracted by the Laplacian operator are the most significant perceptually”).

137. Therefore, as discussed above: (i) Mualla and Shirani both recognize that **image processing** techniques can be utilized to implement **second-stage spatial** error concealment in the Mualla-Shirani two-stage hybrid error concealment technique for video frames, (ii) image processing techniques that involve **solving Poisson’s equation** were well-known to provide specific benefits for improving the perceptual

quality of reconstructed images for the human visual system, thus addressing a fundamental objective of Mualla and Shirani's error concealment. As such, a POSITA would have understood or found obvious that image-processing techniques based on solving Poisson's equation would have been naturally applicable for implementing the second-stage "spatial" concealment of the Mualla-Shirani two-stage hybrid error concealment algorithm for video frames. Indeed, literature in video coding spatial error concealment and literature in image processing by solving Poisson's equation both cited to similar techniques. For example, Wexler (SAMSUNG-1011, which describes using classical spatial image processing techniques for correcting video frames) and Perez (SAMSUNG-1010, which describes Poisson image editing as an example of an image processing technique) both discuss a technique called "image inpainting" as an example of image processing and cite to many of the same references as related art for details of image inpainting.

138. Saito provides details of implementing solutions to Poisson's equation for image approximation. A POSITA would have understood that Saito, which was published in 2006 (over 4 years after Mualla and Shirani), was a natural advancement of applying Poisson's equation to improve the visual quality of image approximation and represented a state-of-the-art solution at the time of the Critical Date. Like Mualla and Shirani, Saito expresses an overarching goal of improving "the perceptual quality of these approximations" and a desire for a "perceptually correct metric" that can improve

the “visual quality” of approximated images. SAMSUNG-1007, 18. Saito also discusses the relevance of “psychophysical experiments” in selecting appropriate image approximation techniques that improve “visual fidelity” of reconstructed images. SAMSUNG-1007, 24.

139. As discussed above, Saito discloses a “polyharmonic local sine transform” (PHLST) and a “polyharmonic local cosine transform” (PHLCT) that solve Poisson’s equation and are “effective for image approximation.” SAMSUNG-1007, 6, 27. In particular, Saito explains that its PHLCT technique “shall solve the $\square$ Poisson equation with the Neumann boundary condition.” SAMSUNG-1007, 27.

140. Furthermore, as discussed above, a POSITA would have recognized or found obvious that Mualla, Shirani, and Saito all strive to achieve similar goals in spatial image approximation, and in correspondence with that, a POSITA would have had a reasonable expectation of success in combining Saito’s techniques into Mualla-Shirani. For example, both Shirani and Saito strive to improve reconstruction of high-frequency edges and discontinuities in an image. *See, e.g.*, SAMSUNG-1006, 5 (explaining a key goal of Shirani’s second-stage spatial error concealment is to improve “reconstruction quality, particularly in retrieving the edges and in the areas of the frame that correspond to adjacent missing blocks.”), and 7 (describing that a “performance advantage is demonstrated in the blocks that contain edges”); and SAMSUNG-1007, 1 (explaining that Saito’s techniques “can distinguish intrinsic singularities in the data from the

artificial discontinuities created by the local windowing”), 2 (explaining that a goal of Saito’s techniques is to avoid “artificial discontinuities due to the local windowing or the brute-force periodization so that we can focus on the analysis of intrinsic discontinuities and singularities in the signal”), 4 (explaining that Saito’s techniques “can distinguish intrinsic singularities in the data from the artificial discontinuities created by the local windowing”).

141. As discussed above, Saito’s PHLCT technique ensures that the derivative of the estimated signal at a boundary of a block is equal to the derivative of the signal to be estimated at the boundary. SAMSUNG-1007, 27; *see also* 5, Abstract; *see above* §VI.C. A POSITA would have understood or found obvious that this is consistent with Shirani’s “second stage” technique generating a “refined initial estimate” that has border pixel values with a “border error” that is equal to the “border error” of the “initial estimate” that was generated in Shirani’s “first stage.” SAMSUNG-1006, 1, 3; SAMSUNG-1007, 27; *see also* 5, Abstract. Shirani’s “border error” is equivalent to Saito’s “derivative at the boundary” (which is equivalent to the ’025 patent’s “gradient” value at a boundary) because both Shirani’s “border error” and Saito’s “derivative at the boundary” are equal to a difference of adjacent pixel values across a border/boundary between two blocks. Furthermore, a POSITA would have understood or found obvious that because Saito’s PHLCT technique can achieve a faster “decay rate” for the error signal at the boundaries of blocks, this is consistent with Shirani’s goal of

“improv[ing] the video reconstruction quality” by ensuring that “image continuity inside the block and across its boundaries is preserved.” SAMSUNG-1007, 27; SAMSUNG-1006, Abstract, 3.

142. As explained below in more detail, combining Mualla-Shirani and Saito would have been obvious at least because such a combination would have merely involved (1) combining prior art elements according to known methods to yield predictable results; and the (2) use of known techniques to improve similar devices in the same way.

143. In the resulting combination of Mualla, Shirani, and Saito, if no errors are detected in a frame of video, then conventional motion compensation is applied to the frame “to provide a prediction of the current frame,” as taught by Mualla and Shirani. SAMSUNG-1005, 27, Figure 1.1, 115-116; SAMSUNG-1006, Abstract 2-3. Otherwise, if an error is detected in one or more blocks of a frame, then a motion-compensated two-stage hybrid error concealment technique is applied to the frame. The “first stage” applies Shirani’s “temporal” concealment to find a block X_i in the previous frame with border pixels that have the smallest sum of “border errors” relative to surrounding blocks, as taught by Shirani. SAMSUNG-1005, 242-245; SAMSUNG-1006, 1-3. The resulting block X_i is an “initial estimate” of the erroneous/missing block.

144. Then, the “second stage” of the Mualla-Shirani two-stage hybrid error concealment technique refines the “initial estimate” X_i by applying “spatial”

concealment in which “the information around each missing block” is utilized to estimate pixels values in the interior of the estimated block X_i . SAMSUNG-1005, 242-245; SAMSUNG-1006, 1-3. Here, the second-stage spatial concealment of Mualla-Shirani is modified to implement Saito’s PHLCT to interpolate the interior pixels of the Mualla-Shirani initial estimate X_i . In particular, the second-stage spatial concealment obtains a solution to Poisson’s equation with Neumann boundary conditions equal to the normal derivatives at boundaries of the missing block (as taught by Saito). These normal derivatives at the boundaries are based on Shirani’s “border errors” that were obtained in Shirani’s first stage. As a result, the Mualla-Shirani-Saito combination uses a Poisson-equation-solving image approximation technique (e.g., PHLCT as taught in Saito) to implement spatial error concealment in the second stage of the Mualla-Shirani two-stage hybrid error concealment technique, thereby generating a refinement of the “initial estimate” that was obtained in Shirani’s first stage. The result is an estimated frame in which erroneous/missing blocks have been concealed. A POSITA would have recognized and found obvious that Saito’s image approximation techniques based on solving Poisson’s equation would have enhanced Shirani’s “second stage” techniques, “improv[ing] the video reconstruction quality” in order to achieve similar goals of image approximation. SAMSUNG-1007, 27; SAMSUNG-1006, Abstract, 3.

145. Furthermore, as discussed above, the modified two-stage hybrid error concealment of the Mualla-Shirani-Saito combination is implemented in both the

encoder and the decoder, as taught by Mualla, so that the encoder and decoder can “cooperate to minimize the effects of transmission errors” and in particular so that “coding efficiency can also be improved by performing error concealment in the encoder so that both encoder and decoder use the same reference frames for prediction.” SAMSUNG-1005, 246-250.

VII. Ground 1A/1B – Claims 1-10 are Obvious under 35 U.S.C. § 103 based on Mualla, Shirani, and Saito (1A) and Mualla, Shirani, Saito, and Stockhammer

A. Analysis⁴

146. In my opinion, a person of ordinary skill in the art would have found claims 1-10 of the '025 patent to have been obvious based on Mualla, Shirani, and Saito, and additionally based on Mualla, Shirani, Saito, and Stockhammer.

147. As an initial matter, the '025 Patent includes claims that recite both encoding and decoding operations (despite the claim being directed to an “encoding” or “decoding” apparatus by the preamble). *See, e.g.*, SAMSUNG-1006, Claim 6. To indicate which limitations include predominately encoding or decoding steps, I have

⁴ Although my discussion in this section focuses on the combination of Mualla-Shirani-Saito, it is similarly applicable to the combination of Mualla-Stockhammer-Shirani-Saito in Ground 1B, with Stockhammer supplementing Mualla merely to provide illustrative details of implementing what a POSITA would have understood or found obvious to already be taught by Mualla’s error concealment disclosure.

added the annotations of COD (“encoding”) and DEC (“decoding”) to the title of each claim limitation. This annotation is solely an aide to the reader and should not be viewed as an argument that a limitation discloses only one operation or the other.

1. “Moving picture decoding” claims 6-8, and 10;

[6.pre] A moving-picture decoding apparatus comprising:

148. Mualla teaches extensive details of an H.263-based video codec system, which implements a ***decoding apparatus*** for decoding ***moving pictures*** (e.g., “video”). SAMSUNG-1005, 23-26, 31, 36, 51-52, 227-228, 241-242, 265. For example, in describing “Transform Coding” which “forms the basis of almost all video coding standards,” Mualla describes a ***decoder*** implemented in a “transform coding system.” SAMSUNG-1005, 51 (last paragraph), Figure 2.9 (reproduced below). As another example, in describing techniques for “error resilience” in video coding systems, Mualla discloses a ***decoder*** implemented in a “typical video communication system.” SAMSUNG-1005, 227-228, Figure 9.1 (reproduced below).

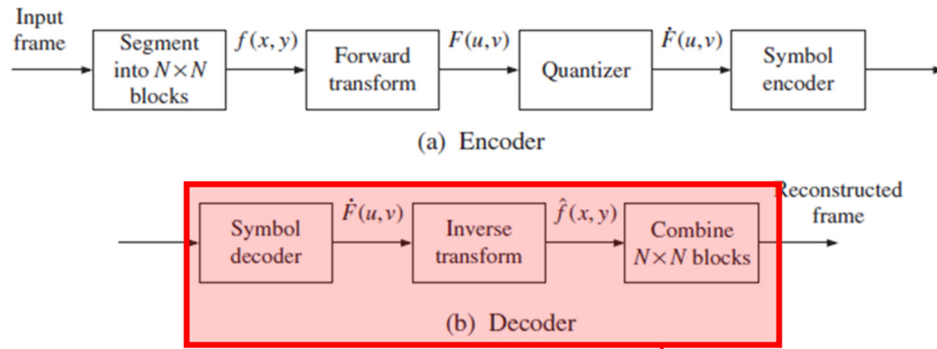


Figure 2.9: Block diagram of a transform coding system

A "moving-picture
decoding apparatus"

SAMSUNG-1005, FIG. 2.9 (annotated and color added).

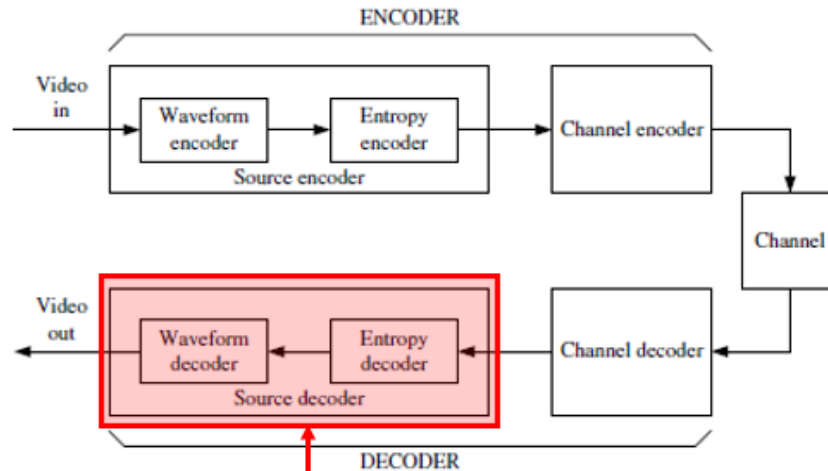


Figure 9.1: Typical video communication system

A "moving-picture
decoding apparatus"

SAMSUNG-1005, FIG. 9.1 (annotated and color added).

149. Shirani similarly discloses using the H.263-based video codec system and its associated *decoding apparatus*. SAMSUNG-1006, 2-4 (“[w]hen channel errors occur, **the decoder** usually discards the erroneous data”), 4 (“H.263”).

[6.1.DEC] a demultiplexer to demultiplex coded data from an input signal based on a specific syntax structure,

150. Shirani discloses that “[c]oded video information [(“***coded data from an input signal***”)] is first grouped into packets” and the “video packets are ... multiplexed with audio information” using an “H.223 multiplexing” protocol. SAMSUNG-1006, 5. Multiplexing video packets at an encoder would have required a means for “***demultipex[ing]***” the video packets at the decoder, for example, by using a ***demultiplexer***. Indeed, the H.263 standard (the standard used by Mualla and Shirani) corroborates the use of demultiplexers in H.263 codecs for “***demultiplex[ing] coded data from an input signal.***” SAMSUNG-1016, 2.

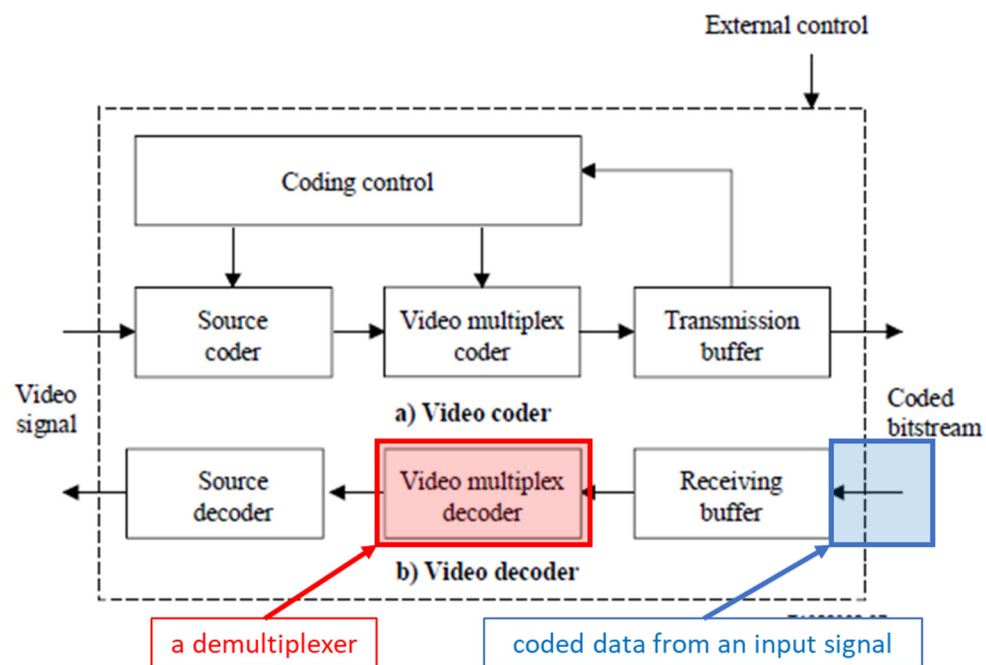
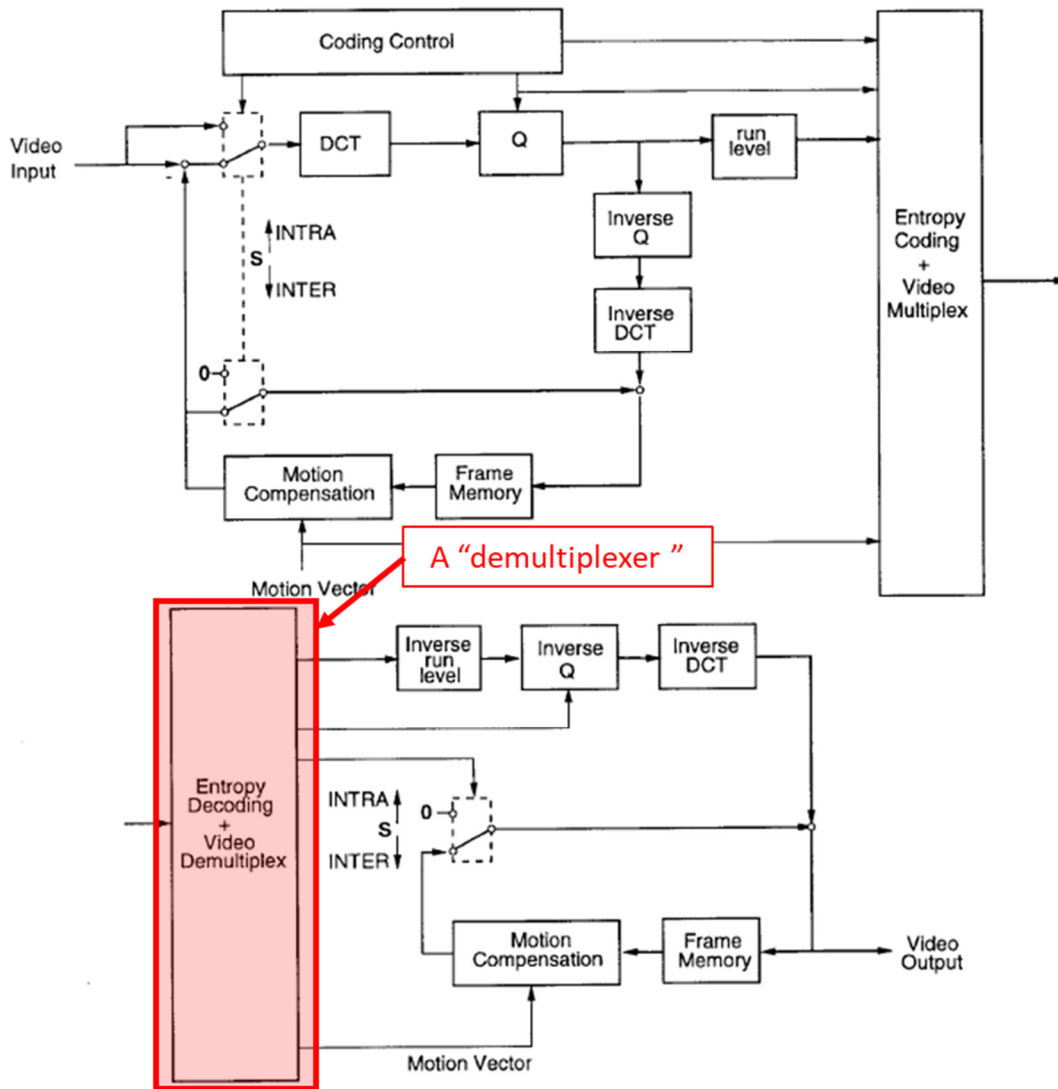


Figure 1/H.263 – Outline block diagram of the video codec

SAMSUNG-1016, FIG. 1 (annotated and color added).

151. Additionally, Girod – a H.263 codec reference cited by Mualla as reference 201 – discloses that information is “multiplexed to the video bitstream.” SAMSUNG-1008, 2, FIG. 1(b). FIG. 1(b) illustrates an example decoder with a “**demultiplexer**.”



SAMSUNG-1008, FIG. 1(a) (“encoder”) and 1(b) (“decoder”) (annotated and color added).

152. Furthermore, Mualla and Shirani both disclose the H.263 *specific syntax structure*. SAMSUNG-1005, 93, 232; SAMSUNG-1006, 2, 4-5. Indeed, Mualla refers

to the H.263 codec standard as “the ***syntax*** of H.263.” SAMSUNG-1005, 93. Mualla and Shirani also both use the specific syntax structure of the H.263 codec standard as a gauge for detecting errors in a video bitstream. SAMSUNG-1005, 231-232; SAMSUNG-1006, 2. For example, Mualla’s process of “error correction” uses “***syntax*** ... violations” to detect errors in a video bitstream. SAMSUNG-1005, 231-232. Shirani discloses a similar process where a decoder determines the “location of missing blocks” by “detecting ... semantic or ***syntactic*** violations.” SAMSUNG-1006, 2.

[6.2.COD] the input signal being obtained by multiplexing a coded bitstream obtained by predictive coding, border motion-vector data and post-quantization data obtained by quantization in the predictive coding,

153. As described above in 6.1.DEC, Shirani discloses ***multiplexing a coded bitstream***, and a POSITA would have understood or found obvious that the H.263 codec standard, as used in Mualla and Shirani, included ***multiplexing*** operations. SAMSUNG-1006, 5; *see above*, [6.1.DEC]. Indeed, the H.263 standard discloses multiplexing and demultiplexing a “***coded bitstream***.” SAMSUNG-1016, 2, 9.

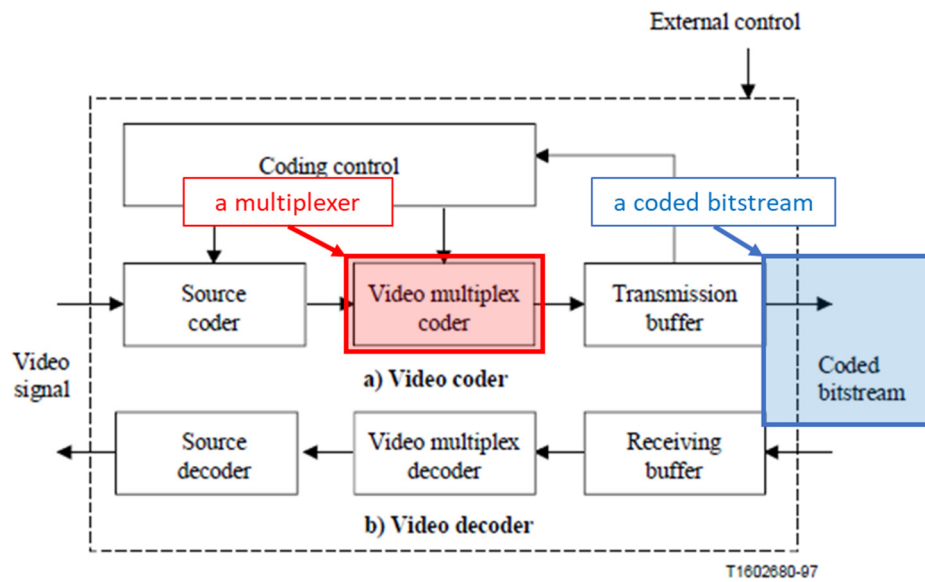


Figure 1/H.263 – Outline block diagram of the video codec

SAMSUNG-1016, FIG. 1 (annotated and color added).

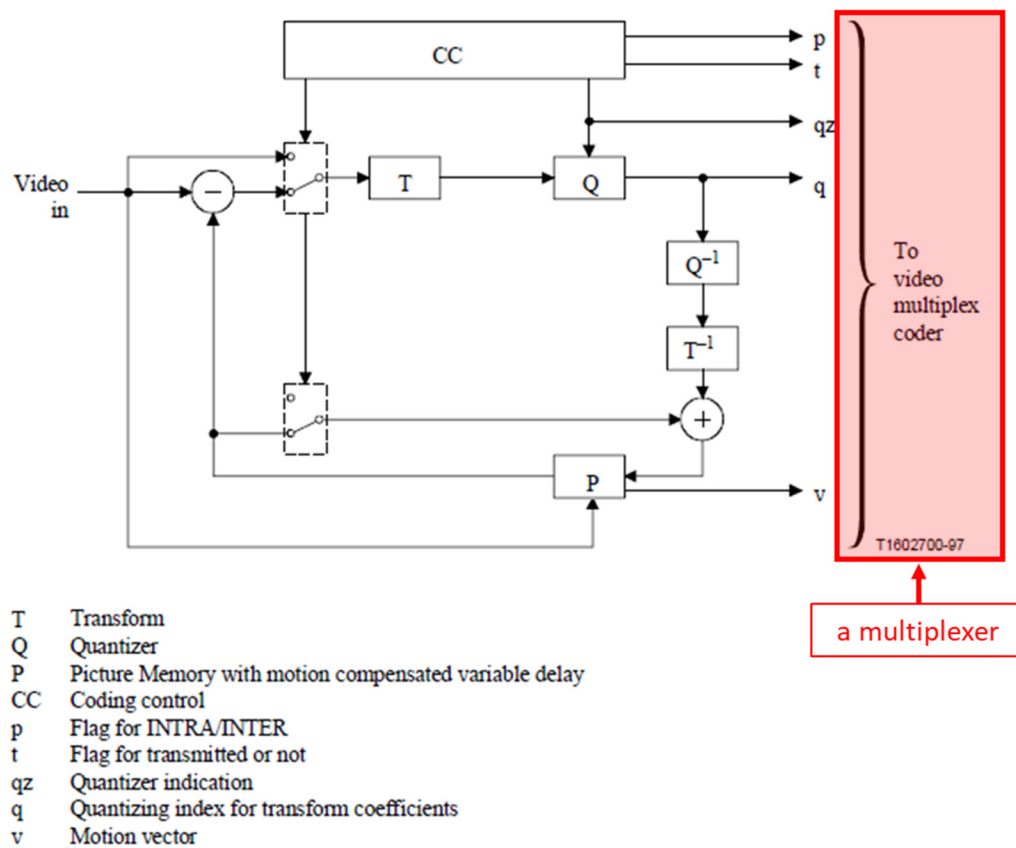


Figure 3/H.263 – Source coder

SAMSUNG-1016, FIG. 3 (annotated and color added).

154. Furthermore, as shown in Mualla’s Figure 3.1 and explained in further detail below, a POSITA would have understood or found obvious, based on the teachings of Mualla, that the coded bitstream is obtained by encoding motion vectors (which include the claimed “*border motion-vector data*”) and a quantization index (the claimed “*post-quantization data*”), along with various coding control information. SAMSUNG-1005, Figure 3.1 (reproduced below), 71-75.

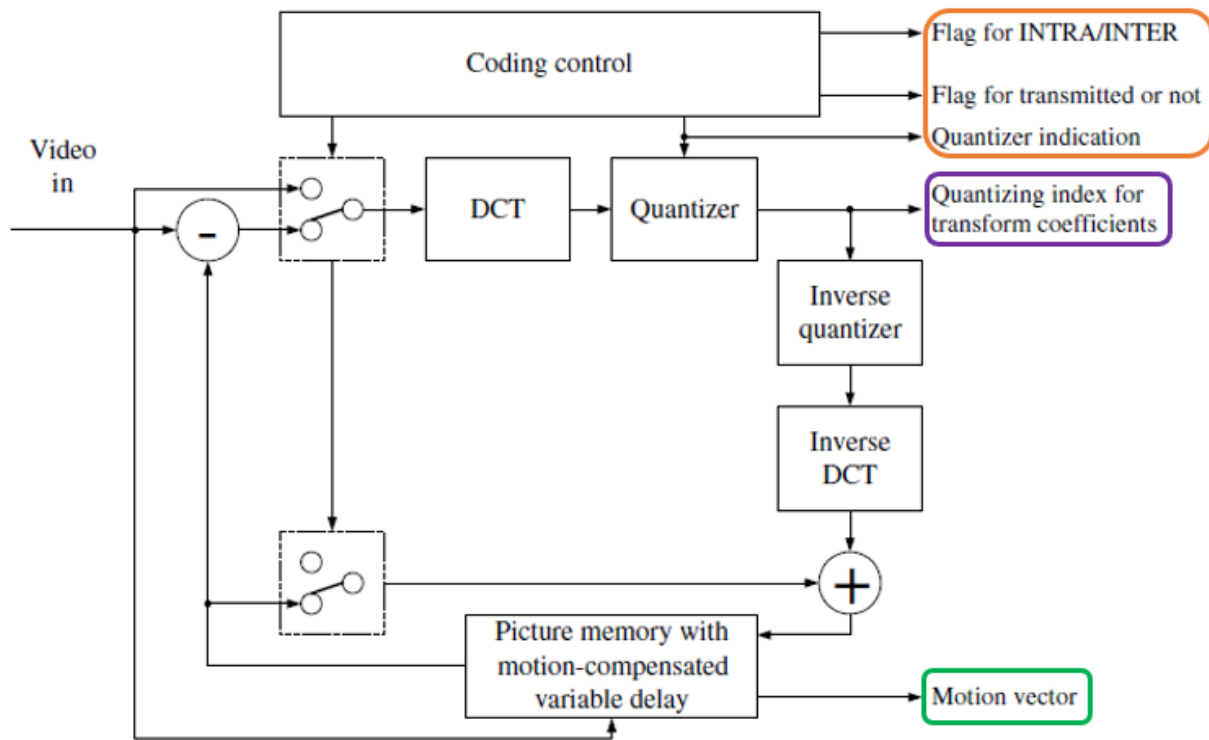


Figure 3.1: H.263 video encoder

SAMSUNG-1005, Figure 3.1 (annotated).

...obtained by predictive coding

155. Mualla describes numerous operations at the encoder that perform predictive coding. For example, Mualla discloses a “video codec” that includes a “motion estimation (ME) block ... to estimate the movement that occurred between the current frame and a reference frame.” SAMSUNG-1005, 26-27, 115-117, FIG. 1.1. Mualla refers to this estimation as “motion information.” *Id.* Motion information is then “utilized by the motion compensation (MC) block to move the contents of the reference frame to provide a prediction of the current frame” (“***predictive coding***”) which Mualla also refers to as the “motion-compensated prediction (MCP).” *Id.*

Mualla refers to “motion compensated prediction” as a type of “predictive coding” in which regions of an input frame are predictively coded “with respect to the corresponding regions in the reference frame.” SAMSUNG-1005, 61. Mualla’s “typical video codec” illustrates these components.

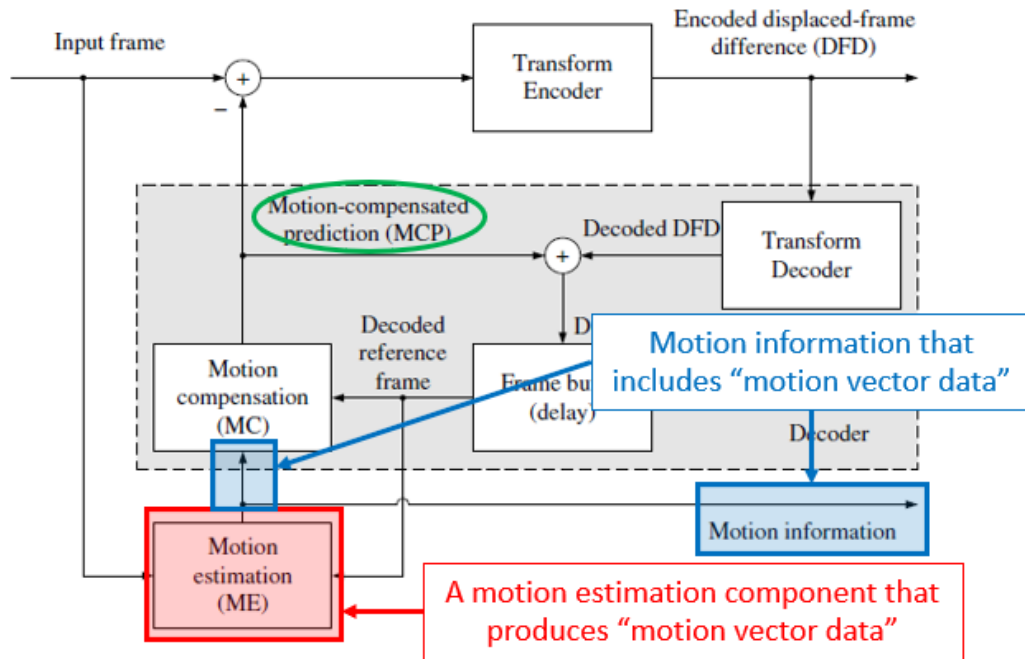


Figure 1.1: Typical video codec

SAMSUNG-1005, FIG. 1.1 (annotated and color added).

156. As another example of predictive coding, Mualla discloses that the “motion information” (motion vector) itself is predictively coded. Mualla discloses that the “motion of the [a] current block” (e.g., the motion information) is “represented by a motion vector” (“***motion-vector data***”) which is the “displacement between the block and its best-match block in the reference frame.” SAMSUNG-1005, 62, FIG. 2.16. An example motion vector is illustrated by Mualla in FIG. 2.16 below.

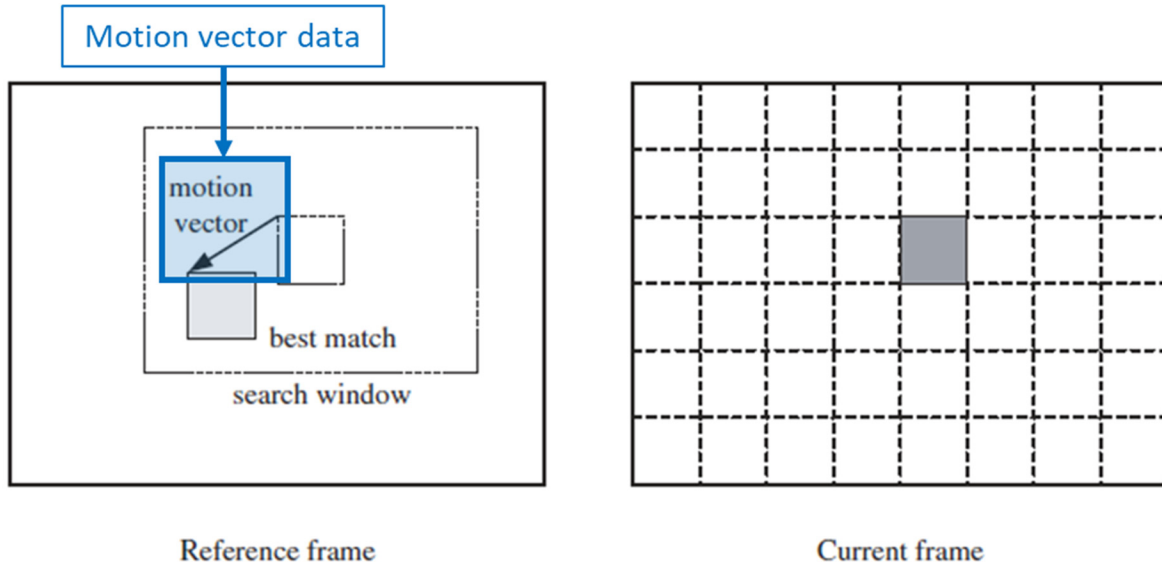


Figure 2.16: Block-matching motion estimation

SAMSUNG-1005, FIG. 2.16 (annotated and color added).

157. Mualla discloses that the “estimated motion vector” is “predictively coded” (part of “*a coded bitstream obtained by predictive coding*”), meaning that the “motion vector difference $MVD = MV - MVP$ is encoded instead of the motion vector itself.” SAMSUNG-1005, 74, *see also* 115-117. The MVP is “the median of three candidate predictors, which are the motion vectors of three surrounding macroblocks” (“a motion vector from a border of the rectangular zone”). One example of this grouping of motion vectors is annotated in Mualla’s FIG. 3.3.

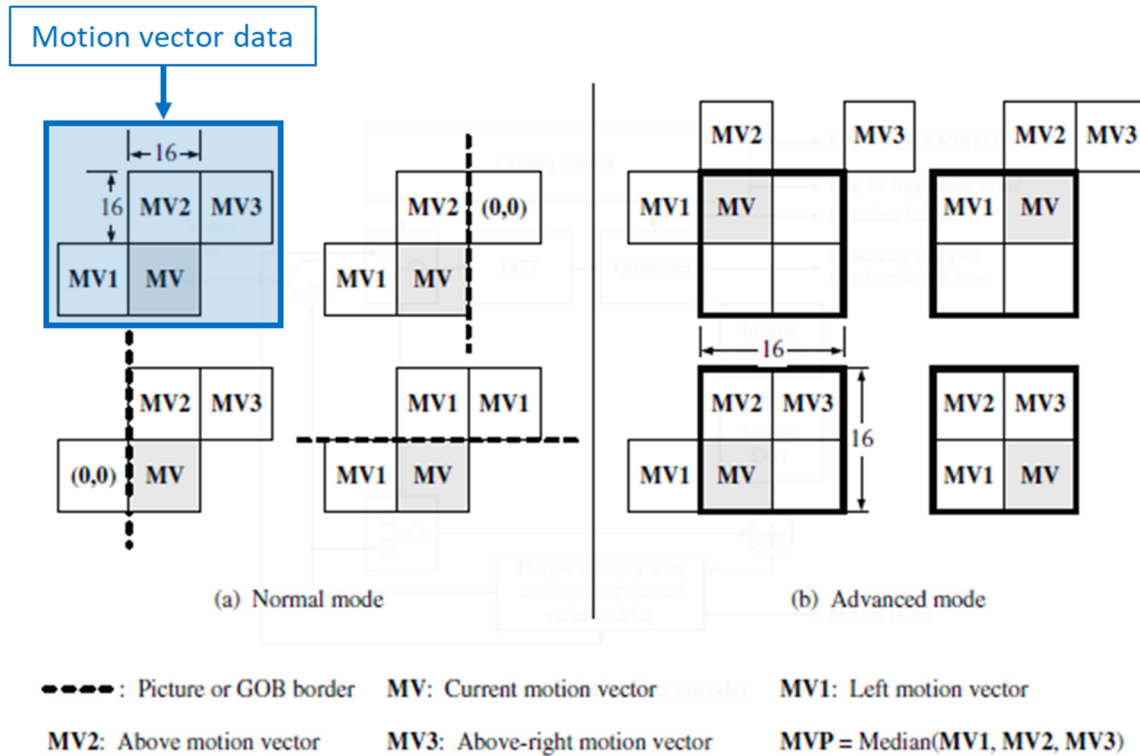


Figure 3.3: H.263 motion vector prediction

SAMSUNG-1005, FIG. 3.3 (annotated and color added).

border motion-vector data

158. As an initial matter, the '025 patent describes “**border motion-vector data**” as “data on a motion vector from a border of the rectangular zone in the picture to be coded to the border of the reference picture thus found.” SAMSUNG-1001, 2:59-61; *see below*, [6.6.COD].

159. As discussed above, the Mualla-Shirani-Saito combination implements a two-stage hybrid error concealment in the encoder (as well as the decoder), as taught by Mualla. SAMSUNG-1005, 246-250. In particular, the encoder of the Mualla-Shirani-Saito combination implements the first-stage of Shirani's two-stage error

concealment technique to the motion of a missing/erroneous macroblock by performing temporal concealment. *See above*, §§VI.B, E. Notably, in the combination, Shirani's first stage uses motion vectors of neighboring blocks to obtain estimates of pixels at the borders of a missing block. *See above*, §§VI.B, E; SAMSUNG-1006, 2-3. In particular, the first stage of Shirani estimates motion vectors of subblocks adjacent to the missing block, and in doing so, utilizes “candidate motion vectors” (“data on a motion vector”) which can include motion vectors of “neighboring blocks.” *See above*, §§VI.B, VI.D, VI.E; SAMSUNG-1006, 2-3. These motion vectors of neighboring blocks are used to obtain an estimate of pixels at each border of the missing block (“***from a border of the rectangular zone in the picture to be coded***”), by minimizing the “squared sums of border errors” (in total, “***border motion-vector data***” or, “data on a motion vector from a border of the rectangular zone in the picture to be coded to the border of the reference picture thus found”). *Id.*

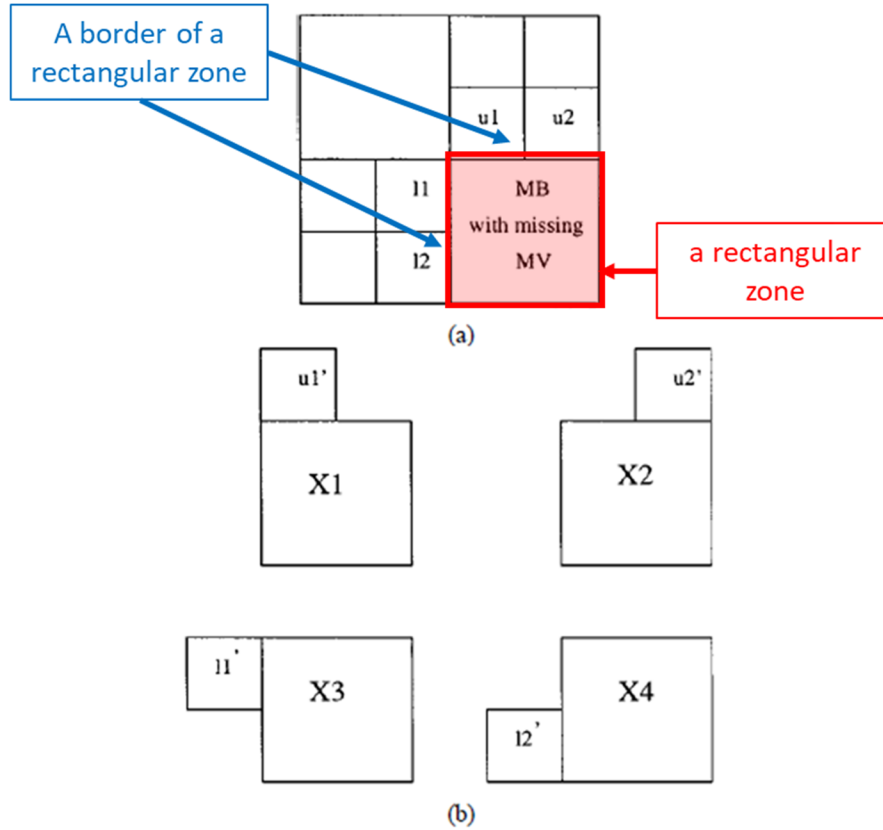


Fig. 1. (a) The four subblocks, (b) their corresponding subblocks in the previous frame, and the blocks connected to them.

SAMSUNG-1005, FIG. 1(a) (annotated and color added).

160. As discussed above, after Shirani's first stage of the hybrid two-stage error concealment technique estimates the pixels at the borders of the missing block, the second stage of the Mualla-Shirani-Saito combination estimates the pixels in the interior of the missing block using Saito's technique for solving Poisson's equation with the border pixels (specifically, Shirani's "border errors" of the missing block) providing boundary conditions in Saito's techniques. *See above*, §VI.E; see below [6.7.COD]. Therefore, because Shirani's first stage temporal concealment uses the motion vectors

of neighboring blocks to estimate only the motion of pixels at the border of the missing block, Shirani discloses the claimed “border motion vector data.”

post-quantization data obtained by quantization in the predictive coding

161. Mualla discloses that “quantization is a key element of a video coding system” and illustrates a “quantizer” in its example “video encoder” and “transform coding system.” SAMSUNG-1005, 40-42, 52, FIGS. 2.3, 2.9, 3.1. Mualla discloses that, in “transform coding” (also known as “DCT coding”), “coefficients can be quantized according to their visual importance” (“*post-quantization data*”). SAMSUNG-1005, 52, 75.

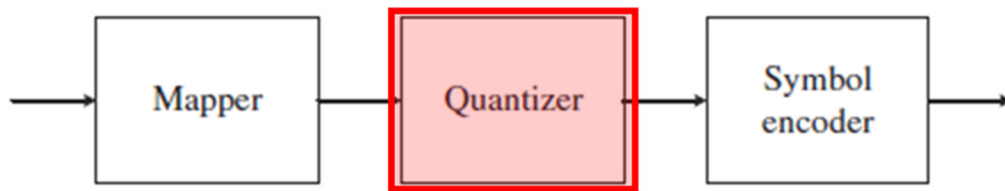


Figure 2.3: Elements of a video encoder

SAMSUNG-1005, FIG. 2.3 (annotated and color added).

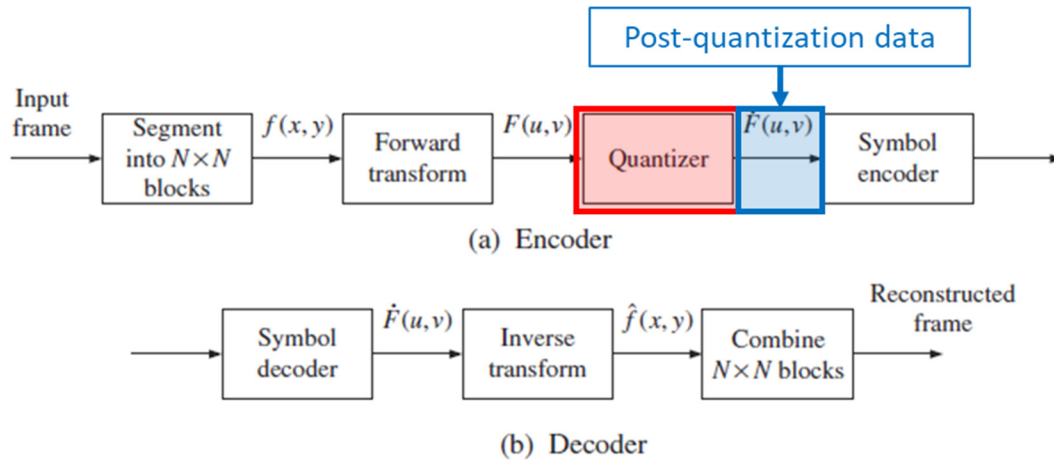


Figure 2.9: Block diagram of a transform coding system

SAMSUNG-1005, FIG. 2.9 (annotated and color added).

162. In particular, Mualla discloses that these coefficients are derived by obtaining a “displaced frame difference (DFD)” that represents “the coded prediction error signal” (“*the predictive coding*”). SAMSUNG-1005, 61, FIG. 2.15. The DFD signal can be coded “using any of the intraframe coding methods discussed in Section 2.6” and “the most commonly used method is transform coding, in particular block-based DCT transform coding.” SAMSUNG-1005, 62. Mualla discloses that the DCT transform “is applied to the DFD values” and that this “results in ... transform coefficients for each [macro block].” SAMSUNG-1005, 74. These coefficients are then “quantized using a uniform scalar quantizer” (“*post-quantization data obtained by quantization in the predictive coding*”). SAMSUNG-1005, 75, FIG. 3.1. This process is illustrated in Mualla’s example “H.263 video encoder.”

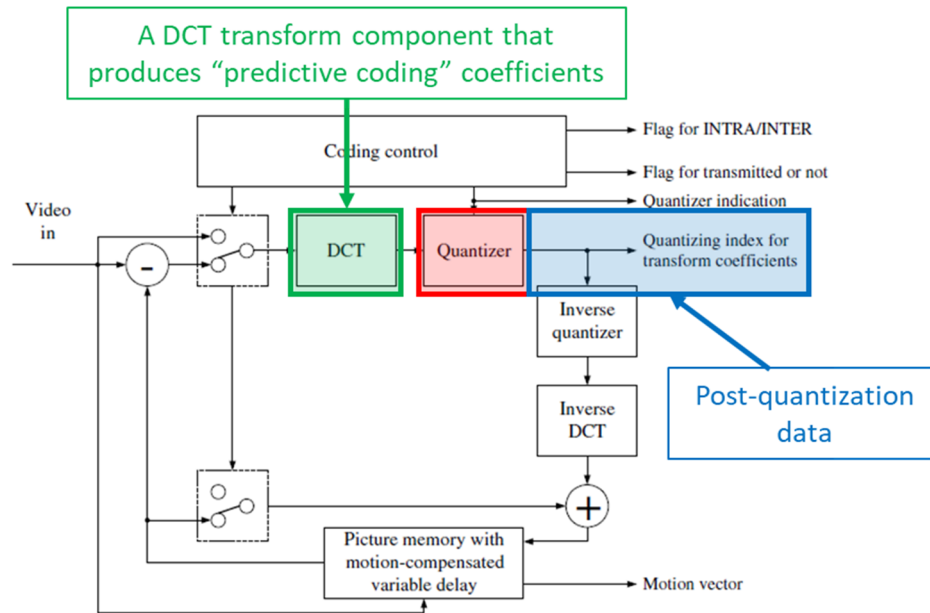


Figure 3.1: H.263 video encoder

SAMSUNG-1005, FIG. 3.1 (annotated and color added).

[6.3.COD] the coded bitstream obtained by producing and encoding a residual picture that is a residual signal between a picture to be coded that is an input moving-picture video signal to be subjected to coding and a predictive picture produced from a reference picture that is a local decoded video signal for each of a plurality of rectangular zones, each composed of a specific number of pixels, into which a video area of the moving-picture video signal is divided,

163. As discussed above in [6.2.COD], Mualla's DFD represents "the coded prediction error signal" ("***residual picture that is a residual signal***") which is created by subtracting a "motion compensation prediction (MCP)," produced from the "reference frame" ("***a predictive picture produced from a reference picture that is a local decoded video signal***"), from the "current frame" ("***a picture to be coded that is an input moving-picture video signal to be subjected to coding***").

SAMSUNG-1005, 26-27, FIG. 1.1. Mualla's "typical video codec" illustrates this process.

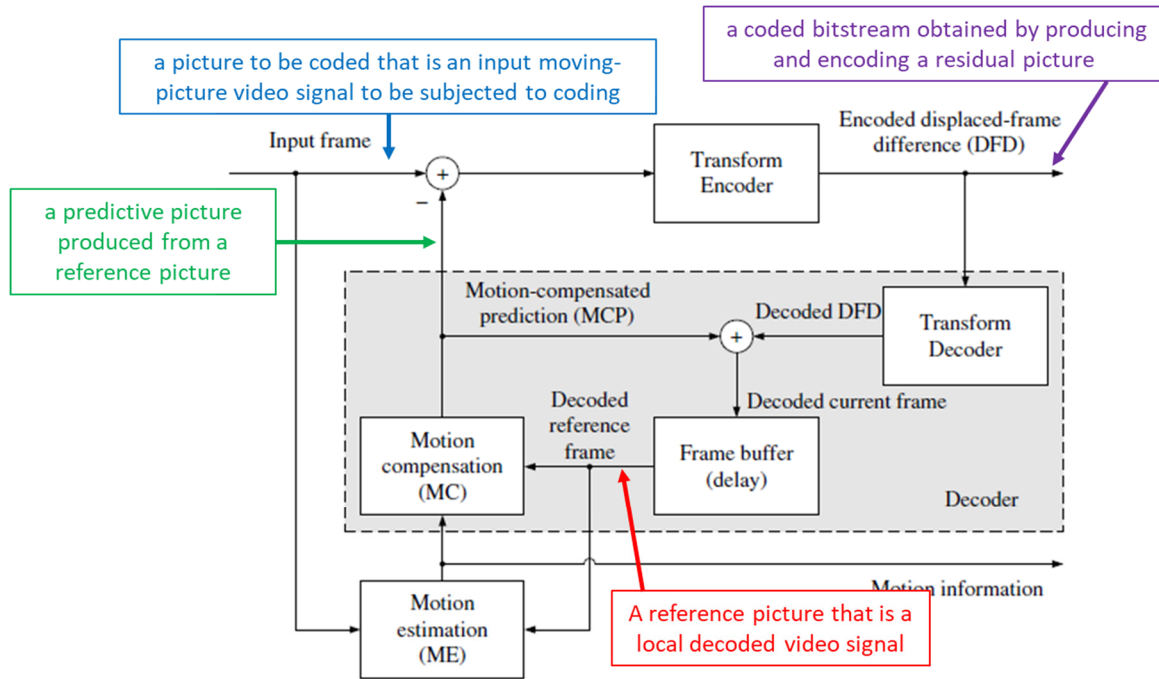


Figure 1.1: Typical video codec

SAMSUNG-1005, FIG. 1.1 (annotated).

164. Mualla also discloses that an input video signal “consists of a sequence of pictures (or frames)” where “[e]ach picture is divided into groups of blocks (GOBs)” and each GOB “is divided into macroblocks (MBs)” (“*each of a plurality of rectangular zones*”). SAMSUNG-1005, 71-72. These MBs are further divided into individual “pixels,” or “pels” (“*each composed of a specific number of pixels, into which a video area of the moving-picture video signal is divided*”). SAMSUNG-1005, 36, 71-72, FIG. 3.2. FIG. 3.2 of Mualla illustrates this breakdown.

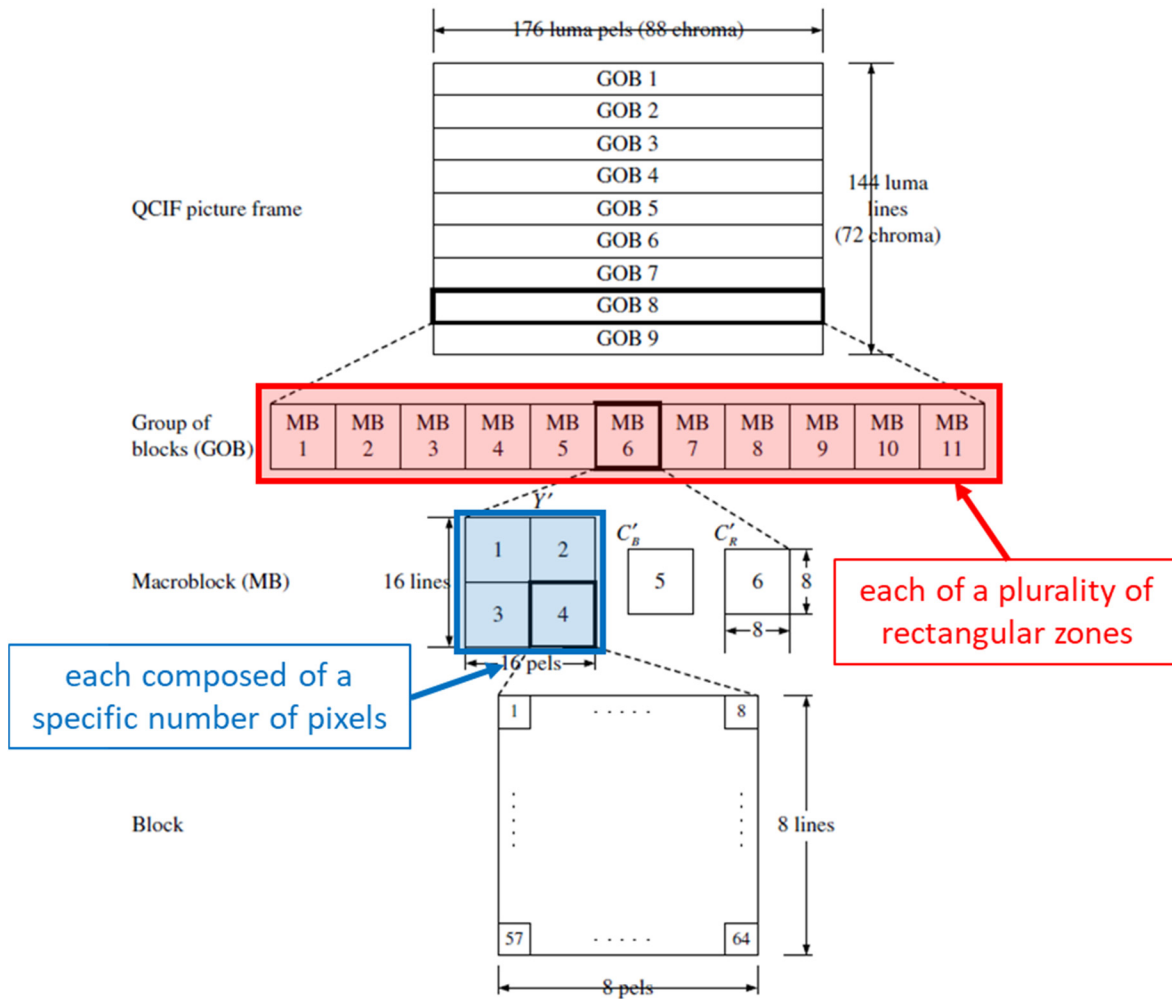


Figure 3.2: H.263 picture structure for a QCIF frame

SAMSUNG-1005, FIG. 3.2 (annotated and color added).

[6.4.COD] obtaining a boundary condition of each of a plurality of borders between the rectangular zones and another plurality of rectangular zones adjacent to the rectangular zones,

165. As discussed above, the Mualla-Shirani-Saito combination implements a two-stage hybrid error concealment in the encoder (as well as the decoder), as taught by Mualla. SAMSUNG-1005, 246-250.

166. In particular, for the first stage, as discussed above in [6.2.COD], Mualla discloses “boundary matching (BM),” a temporal error concealment technique, which selects a “suitable replacement [motion vector] from a set of candidate [neighboring] motion vectors. SAMSUNG-1005, 245; *see above* [6.2.COD]. Shirani’s “first stage” of its two-stage error concealment technique applies a similar technique to estimate a missing motion vector by considering “subblocks adjacent to the missing block.” SAMSUNG-1006, 2-3, FIG. 1(a); *see above* [6.2.COD].

167. In more detail, Shirani explains that in order to obtain an “initial estimate” for each of the missing blocks (“***the rectangular zones***”), “subblocks adjacent to the missing block, i.e., $u1$, $u2$, $l1$, and $l2$ in Fig. 1(a), are considered” (“***another plurality of rectangular zones adjacent to the rectangular zones***”). SAMSUNG-1006, 3, FIG. 1(a) (reproduced below).

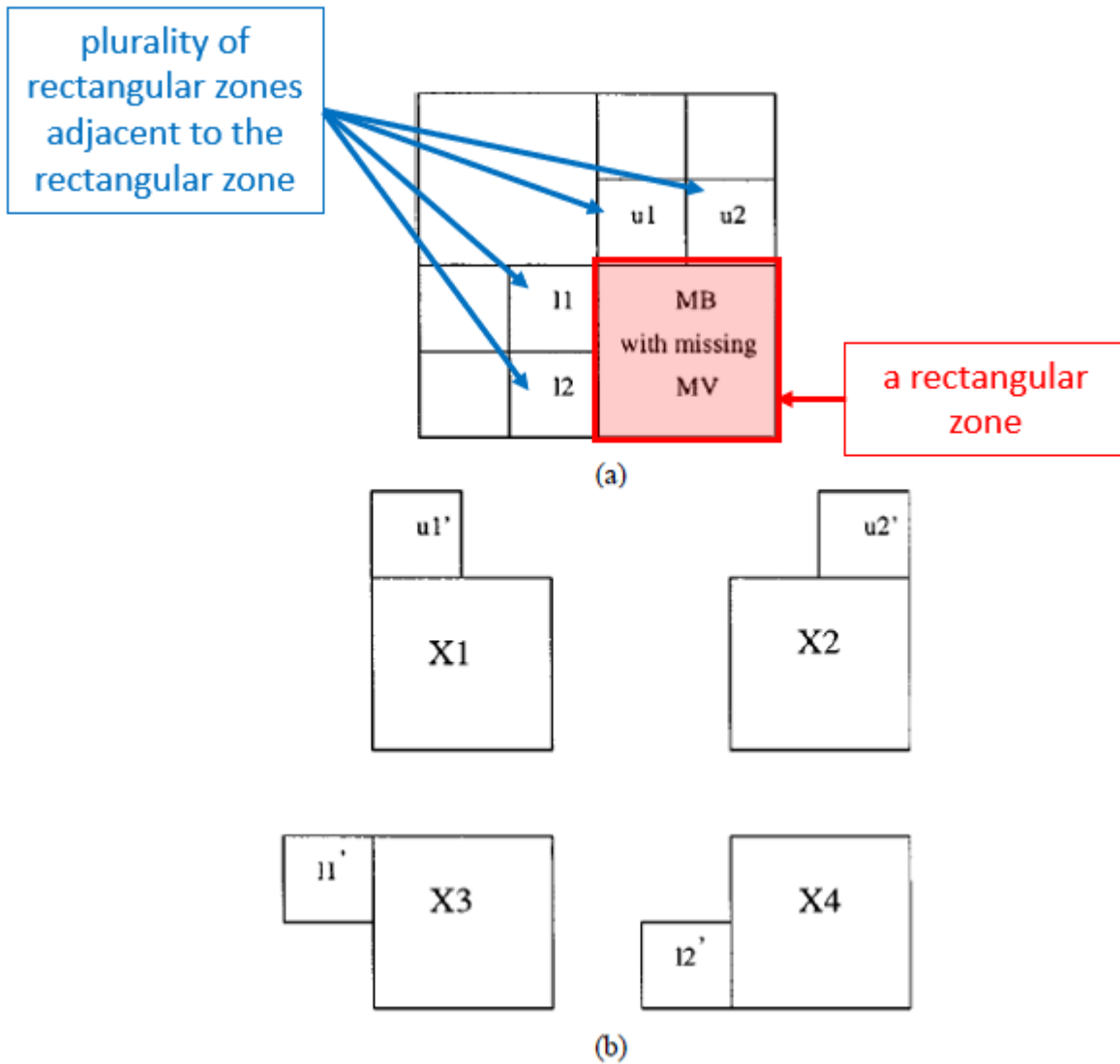


Fig. 1. (a) The four subblocks, (b) their corresponding subblocks in the previous frame, and the blocks connected to them.

SAMSUNG-1006, FIG. 1(a) (annotated and color added).

168. As explained in Section VI.B, above, Shirani discloses that “for each of these subblocks [$u1$, $u2$, $l1$, and $l2$], a corresponding subblock in the previous frame is determined” (denoted $u1'$, $u2'$, $l1'$, and $l2'$ at the bottom of FIG. 1(a), above). SAMSUNG-1006, 3. Then, Shirani discloses that “four blocks, namely X1, X2, X3,

and X4, which are connected to $u1'$, $u2'$, $l1'$, and $l2'$, and (respectively), are determined” and “a block from the above four blocks [(X1, X2, X3, and X4)] that minimizes the squared sums of border errors, between the estimated block and its adjacent above and left blocks, is selected.” SAMSUNG-1006, 3. This is accomplished by defining “border error[s]” in “terms of pixels,” including an error for the “bottom line pixels of the block to the top of the missing block” and an error for the “right column pixels of the block to the left of the missing block” and applying the same technique to define border errors for pixels adjacent to “the subblocks ... to the right and below of the missing block” (*“obtaining a boundary condition of each of a plurality of borders between the rectangular zones and another plurality of rectangular zones adjacent to the rectangular zones”*). *Id.* Furthermore, although the above description focused on adjacent subblocks above and to the left of the missing block, Shirani also discloses that “the same method can be extended to include the subblocks of the blocks to the right and below of the missing block” (“... *of each of a plurality of borders between the rectangular zones and another plurality of rectangular zones adjacent to the rectangular zones*”). *Id.*

169. FIG. 5 of Shirani illustrates an example of how these techniques can be applied to conceal errors for multiple damaged macroblocks (a “*plurality*” of “*rectangular zones*”) in a frame. SAMSUNG-1006, FIG. 5.

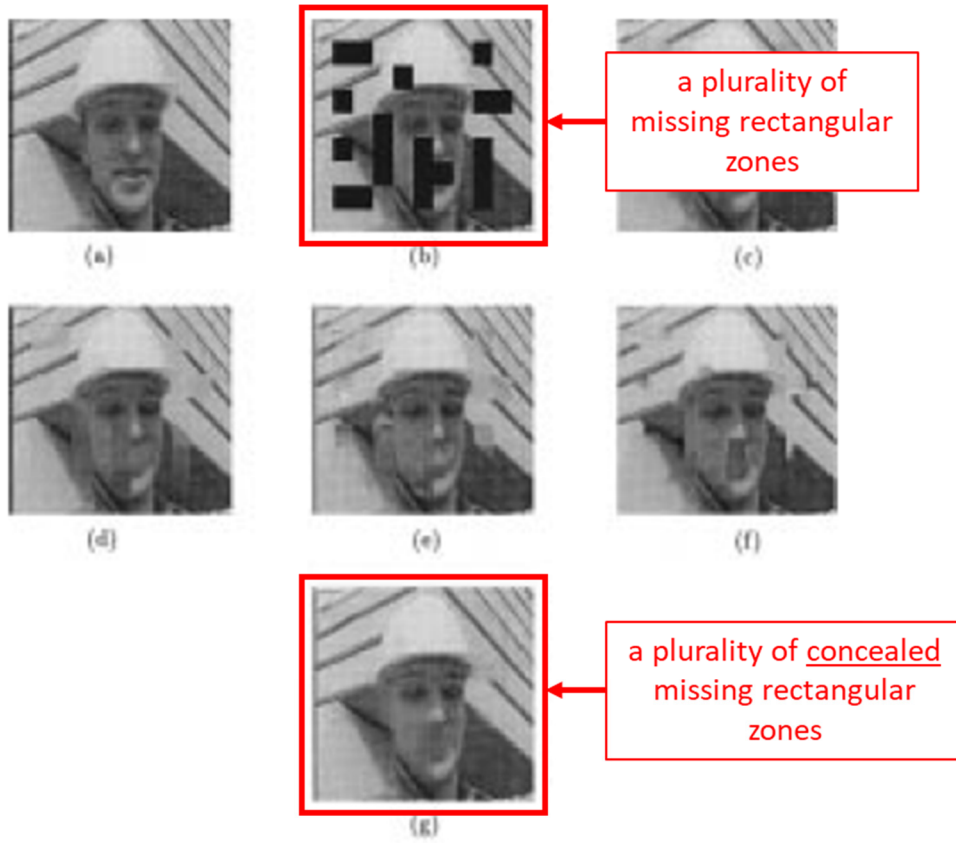


Fig. 5. A frame from the video sequence Foreman: (a) original; (b) missing blocks; reconstructed using (c) a nonadaptive GMRF model; (d) a suboptimal MRF model; (e) the method proposed in [4]; (f) the method proposed in [3]; and (g) our adaptive MRF model.

SAMSUNG-1006, FIG. 5 (annotated).

[6.5.COD] finding a border, of the reference picture, having a boundary condition that matches the boundary condition, by motion-vector search in the reference picture,

170. As discussed above, the Mualla-Shirani-Saito combination implements a two-stage hybrid error concealment in the encoder (as well as the decoder), as taught by Mualla. SAMSUNG-1005, 246-250.

171. In particular, as described above in [6.4.COD], Shirani finds and evaluates the “border error” of a plurality of neighboring subblocks when considering the

suitability of these subblocks in concealing missing or damaged data (“***finding a border, of the reference picture, having a boundary condition that matches the boundary condition***”). SAMSUNG-1006, 2-3, FIG. 1; *see above* [6.2.COD], [6.4.COD]. Additionally, Shirani discloses that the “search for displacement of each of the subblocks is restricted to a set of candidate motion vectors,” specifically, “the motion vectors of available neighboring blocks” (“***finding a border ... by motion-vector search in the reference picture***”). SAMSUNG-1006, 3, FIG. 1(a); *see above* [6.2.COD], [6.4.COD].

[6.6.COD] and generating the border motion-vector data that is data on a motion vector from a border of the rectangular zone in the picture to be coded to the border of the reference picture thus found, defining a boundary condition of a border that corresponds to the border motion vector data, from the reference picture based on the border motion vector data,

172. As discussed above, the Mualla-Shirani-Saito combination implements a two-stage hybrid error concealment in the encoder (as well as the decoder), as taught by Mualla. SAMSUNG-1005, 246-250.

173. In particular, as described in [6.2.COD], [6.4.COD], and [6.5.COD] above, Shirani’s “first stage” temporal error concealment technique searches for candidate replacement motion vectors and generates border errors that define the similarity of the neighboring subblock’s motion vector (“***border motion-vector data***”). *See above*, [6.2.COD], [6.4.COD], [6.5.COD]. Indeed, Shirani’s “candidate motion vectors” are “***data on a motion vector from a border of the rectangular***

zone in the picture to be coded to the border of the reference picture thus found,”

at least because these candidate motion vectors conceal missing motion vectors between “*the reference picture*” and “*the picture to be coded.*” *Id.*

174. Moreover, as described above, Shirani generates border errors that quantify the similarity of the neighboring subblocks’ motion vectors compared to the missing block to be concealed (“*defining a boundary condition of a border that corresponds to the border motion vector data, from the reference picture*”). *See above*, [6.4.COD], [6.5.COD]. Shirani’s border errors evaluate the similarity of the neighboring subblocks’ motion vectors, so they are therefore “*based on the border motion vector data*” of the neighboring subblocks. *Id.*

[6.7.COD] and generating an estimated video signal in each rectangular zone in the picture to be coded, that satisfies Poisson's Equation, thus producing the predictive picture;

175. As discussed above, the Mualla-Shirani-Saito combination implements a two-stage hybrid error concealment in the encoder (as well as the decoder), as taught by Mualla. SAMSUNG-1005, 246-250.

176. In particular, as described above in [6.6.COD], Shirani generates *border motion-vector data* for each damaged or missing subblock. *See above*, [6.2.COD], [6.4.COD]-[6.6.COD]. Additionally, the “second stage” of the Mualla-Shirani-Saito combination (similar to the “spatial error concealment” methods of Mualla) uses “the information around each missing block ... to refine the initial estimate” (as taught by

Shirani) by using Saito's technique for solving Poisson's equation with known boundary conditions. SAMSUNG-1006, 3; SAMSUNG-1007, 27; *see above* §§VI.B, VI.C, VI.E.

177. As discussed above in the combination, a POSITA would have recognized and found obvious that Saito's image approximation techniques based on solving Poisson's equation would have enhanced Shirani's "second stage" techniques, "improv[ing] the video reconstruction quality" in order to achieve similar goals of image approximation. SAMSUNG-1007, 27; SAMSUNG-1006, Abstract, 3. Saito's Polyharmonic Local Cosine Transform (PHLCT) is an enhancement of a Polyharmonic Local Sine Transform (PHLST) technique for image approximation. SAMSUNG-1007, Abstract, 27. Saito discloses that the PHLST method "segments an image into local pieces using ... characteristic functions, then decomposes each piece into two components: the polyharmonic component and the residual." SAMSUNG-1007, Abstract, 4. Saito explains that the polyharmonic component is "obtained by solving the elliptic boundary value problem associated with the so-called polyharmonic equation (e.g., Laplace's equation, biharmonic equation, etc.) given the boundary values (the pixel values along the boundary created by the characteristic function)." *Id.* The PHLCT variation of PHLST approximates an image between two boundaries by "solv[ing] the ... Poisson equation with the Neumann boundary condition" ("***generating an estimated video signal in each rectangular zone in the picture to be coded, that satisfies Poisson's Equation***"). SAMSUNG-1007, 27.

178. In implementing Saito's teachings into the Mualla-Shirani combination, a POSITA would have recognized and found obvious that the "border errors" of Shirani are suitable to use as the "Neumann boundary condition" for Saito's the PHLCT method, and that PHLCT would have been capable of approximating the image between these boundary conditions ("*thus producing the predictive picture*"). SAMSUNG-1007, 27 ("this method of course requires to estimate the **first order normal derivative** of data at the **boundary**"). Indeed, as described above, Saito's techniques represent a natural improvement of image approximation techniques, at least because they can achieve a faster "decay rate" for the error signal at the boundaries of blocks – an improvement that is consistent with the goals of Mualla-Shirani. SAMSUNG-1007, 27; SAMSUNG-1006, Abstract, 3.

179. Moreover, Saito's process of PHLCT is described by the '025 patent itself, and the '025 patent cites a subsequent publication by Dr. Naoki Saito that explains the PHLCT method. SAMSUNG-1001, Cover, 11:34-12:25.

[6.8.DEC] an entropy decoder to perform entropy decoding to the data thus demultiplexed to generate, at least, motion-vector data, the post-quantization data, the border motion-vector data and parameter data required for constructing a specific syntax structure;

180. As discussed above in [6.2.COD], Mualla-Shirani-Saito discloses "***border motion-vector data***" and "***post-quantization data***." See above, [6.2.COD]. In particular, as discussed above, the first stage of Shirani's two-stage hybrid error concealment technique uses motion vectors of "neighboring blocks" ("***border motion-***

vector data”) to estimate motion vectors of subblocks adjacent to the missing block. SAMSUNG-1006, 3. Furthermore, as discussed in Section VI.A, above, the motion vectors of these neighboring blocks (“***border motion-vector data***”) are encoded and transmitted to the decoder. In particular, when a frame of video is encoded, Mualla explains that all the macroblocks in the frame are “coded from left to right (and from top to bottom if the GOB contains more than one row of MBs) in increasing number.” SAMSUNG-1005, 71, Figure 3.2. The motion vector information for the macroblocks are then “entropy coded” and output from the encoder as encoded motion information. SAMSUNG-1005, 74. Because the encoding and transmission of motion vector information is performed for all macroblocks in a frame/picture, Mualla teaches that the motion vectors of neighboring blocks (“***border motion-vector data***”) around a missing block are encoded and transmitted to the decoder, and can be used by the decoder to perform temporal error concealment in Shirani’s first-stage.

181. Mualla-Shirani-Saito also discloses conventional “***motion vector data***.” *See above*, VI.A; *see below*, [6.14.DEC]. As discussed above, Mualla encodes and transmits motion information for each macroblock in a frame, which includes motion information for the macroblock being decoded (“***motion vector data***”) as well as motion information for neighboring blocks (“***border motion-vector data***”) which can be used for error concealment in case the macroblock being decoded is received in error or corrupted. SAMSUNG-1005, 71, 74.

182. In particular, a POSITA would have understood or found obvious that, in the system of Mualla-Shirani-Saito, motion information for a macroblock being decoded (“***motion vector data***”) can be received and decoded, even if the macroblock is detected as having errors. For example, Mualla explains that a macroblock is detected as having an “error” if the “**decoded motion vector** points outside the permissible range.” SAMSUNG-1005, 232; 244 (explaining that “the motion vector of a damaged block is usually lost or **erroneously received**” and disclosing techniques for recovering a “damaged motion vector”); *see also* Girod, 4 (“Transmission errors can be detected in a variety of ways ... **detect** that the **decoded motion vectors**, DCT coefficients, or quantizer step sizes **exceed their permissible range** (semantic violations)”). In view of these teachings, even if a macroblock is detected as having errors, and even if a particular example disclosed in Mualla or Shirani refers to motion vectors as “missing,” “lost,” or “not available,” a POSITA would have understood or found obvious that the techniques of Mualla and Shirani are applicable to motion vectors (“***motion vector data***”) that are received and decoded and detected as having errors. As such, a POSITA would have understood or found obvious that, according to the teachings of Mualla and Shirani, “motion vector data” for a macroblock is received and decoded regardless of whether the macroblock is detected as having errors (in which case the motion vectors are received and decoded with errors) or without errors (in which case the motion vectors are received and decoded without errors).

183. As discussed in [6.1.DEC], above, Mualla-Shirani-Saito includes a multiplexer that “demultiplex[es]” received data. In addition, Mualla-Shirani-Saito implements an entropy decoder to perform entropy decoding on the demultiplexed data. *See above*, [6.1.DEC]. In particular, Mualla also discloses an “**entropy decoder**” in a “[t]ypical video communication system” that “obtain[s] the output video” (“*generate ... motion-vector data, the post-quantization data, the border motion-vector data and parameter data required for constructing a specific syntax structure*”). SAMSUNG-1005, 227-228, FIG. 9.1. Illustrated below is Mualla’s typical video communication system.

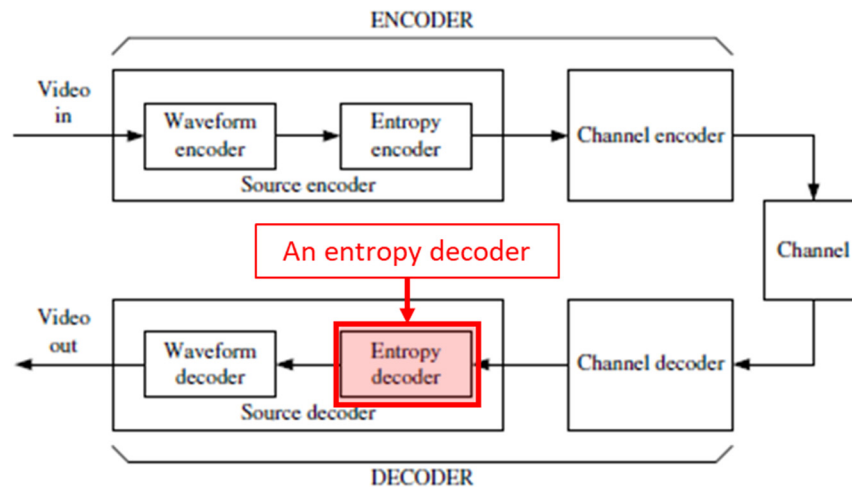


Figure 9.1: Typical video communication system

SAMSUNG-1005, FIG. 9.1 (annotated and color added).

[6.9.DEC] an inverse-quantizer to perform inverse-quantization to the post-quantization data to generate post-quantization orthogonal transform coefficients data;

184. Mualla discloses that the H.263 standard includes the techniques of inverse-quantization. SAMSUNG-1005, 51-52, 76. Specifically, Mualla discloses that “quantization is achieved by dividing the transform coefficient by a quantization step size and rounding the result (***“post-quantization data”***) ... [i]nverse quantization is the process of reconstructing an approximation of the original coefficient by multiplying the quantized coefficient by the same step size” (***“inverse-quantization to the post-quantization data to generate post-quantization orthogonal transform coefficients data”***). SAMSUNG-1005, 76. Mualla illustrates an ***“inverse quantizer”*** in its example H.263 video encoder. SAMSUNG-1005, FIG. 3.1. A POSITA would have recognized and found obvious that a similar component would have been included in the decoder of a codec.

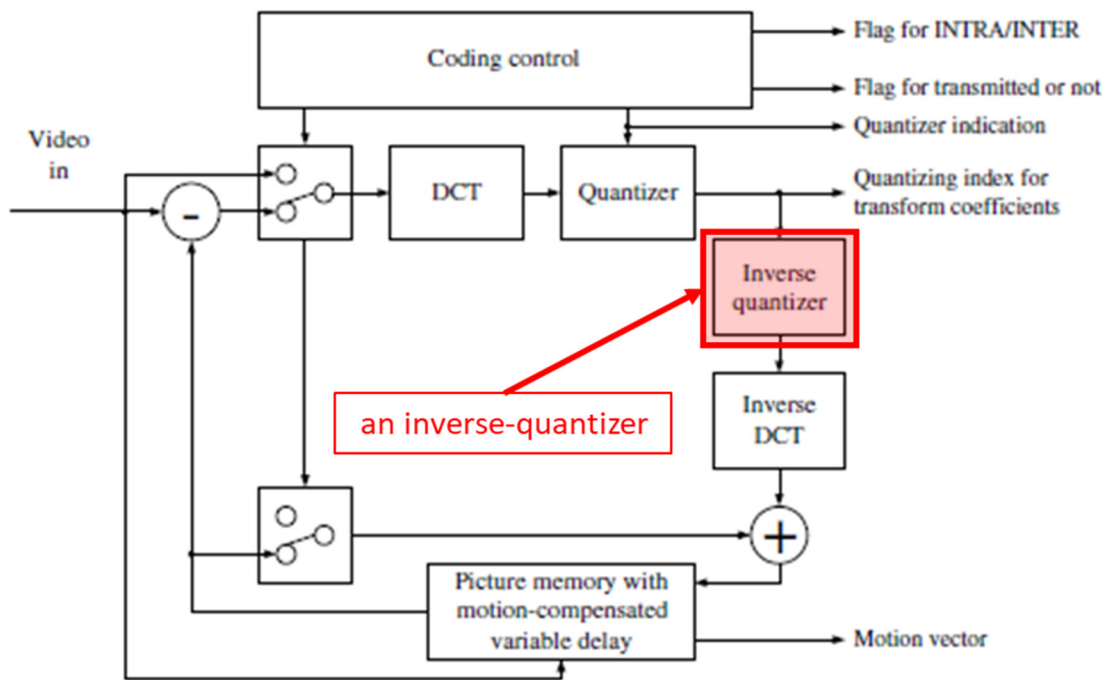
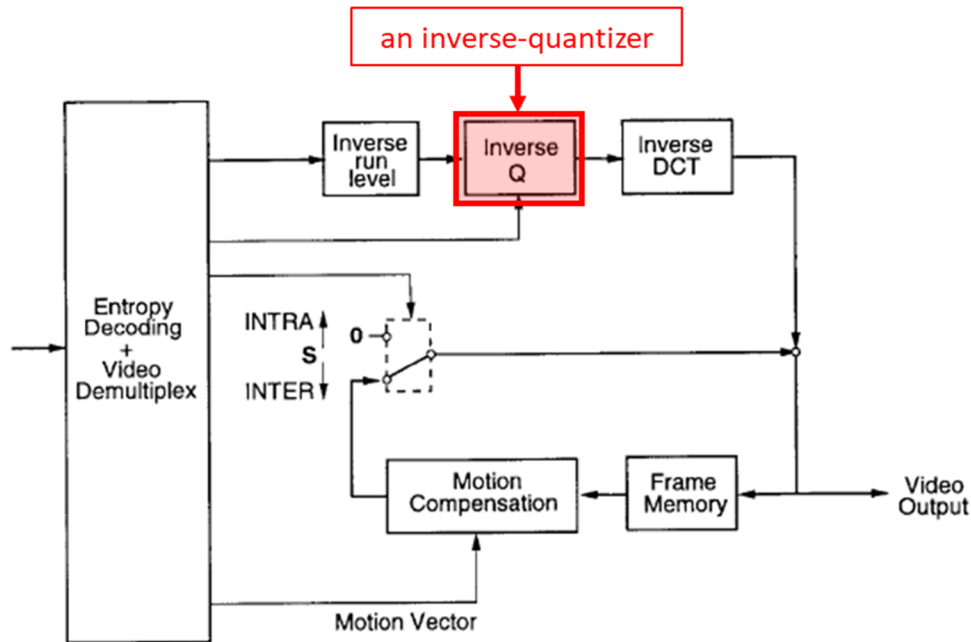


Figure 3.1: H.263 video encoder

SAMSUNG-1005, FIG. 3.1 (annotated and color added).

185. Moreover, a POSITA would have recognized or found obvious that the decoder would “*perform inverse quantization*,” for example, by using an “*inverse-quantizer*,” as this was well-known before the Critical Date. Indeed, Girod corroborates the use of “inverse-quantizer[s]” in H.263 decoders and illustrates this component in its example H.263 decoder. SAMSUNG-1008, 2, FIG. 1(b)



SAMSUNG-1008, FIG. 1(b) (annotated and color added).

[6.10.DEC] an inverse-orthogonal transformer to perform inverse-orthogonal transform to the post-quantization orthogonal transform coefficients data to produce a decoded residual picture of one video area;

186. As discussed in Section VI.A, above, Mualla discloses that the H.263 standard includes the techniques of inverse-orthogonal transforms. SAMSUNG-1005, 51-52, 76. Specifically, Mualla discloses the encoder performs “transform coding” where a “unitary space-frequency transform is applied to each block [in an input frame] to produce an $N \times N$ block of transform (spectral) coefficients that are then suitably quantized” (“***post-quantization orthogonal transform coefficients data***”). SAMSUNG-1005, 52, FIG. 2.9. Next, at the decoder, “an inverse transform is applied to reconstruct the frame” (“***an inverse-orthogonal transformer to perform inverse-orthogonal transform to the post-quantization orthogonal transform coefficients***”).

data”). *Id.* FIG. 2.9 of Mualla illustrates an “[i]nverse transform” component in an example “transform coding system.” *Id.*

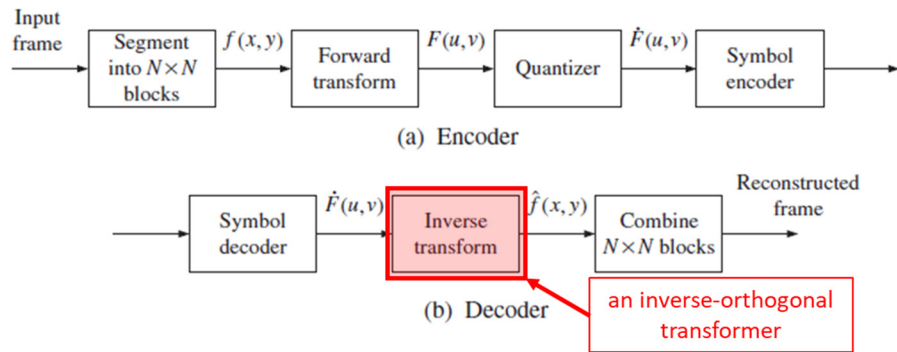
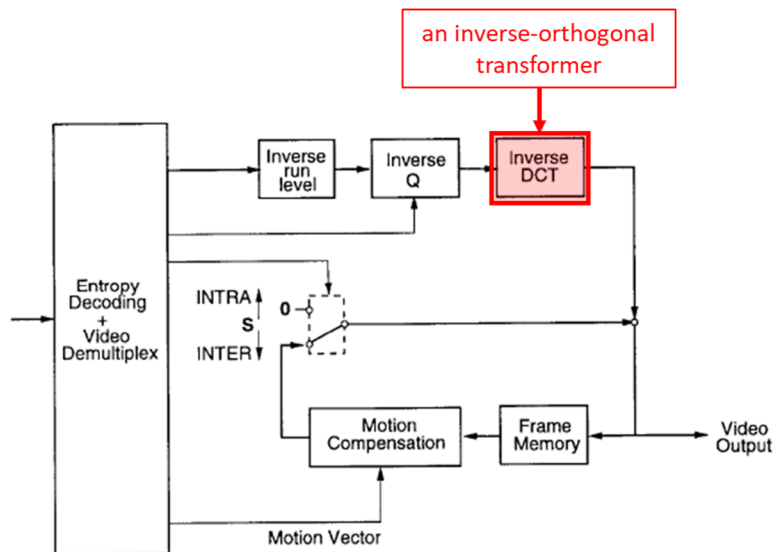


Figure 2.9: Block diagram of a transform coding system

SAMSUNG-1005, FIG. 2.9 (annotated and color added).

187. Moreover, a POSITA would have recognized or found obvious that the decoder would include an “*inverse-orthogonal transformer*” as this was well-known in the art before the Critical Date. Indeed, Girod corroborates the use of inverse transforms in H.263 decoders. SAMSUNG-1008, 2, FIG. 1(b).



SAMSUNG-1005, FIG. 1(b) (annotated and color added).

[6.11.DEC] a zone-border motion compensator to define a boundary condition of a border that corresponds to the border motion vector data, from the reference picture based on the border motion-vector data, and generate an estimated video signal in each rectangular zone in the picture to be coded, that satisfies Poisson's Equation, thus producing a first predictive picture;

188. As discussed above, the Mualla-Shirani-Saito combination implements a two-stage hybrid error concealment in **both** the **encoder** and the **decoder** by using “interactive techniques,” as taught by Mualla. SAMSUNG-1005, 246-250. As described above in [6.2.COD] and [6.6.COD]-[6.7.COD], the **encoder** of the Mualla-Shirani-Saito combination defines “*a boundary condition of a border that corresponds to the border motion vector data, from the reference picture based on the border motion vector data*” and “*generate[s] an estimated video signal in each rectangular zone in the picture to be coded, that satisfies Poisson's Equation, thus producing a first predictive picture.*” See above, [6.2.COD], [6.6.COD]-[6.7.COD]. Thus, a POSITA would have understood or found obvious that the **decoder** of the Mualla-Shirani-Saito combination would perform analogous operations by using the same two-stage hybrid error concealment technique.

189. Furthermore, Mualla refers to the first-stage temporal concealment as “**motion-compensated** error concealment.” SAMSUNG-1005, 27. Mualla explains that “[a]s in **motion-compensated prediction**, the process of temporal concealment involves two stages: *concealment displacement estimation* and *displacement compensation*, as shown in Figure 9.8(a). For this reason, temporal concealment is sometimes referred to

as **motion-compensated concealment.**” SAMSUNG-1005, 243, Figure 9.8(a)
(reproduced below, annotated).

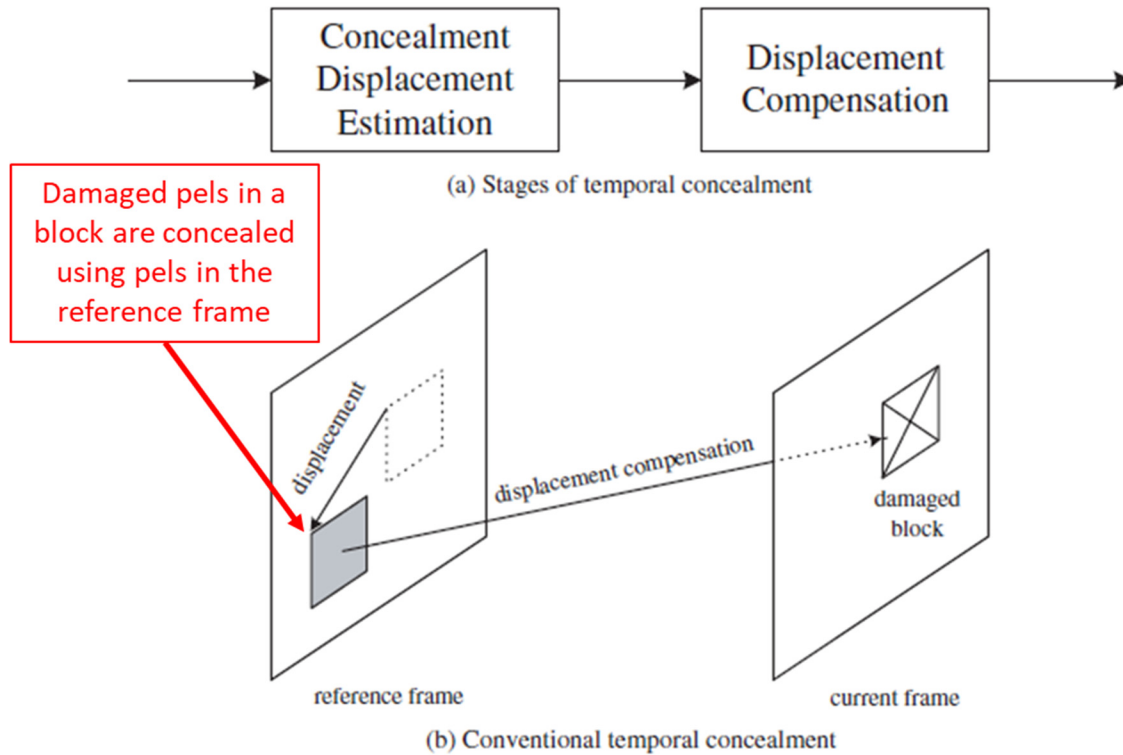


Figure 9.8: Temporal error concealment

SAMSUNG-1005, FIG. 9.8 (annotated).

190. Moreover, the additional techniques of Shirani and Saito are simply ‘algorithms’ that can be executed by computer program modules (“***a zone-border motion compensator***”). SAMSUNG-1006, 1-2; SAMSUNG-1007, 6. Therefore, the encoding features discussed in encoding limitations [6.2.COD], [6.6.COD]-[6.7.COD] would be similarly implemented within the decoder of Mualla-Shirani-Saito.

191. Thus, a POSITA would have understood or found obvious that the **decoder** of the Mualla-Shirani-Saito combination implements “motion compensated

error concealment techniques” as part of a two-stage hybrid “error concealment” algorithm (the claimed “***zone-border motion compensator***”), which includes a first-stage temporal concealment stage (which defines “***a boundary condition of a border that corresponds to the border motion vector data, from the reference picture based on the border motion vector data***”) and a second-stage spatial concealment stage (which “***generate[s] an estimated video signal in each rectangular zone in the picture to be coded, that satisfies Poisson's Equation, thus producing a first predictive picture***”).

[6.12.DEC] a combiner to combine the first predictive picture and the decoded residual picture to generate a decoded moving picture signal;

192. Mualla describes a well-known decoding process in which a “prediction” (“***the first predictive picture***”) generated by motion-estimation and motion-compensation (the “***zone border motion compensation***” of Mualla-Shirani-Saito) is “added to” (or summed with) (“***combine the first predictive picture and the decoded residual picture***”) an “error signal” (“***the decoded residual picture***”), which is the result of inverse DCT, to “reconstruct the current frame” (“***generate a decoded moving picture signal***”). SAMSUNG-1005, 27, 76, FIG. 10.8; *see above* [6.6.11.DEC]. Indeed, Mualla’s error concealment technique “***generate[s] a decoded moving picture signal***” by concealing missing/erroneous/damaged blocks, as shown in Figure 10.8. *Id.*

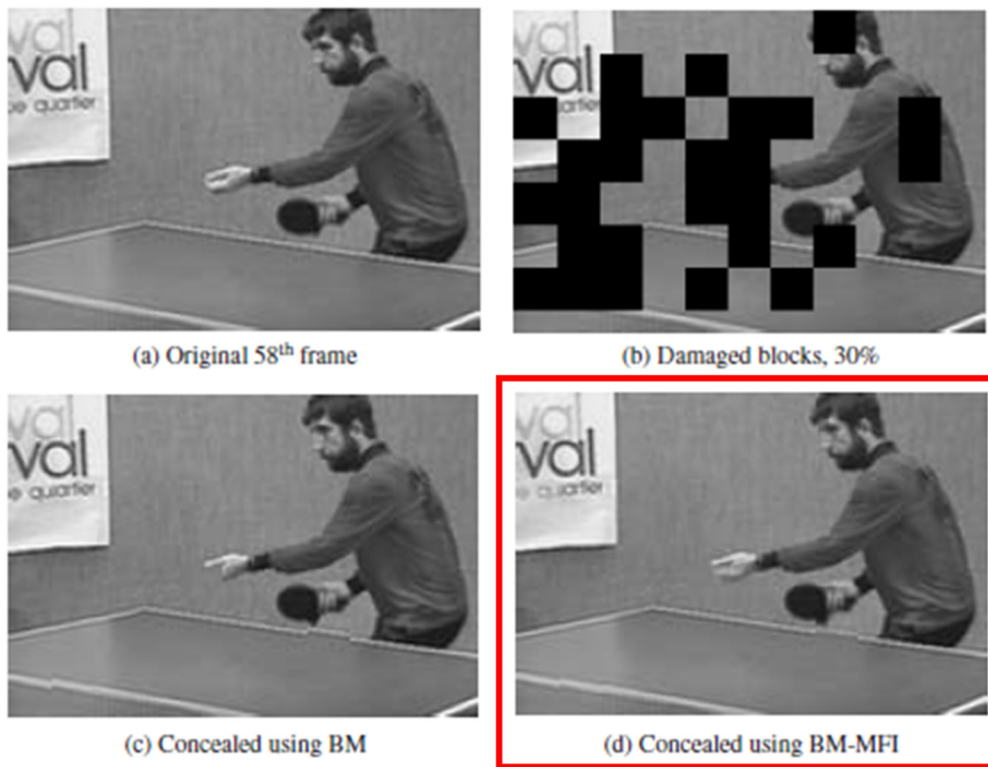


Figure 10.8: Subjective quality of concealed 58th frame of QSIF TABLE TENNIS at 30 frames/s with a block loss rate of 30%

combin[ing] the first predictive picture
and the decoded residual picture to
generate a decoded moving picture signal

SAMSUNG-1005, FIG. 10.8 (annotated).

193. Thus, for a given frame (picture) that is being decoded, (i) coded data for some macroblocks of the frame are received without error and are decoded using Mualla's conventional "motion estimation" and "motion compensation," whereas (ii) coded data for other macroblocks of the frame are erroneously received and concealed using the Mualla-Shirani-Saito two-stage hybrid error concealment technique. The result is an aggregate predicted frame ("*the first predictive picture*") that is combined with Mualla's "decoded [displaced-frame difference] DFD" ("*the decoded residual*

picture”). The combining technique is analogous to the combining technique implemented in Mualla’s conventional motion-estimation-compensation decoding. SAMSUNG-1005, FIG. 1.1.

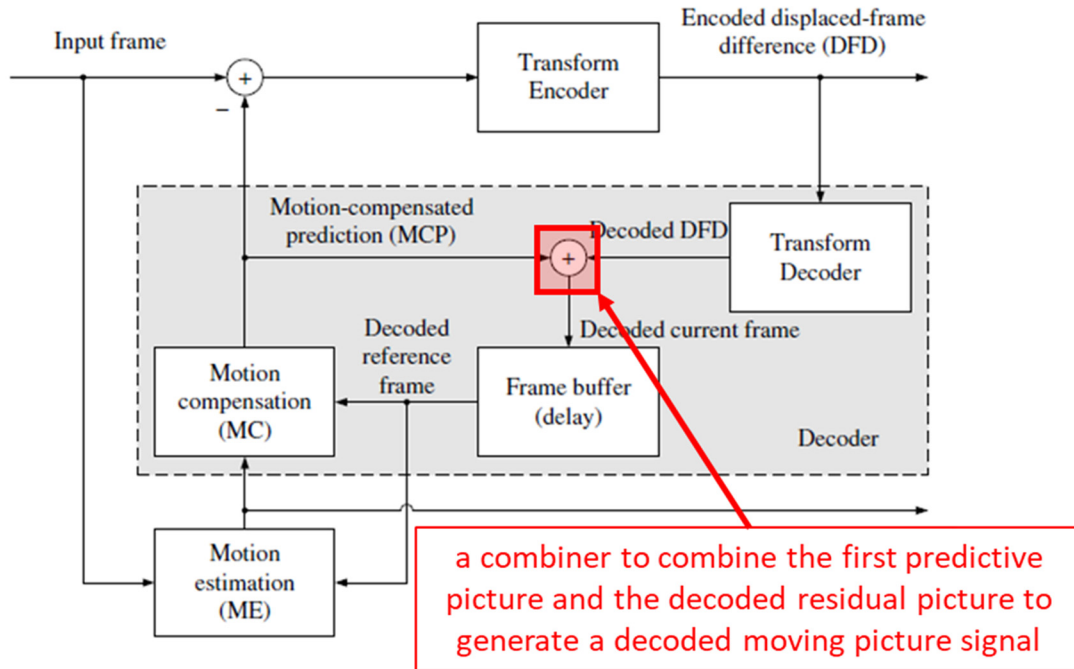
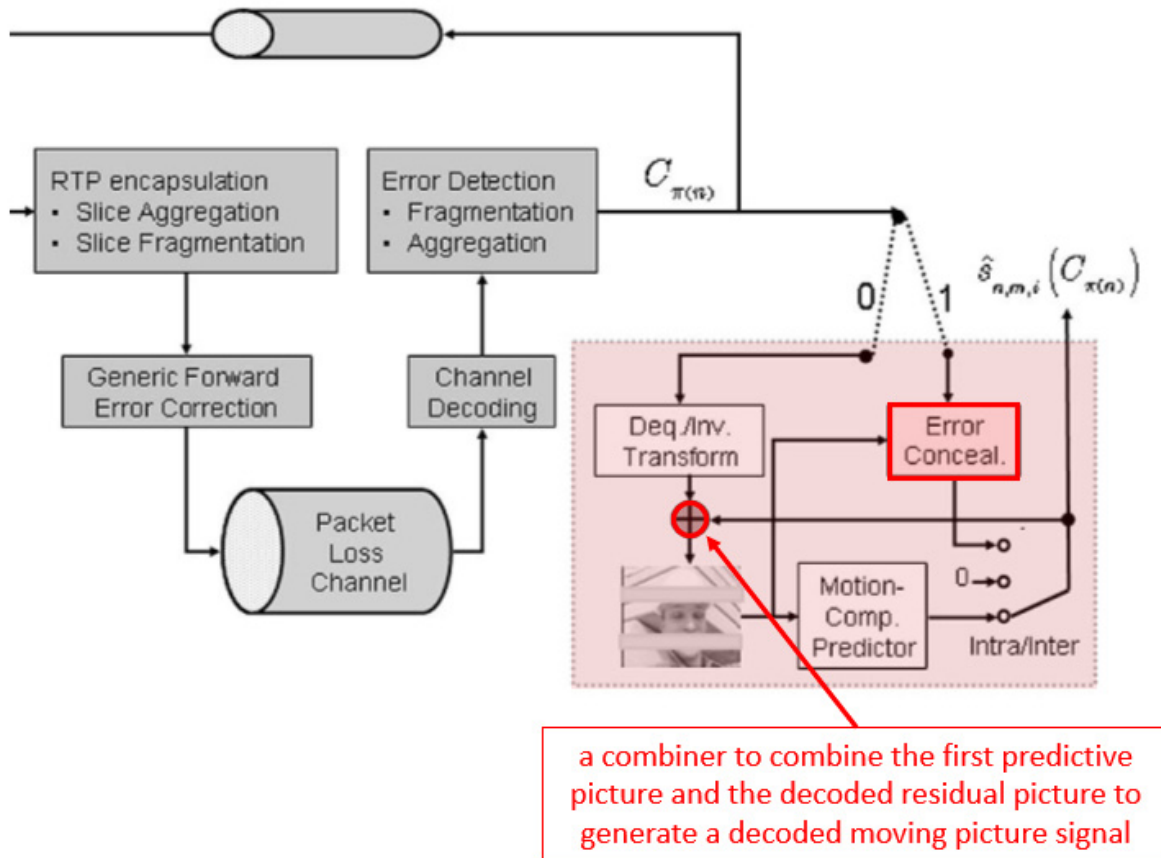


Figure 1.1: Typical video codec

SAMSUNG-1005, FIG. 1.1 (annotated and color added).

194. A detailed example of such a combining step for error concealment is provided in Stockhammer (SAMSUNG-1009), which discloses an example of error concealment implemented in an H.264-based system in Figure 9.8 (reproduced below, annotated). As discussed in Section VI.A, above, decoding is performed on a per-macroblock basis. For a given macroblock of the frame, if an error is detected in the coded data of the macroblock, then the decoder performs “error concealment” and the second selector at the bottom-right-hand corner of the red shaded area is in the upper-

most position and provides the error concealment output (the “***first predictive picture***”) to a combiner (annotated). SAMSUNG-1009, 8, Fig. 6 (reproduced below, annotated). As shown in Fig. 6, the other input to the combiner is the output of the “dequantizer/inverse transform.” *Id.* As explained in [6.9.DEC] and [6.10.DEC], the output of dequantizer/inverse transform is a “***decoded residual picture***.”



SAMSUNG-1009, FIG. 6 (annotated and color added).

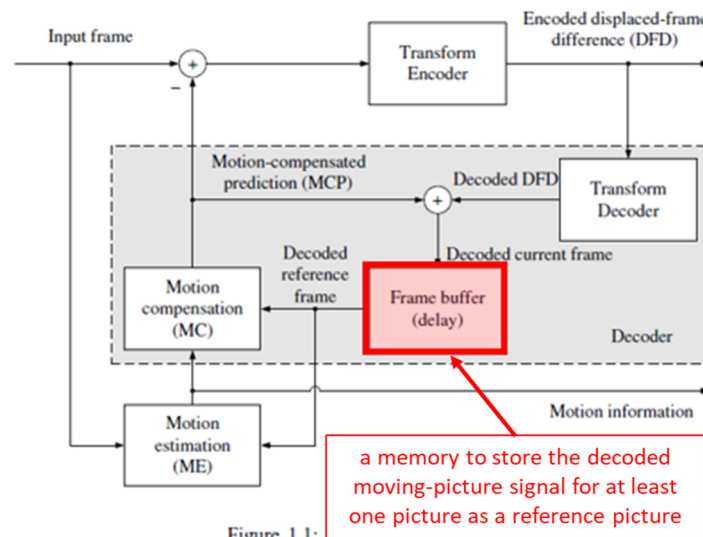
195. Conversely, if no errors are detected in the coded data of the macroblock, then the decoder applies the conventional “motion compensated predictor” and the second selector at the bottom-right-hand corner of the red shaded area is in the lower-

most position and provides the output of the motion compensated predictor to the combiner (annotated). SAMSUNG-1009, 8, Fig. 6.

196. Ultimately, for all macroblocks in the frame (both those received in error and without error), the decoder generates reconstructed samples $\hat{s}_{n,m,i}(0, C_{\pi(n)})$ that form a reconstructed image (the “*decoded moving picture signal*”).

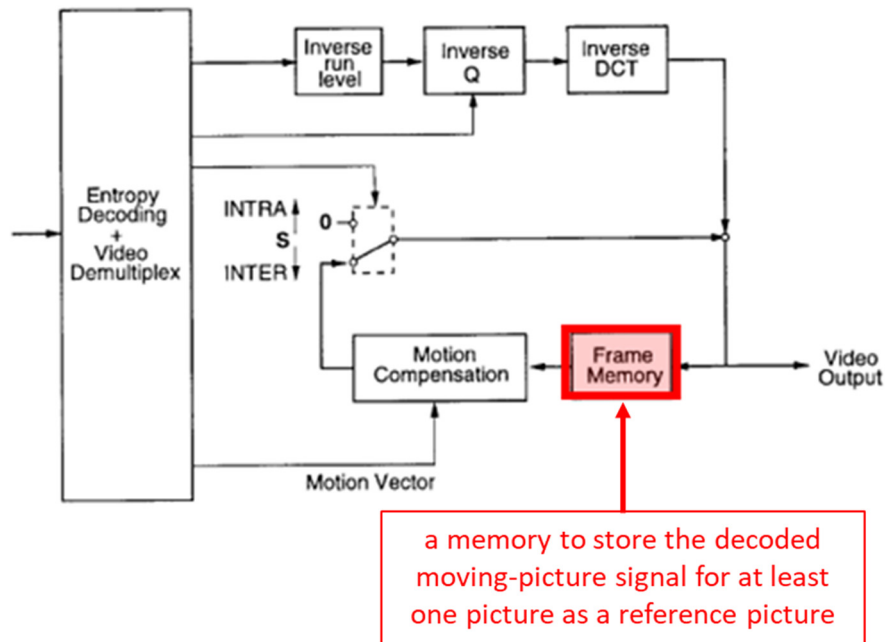
[6.13.DEC] a memory to store the decoded moving-picture signal for at least one picture as a reference picture;

197. Mualla describes the well-known feature of a decoder including a “*memory*” to store a “*reference picture*” which is the “*decoded moving-picture signal*” that was generated by combining the residual picture and the predictive picture. SAMSUNG-1005, 26-27, FIG. 1.1; *see above*, [6.12.DEC]. For example, Mualla discloses that “reference frame[s]” (“*reference picture[s]*”) are “stored in a frame buffer” (“*a memory*”). *Id.*



SAMSUNG-1005, FIG. 1.1 (annotated and color added).

198. Additionally, the use of a “*memory*” to “*store ... a reference picture*” was well-known in the art before the Critical Date. For example, Girod discloses that a H.263 decoder includes a “frame memory” which stores “decoded frames.” SAMSUNG-1008, 2.



SAMSUNG-1008, FIG. 1(b) (annotated and color added).

[6.14.DEC] a motion compensator to specify a corresponding rectangular zone in the reference picture based on the motion vector data, thus generating a second predictive picture;

199. Mualla’s “typical video codec” includes the well-known feature of “motion compensation.” SAMSUNG-1005, 26-27, 76, 115-116, FIG. 1.1, 2.16. Indeed, Mualla discloses that a “motion estimation (ME) block uses a motion model to estimate the movement that occurred between [a] current frame and a reference frame” (“*specify a corresponding rectangular zone in the reference picture based on the*

motion vector data”). SAMSUNG-1005, 26-27, 116-117. Then, “[a]t the decoder, the same reference frame is used along with the received motion information to produce the same prediction” (“*thus generating a second predictive picture*”). *Id.* FIG. 1.1 below illustrates motion compensation in Mualla’s typical video codec.

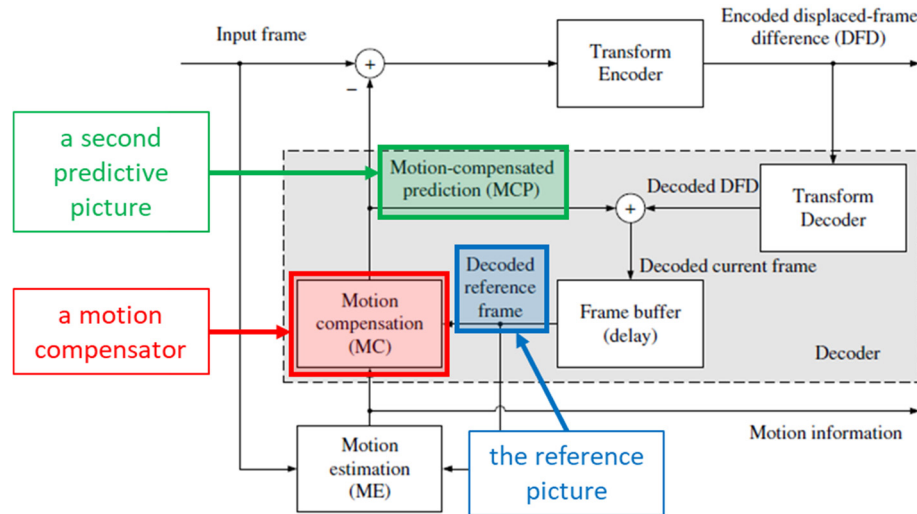
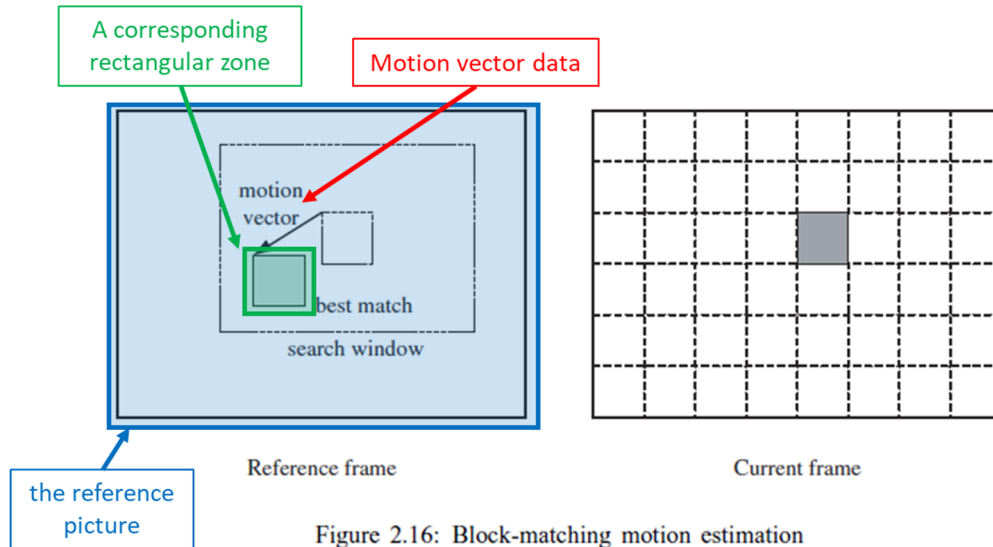


Figure 1.1: Typical video codec

SAMSUNG-1005, FIG. 1.1 (annotated and color added).

200. Additionally, Mualla discloses a process of using a “motion vector” (“*based on the motion vector data*”) to determine a “block” in the reference frame (“*a corresponding rectangular zone in the reference picture*”) that matches the current frame. SAMSUNG-1005, 76. This process is illustrated in FIG. 2.16 below.



SAMSUNG-1005, FIG. 2.16 (annotated and color added).

201. Moreover, the techniques of motion compensation were well-known before the Critical Date. Indeed, Shirani describes the use of “motion compensation” (“*a motion compensator*”) and “motion vectors” (“*motion vector data*”) to identify “motion compensated blocks” (“*a corresponding rectangular zone in the reference picture*”). SAMSUNG-1006, 1-2.

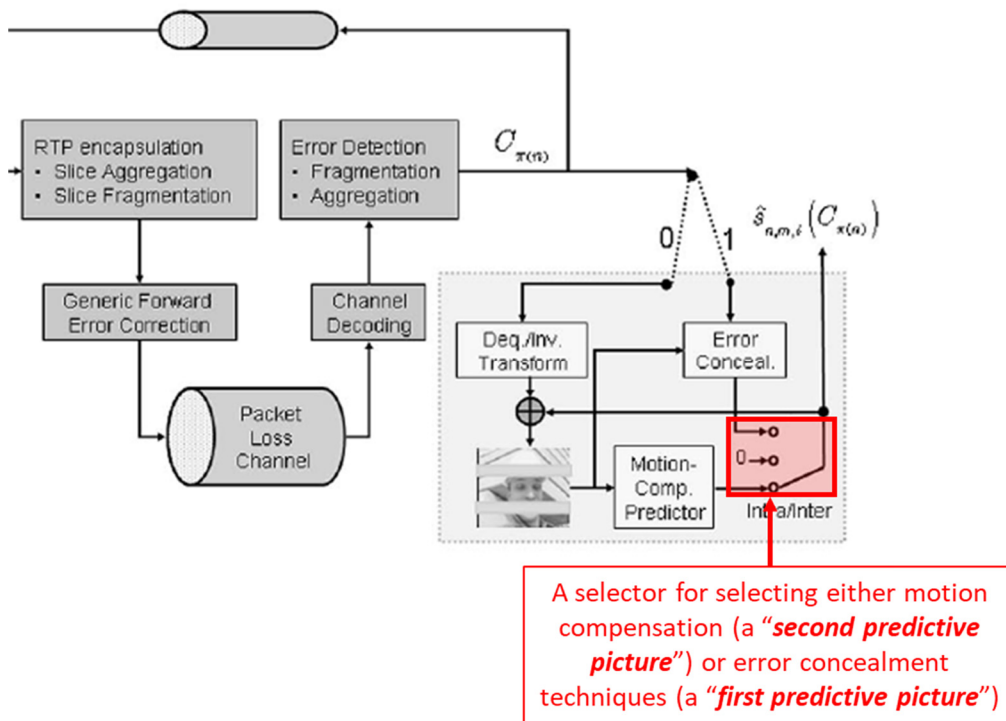
[6.15.DEC] a selector to select either the first predictive picture or the second predictive picture and supply the predictive picture thus selected to the combiner; and

202. Mualla discloses that its error concealment techniques can be deployed “[w]hen an error is detected,” and that during this period, the “decoding process is stopped.” SAMSUNG-1005, 265. From at least this disclosure, a POSITA would have recognized and found obvious that tradition motion compensation (producing a “*second predictive picture*”) would execute until an error was detected by the decoder

in the bitstream, at which point the error concealment techniques of the Mualla-Shirani-Saito combination would be used to generate replacement motion vector and video data (a “*first predictive picture*”). SAMSUNG-1005, 265.

203. A POSITA would have recognized or found obvious that switching between these two methods of decoding (“*select[ing] either the first predictive picture or the second predictive picture*”) would be effectuated by a switching component, such as a “*selector*.” Indeed, Girod (cited by Mualla) corroborates selecting between two different decoding modes in response to detected errors, as “an erroneous bit stream cannot be gracefully decoded by an ‘off-the-shelf’ video decoder build [sic] for error-free transmission.” SAMSUNG-1008, 4. Girod explains that, in the case of errors, “[s]pecial provisions for error detection, resynchronization, and concealment are required.” *Id.* Stockhammer⁵ also corroborates the use of a “selector” to switch between traditional motion compensation and error concealment. SAMSUNG-1009, FIG. 6.

⁵ Although Stockhammer’s teachings are within the general knowledge of a POSITA, a POSITA would have additionally combined Stockhammer into the Mualla-Shirani-Saito combination for the reasons discussed above. *See above*, §VI.A-E.



SAMSUNG-1009, FIG. 6 (annotated and color added).

204. Moreover, Mualla uses a “**selector**” to control inter or intra coding. SAMSUNG-1005, 72, FIG. 3.1. Using a selector to switch between normal decoding and error concealment “would have been a natural extension of techniques disclosed within Mualla.”

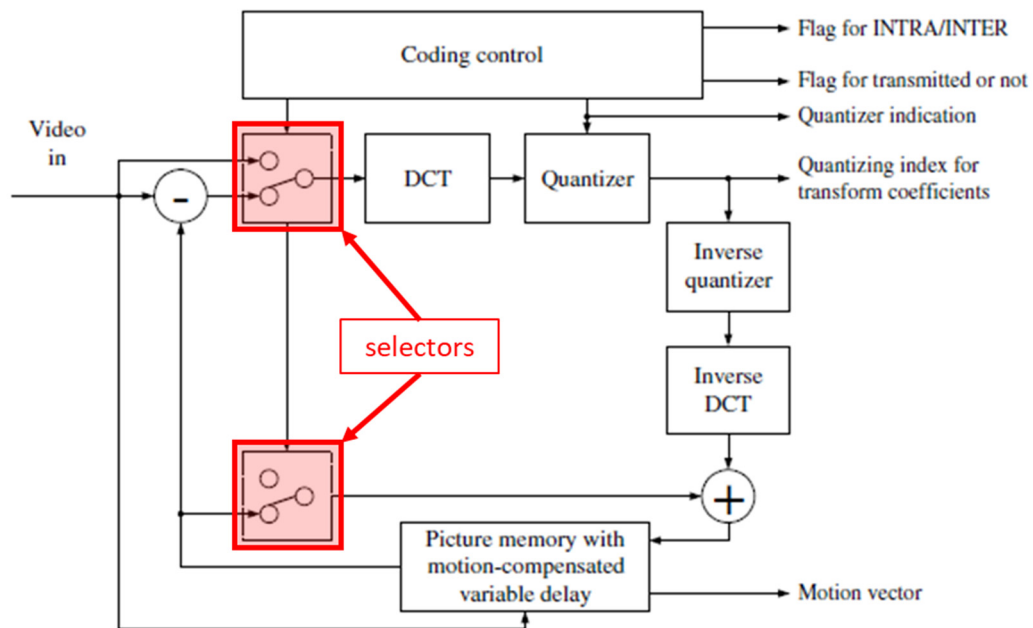


Figure 3.1: H.263 video encoder

SAMSUNG-1005, FIG. 3.1 (annotated and color added).

[6.16.DEC] a decoding controller to receive decoding control data for decoding control from the parameter data and control the selector to switch the predictive picture to be supplied to the combiner between the first and second predictive pictures according to the decoding control data.

205. As explained above in [6.15.DEC], the Mualla-Shirani-Saito combination would have switched, via a “selector” or equivalent component, between conventional motion compensation and error concealment, depending on the presence of errors in the bitstream. *See above*, [6.15.DEC]. Additionally, Mualla also discloses that these errors can be detected from “syntax and semantic violations,” the “header information” being one source of this data (“***decoding control data for decoding control from the parameter data***”). SAMSUNG-1005, 231-232. Additionally, Mualla’s H.263 video

encoder includes a “coding control” component (“*a decoding controller*”) that is “responsible for varying several parameters to control the rate or the quality of the coded video.” SAMSUNG-1005, 72, 75, FIG. 3.1. Examples of functions that are controlled by the coding control component are “INTER/INTRA mode decision at the picture or MB level, the update pattern of the forced INTRA refresh, the TRANSMIT=SKIP decision at the MB level, and the QP and its change at the picture, GOB, or MB level.” SAMSUNG-1005, 75. Illustrated below is Mualla’s example H.263 encoder with a “coding control” component that controls operations of the local decoder (the bottom switch).

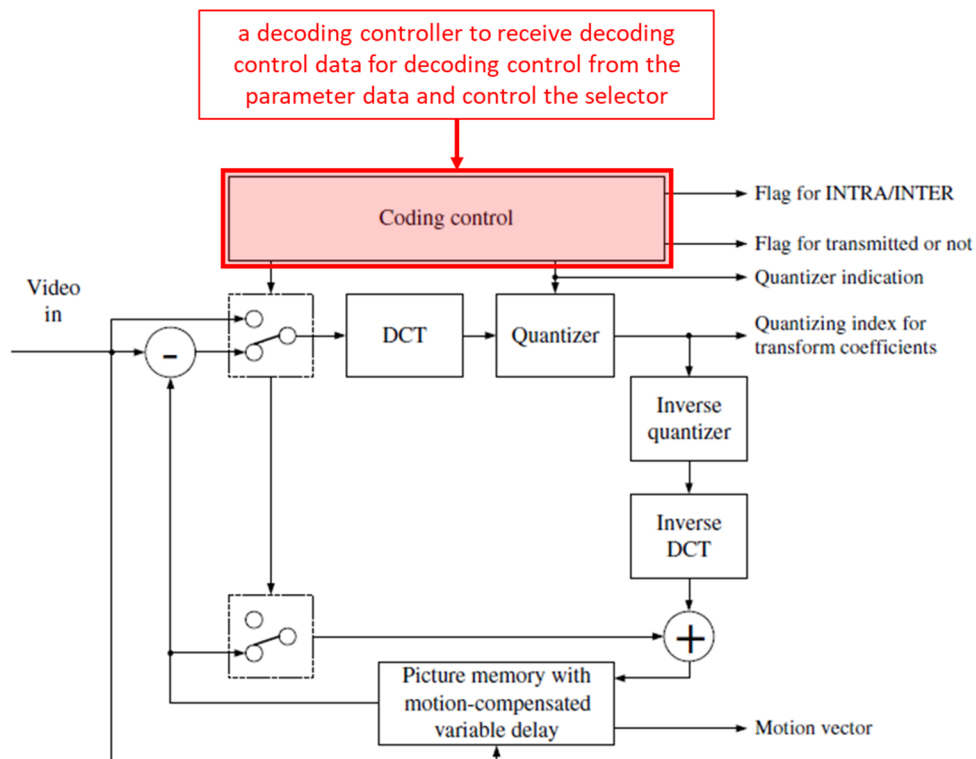
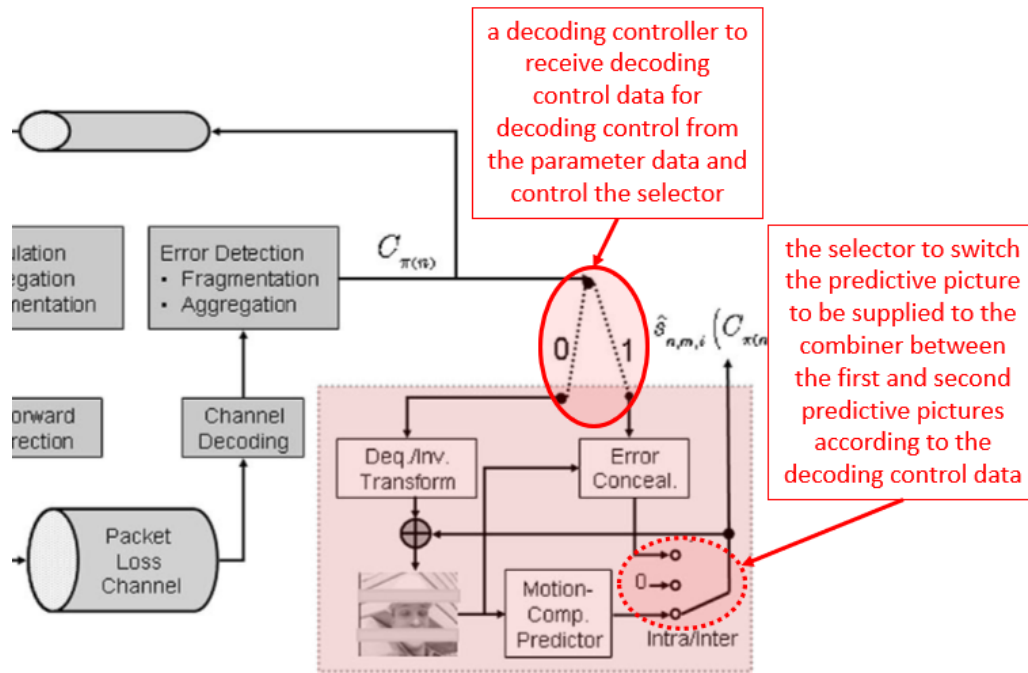


Figure 3.1: H.263 video encoder

SAMSUNG-1005, FIG. 3.1 (annotated and color added).

206. A POSITA would have recognized or found obvious that Mualla's decoder would have implemented an analogous coding control component (“*a decoding controller*”) would have “*receive[d] decoding control data for decoding control from the parameter data*” and subsequently, in response to a detected error, “*control[ed] the selector to switch the predictive picture to be supplied to the combiner between the first and second predictive pictures according to the decoding control data.*” Indeed, this function is consistent with the operations of the coding controller described by Mualla, and Mualla's coding controller must necessarily process syntax data (“*decoding control data for decoding control from the parameter data*”) at least because it must make decisions regarding ‘inter’ or ‘intra’ prediction.

207. Additionally, as illustrated in Stockhammer's Figure 6 (reproduced below) and as discussed in [6.15.DEC], above, it was known that an H.264-based decoder can implement a *decoding controller* that determines whether an error has been detected (either binary 0 or 1) and controls a *selector* to switch between the outputs of the “error concealer” (the “*first predictive picture*”) or the output of the conventional “motion compensated predictor” (the “*second predictive picture*”) SAMSUNG-1009, FIG. 6.



SAMSUNG-1009, FIG. 6 (annotated and color added).

[7.pre] A non-transitory computer readable device having stored thereon a computer program comprising a set of instructions when executed by a computer to implement a method for moving-picture decoding, the program comprising:

208. Mualla discloses “software-based video codecs” (“*non-transitory computer readable device*”) that utilize various “algorithms” (“*a computer program comprising a set of instructions*”). SAMSUNG-1005, 71, 182, 265, 299. For example, Mualla provides an example of a specific software implementation of H.263 called “Telenor” (citing to a “H.263 TMN software codec” as reference [144]) (“*a method for moving-picture decoding*”). SAMSUNG-1005, 265, 299.

209. Moreover, the use of algorithms in implementing codecs was well-known before the Critical Date. Indeed, both Shirani and Stockhammer corroborate the use of “algorithms” and “software” in implementing H.263 and H.264 codecs. SAMSUNG-1006, 1 (“many of the video compression algorithms (e.g., H.263)”); SAMSUNG-1009, 1, 5 (“in the standardization of H.264/AVC for the development of the reference software”).

[7.1.DEC]-[8.3], [10.pre]-[10.13.DEC]

210. These limitations are obvious as explained above for the corresponding limitations listed in the following table.

Claim	Corresponding Claim
[10.pre]	[6.pre]
[7.1.DEC], [10.1.DEC]	[6.1.DEC]
[7.2.COD], [10.2.COD]	[6.2.COD]
[7.3.COD], [10.3.COD]	[6.3.COD]
[7.4.COD], [10.4.COD]	[6.4.COD]
[7.5.COD], [10.5.COD]	[6.5.COD]
[7.6.COD], [10.6.COD]	[6.6.COD]
[7.7.COD], [10.7.COD]	[6.7.COD]
[7.8.DEC], [8.pre], [10.8.DEC]	[6.8.DEC]
[7.9.DEC], [10.9.DEC]	[6.9.DEC]
[7.10.DEC], [10.10.DEC]	[6.10.DEC]
[7.11.DEC], [10.11.DEC]	[6.11.DEC]

[7.12.DEC], [10.12.DEC]	[6.12.DEC]
[8.1]	[6.14.DEC]
[8.2]	[6.15.DEC]
[8.3]	[6.16.DEC]
[10.13.DEC]	[6.13.DEC]

2. “Moving picture coding” claims 1-5, 9

[1.pre], [4.pre], [9.pre]

211. Mualla teaches extensive details of an H.263-based video codec system, which implements ***coding apparatus, method, and media*** for decoding ***moving pictures*** (e.g., “video”). SAMSUNG-1005, 23-26, 31, 36, 51-52, 61-63, 227-228, 241-242, 265. For example, as discussed in §VI.A, above, Mualla’s Figure 9.1 and accompanying description disclose a “typical video communication system” which includes a “source encoder” (“***coding apparatus, method, and media***”). SAMSUNG-1005, Figure 9.1 (reproduced below), 227-228. Further details of Mualla’s “source encoder” are illustrated and described with reference to Figures 2.3, 1.1, and 2.9 of Mualla, as explained in §VI.A, above. To facilitate understanding, I provide aggregated views of the relation between these different figures of Mualla are shown in Diagrams A and B discussed in §VI.A, above, which are reproduced again below.

212. Additionally, as discussed above in [7.pre], “*non-transitory computer readable device*” is both disclosed by Mualla and further would have been an obvious implementation choice to a POSITA. *See above* [7.pre].

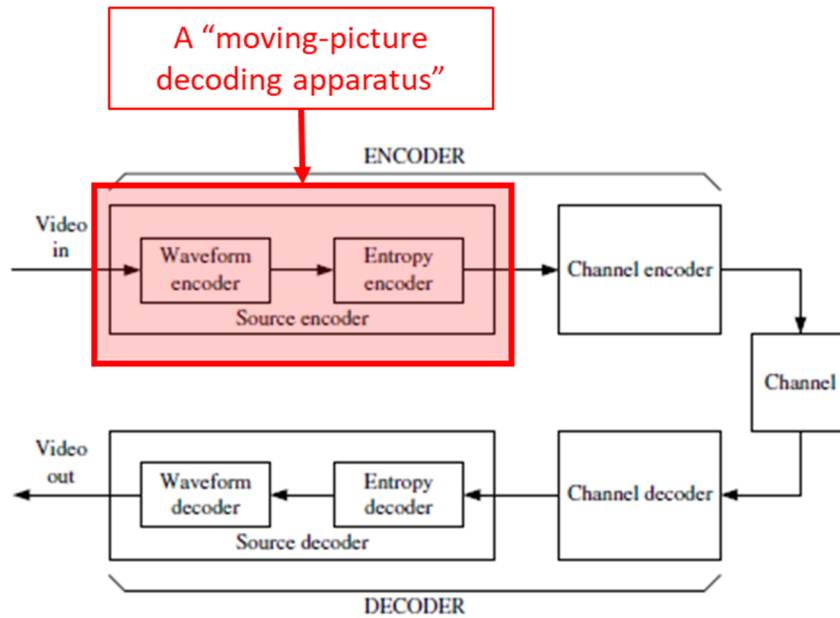


Figure 9.1: Typical video communication system

SAMSUNG-1005, FIG. 9.1 (annotated and color added).

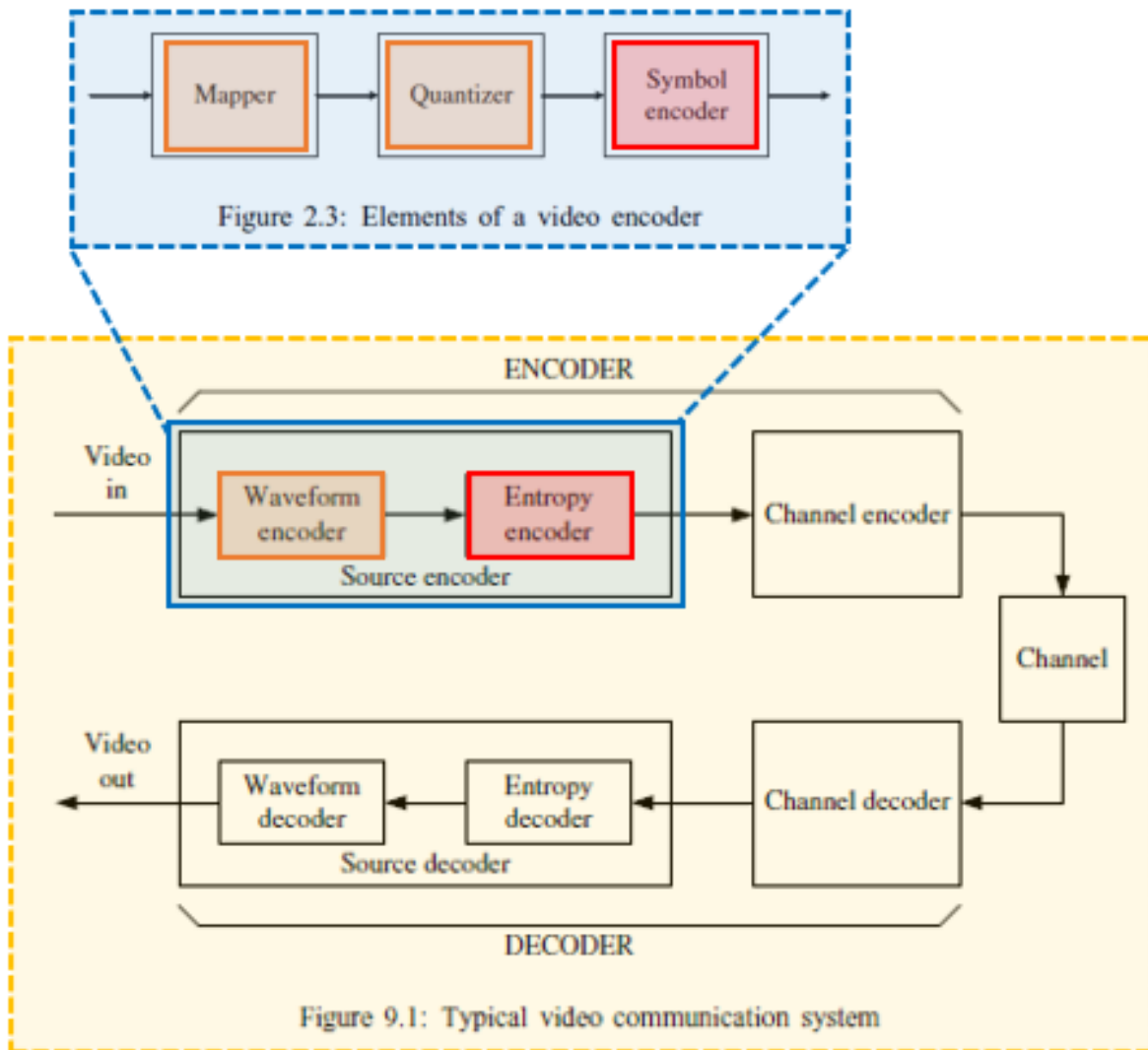


Diagram A (showing the relation between Mualla's Figures 9.1 and 2.3)

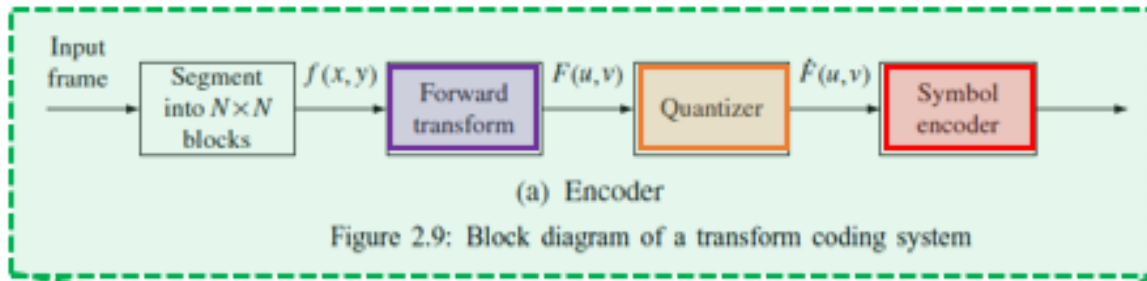
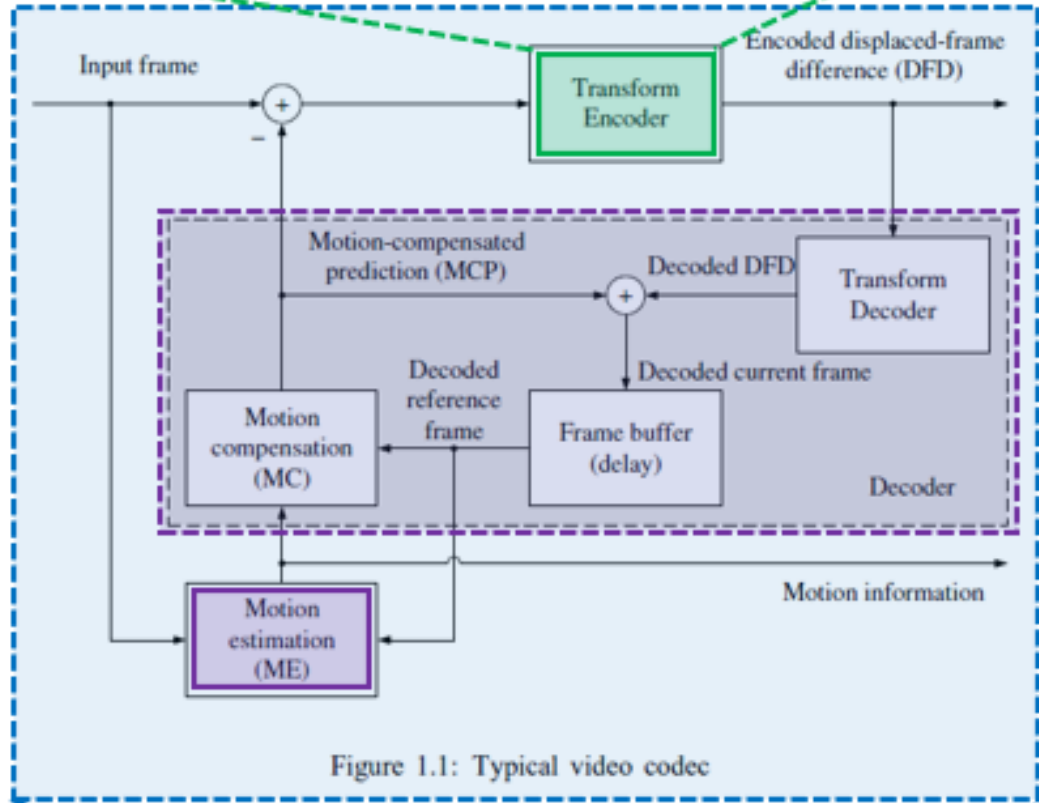
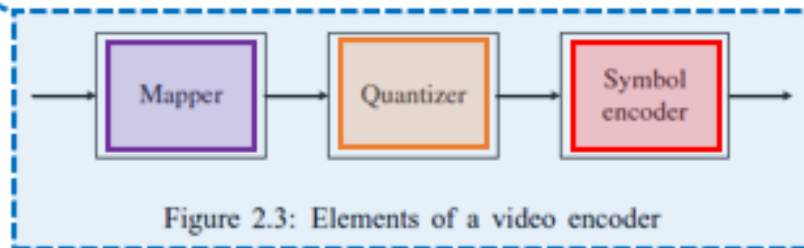


Diagram B (showing the relation between Mualla's Figures 2.3, 1.1, and 2.9)
[1.8.COD], [2.3], [4.8.COD], [5.3], [9.6.COD]

213. Mualla’s “typical video codec” illustrates a component (“*a first subtractor*”) that subtracts the “[m]otion-compensated prediction (MCP)” (“*the first predictive picture*”) from an “[i]nput frame” (“*the picture to be coded*”) to produce, after transform encoding, an “[e]ncoded displaced-frame difference (DFD)” (“*a first residual picture*”). SAMSUNG-1005, 23-26, FIG. 1.1.

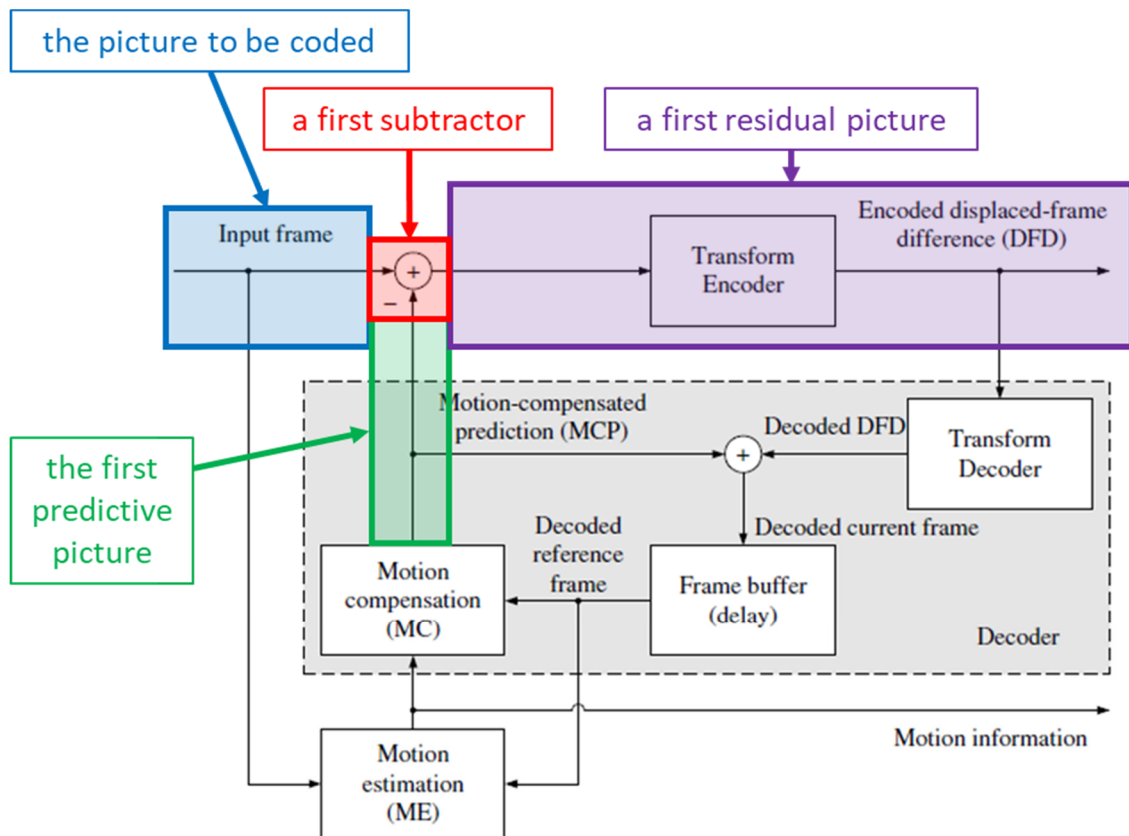


Figure 1.1: Typical video codec

SAMSUNG-1005, FIG. 1.1 (annotated and color added).

3. Remaining limitations of Claims 1, 4, and 9

214. These limitations are obvious as explained above for the corresponding limitations listed in the following table.

Claim	Corresponding Claim
[1.1.COD], [4.1.COD], [9.1.COD]	[6.3.COD]
[1.2.COD], [4.2.COD], [9.2.COD]	[6.4.COD]
[1.3.COD], [4.3.COD], [9.3.COD]	[6.5.COD]
[1.4.COD], [1.5.COD], [4.4.COD], [4.5.COD], [9.4.COD]	[6.6.COD]
[1.6.COD], [4.6.COD], [9.5.COD]	[6.7.COD]
[1.7.COD], [4.7.COD]	[6.3.COD]
[1.9.COD], [1.10.COD], [4.9.COD], [4.10.COD], [4.14.COD], [9.7.COD], [9.8.COD]	[6.2.COD]
[1.11.DEC], [4.11.DEC], [9.9.DEC]	[6.9.DEC]
[1.12.DEC], [4.12.DEC], [9.10.DEC]	[6.10.DEC]
[4.13.COD]	[6.8.DEC]
[2.1], [5.1]	[6.2.COD]
[2.2], [5.2]	[6.14.DEC]
[2.4], [5.4]	[6.15.DEC]
[5.5]	[6.16.DEC]

VIII. Additional Remarks

I currently hold the opinions set expressed in this declaration. But my analysis may continue, and I may acquire additional information and/or attain supplemental insights that may result in added observations.

Cliff Reader, Ph.D.

Expertise

- Real-time Processing and Display
 - Video coding (MPEG-HEVC)
 - Audio coding (MPEG-AAC)
 - Imaging/Video Systems Architecture
 - Imaging/Video Chip Architecture
 - Videoconferencing
 - Speech Processing
 - Consumer audio/video
 - Reconnaissance Imaging
 - Medical Imaging
-

Professional Summary

Dr. Reader has over forty five years of work experience in digital imaging, digital video & audio and digital speech processing. In the 1970's and early 1980's, he was one of the leaders in the digital imaging field, performing extensive work in areas of compression, real-time processing, real-time display, image enhancement, and others. Applications included reconnaissance imaging, medical imaging, earth resources management and videoconferencing. This work anticipated much of the technology being used in contemporary consumer digital video systems. He has in-depth experience of the commercial history and when key parts of technology were first developed and published.

Dr. Reader's career includes technical work in areas of algorithm design, system design, and semiconductor chip design; and business development, marketing and sales work in areas of market analysis, product roadmap development and direct sales.

Dr. Reader has held many leadership roles in standards development: US Head of Delegation to MPEG (1991-1993); chief editor of the MPEG1 standard (1991-1993); instigator of the successful effort to make MPEG2 the market standard for digital TV over proprietary competitors in the US and national competitors in Europe and Japan (1992); MPEG4 Subcommittee Chairman (1993-1996); AVS (China) Subgroup Chairman (2003-Present). He is an expert in all major audio-video standards. MPEG audio (Layer I, II, mp3, AAC), Dolby AC3, MPEG video (1, 2, 4), H.264, Windows Media 9 (VC-1), H.265 (HEVC), AVS and AV1. He is also an expert in DVD standards, including formatting, navigation and authoring.

Dr. Reader has extensive experience in patent licensing and patent pools. He was the technical expert for developing the initial list of potentially essential patents for the first MPEGLA patent pool (MPEG2 video and systems). He is the Co-Director leading the pool formation and license negotiations for the AVS patent pools. Dr. Reader has experience in the valuation of patents and the acquisition and sale of patent portfolios.

Dr. Reader has authored over twenty technical papers, two book chapters and two patents in digital video processing, display, and compression. He taught digital signal processing and image processing at Santa Clara University in the early 1980s and is an Adjunct Professor at Peking University, Beijing, China.

Employment History

From: 2001 **Independent Consultant**
To: Present Escondido, CA
Provide technical and marketing consulting services in the areas of digital imaging, digital video, digital audio and speech including:

- consumer video
- real-time processing and display
- image and video & audio compression (specializing in standards)
- imaging/video systems architecture
- imaging/video chip architecture
- audio/video transmission, including optical & wireless networks

Over 80 clients including Apple, AT&T, Adobe, Broadcom, China Central TV, Chinese Academy of Sciences, Cisco, Comcast, DirecTV, Dish Network, Disney, EchoStar, ETRI, Facebook, Fujifilm, Gateway, GE, Google, Haier, Hisense, HP, Hulu, IBM, Intel, Johnson Controls, KAIST, Lenovo, LG, Matsushita, MediaTek, Microsoft, Motorola, Netflix, Nikon, Nokia, ON2, OPPO, Peloton, Philips, Quanta, Riverbed, Samsung, Sharp, Siemens, Sony, Starz, Sun Microsystems, Toshiba, TPV, Tyco, US Department of Justice, Verizon, Vimeo, Vizio, Wistron, Xiaomi, Yahoo, Zoran and ZTE.

Personal database of patent analysis:

- Evaluation of all the US patents in the MPEG2, H.264 and H.265 patent pools.
- Evaluation of the US patents and published applications underlying the H.264 and H.265 standards.
- Personal archive of over 2000 audiovisual patents.

Personal database of audio and video prior art.

- Virtually complete collection of all contributions to the H.26x and MPEGx families of standards from 1985 to today.
- Many hundreds of technical journal and conference articles documenting the first invention of key technologies.
- Work-in-progress book on the history of video compression.
- Historical collection of technical data from the earliest digital video, image processing and real-time image display systems in the 1970s and 1980s.

From: 1999 **nDSP Corporation**
To: 2001 Campbell, CA
Title: *Vice President of Marketing and Acting Vice President of Sales*

Responsible for marketing and sales in a startup company providing high-quality video signal processors to TV manufacturers. Developed product specifications and roadmap. Built and managed sales and marketing team of 6 direct and contractor staff in the US and Japan to provide technical sales, sales support, application engineering, Marcomm and PR. Established distribution in China, Japan and throughout the Far East. Secured first sales as company moved into production phase with design wins in China, Japan and Europe. Initiated and secured major design wins in emerging Progressive DVD business, with production volumes beginning in 4Q00 at an annualized rate of \$3.5M. Established strategic partnership with Pixelworks in LCD chip business. Pixelworks acquired nDSP in 2001.

From: 1997 **CagEnt Technologies, Inc. (wholly owned by Samsung)**
 To: 1998 Santa Clara, CA
 Position: *Vice President of Sales, Digital Video Products*
 Responsible for a line of PC-based real-time MPEG2 and Dolby Digital encoders. Established distribution agreements for third-party DVD authoring software. Secured OEM contracts for the products. Built the sales channel worldwide. Built sales to break-even point in 9 months leading to sale of the product line.

From: 1993 **Samsung Semiconductor, Inc.**
 To: 1997 San Jose, CA
 Position: *Director of Marketing, Digital Media Products;*
Acting Director of Software Engineering
 Developed business plans for digital audiovisual semiconductor chips. Managed team of over 50 software engineers in US and Korea for development of a media processor. Established strategic partnerships with Microsoft and IBM for media processor

From: 1990 **Cypress Semiconductor, Inc.**
 To: 1993 San Jose, CA
 Position: *Business Development Manager*
 Founding member of new business unit chartered to develop a “video DSP”. Jointly developed a complete business plan, and personally initiated and developed relationships with Philips, Sun Microsystems, Apple Computers and IBM. Chief architect for this early media DSP design, capable of complete MPEG1 decode in real time. (Fully validated by cycle-accurate simulation). Managed R&D team of 10 hardware and software engineers.

Head of US Delegation to MPEG, 1991 to 1992. Chief Editor of the MPEG1 standard. Technical Expert for establishing the

MPEGLA Patent Licensing Pool.

From: 1988 **Sun Microsystems, Inc.**
To: 1990 Mountain View, CA
Position: *Program Manager*
Developed requirements and specifications for real-time imaging system. Managed a team of 20 engineers to develop the architecture and high-level design. Interfaced with two key customers – Philips Medical Systems and Lockheed. Developed design for single-board real-time medical and reconnaissance image display.

From: 1981 **International Imaging Systems, Zoran, Virtual Imaging**
To: 1988 Design and development of real-time image processing and display systems. Details available on request.

From: 1975 **Ford Aerospace & ESL (A Division of TRW)**
To: 1981 Details available on request.

Consulting History

Date 2023 **Intel**
To: Present
Duties: Consulting Expert

Date 2023 **Disney**
To: Present
Duties: Consulting Expert

Date 2023 **Samsung**
To: Present
Duties: Consultant

Date 2023 **Peloton**
To: Present
Duties: Consulting Expert in NEC matter

Date 2023 **Alps Alpine**
To: 2023
Duties: Consulting Expert in DivX matter

Date 2023 **Fish & Richardson**
To: Present
Duties: Consultant

Date	2023	Oppo
To:	Present	
Duties:	Consulting Expert on speech processing in Nokia matter	
Date	2022	Samsung
To:	2023	
Duties:	Testifying Expert on speech processing in Jawbone matter	
Date	2022	Asus, Lenovo, MSI
To:	2023	
Duties:	Consulting Expert in VideoLabs matter	
Date	2022	Google
To:	2023	
Duties:	Consulting Expert on speech processing in Jawbone matter	
Date	2022	Starz
To:	Present	
Duties:	Consulting Expert in VideoLabs matter	
Date	2022	Meta Platforms (Facebook)
To:	Present	
Duties:	Consulting Expert in VideShare matter	
Date	2022	Oppo
To:	Present	
Duties:	Consulting Expert in InterDigital matter	
Date	2022	Apple
To:	2023	
Duties:	Consulting Expert on speech processing in Jawbone matter	
Date	2021	Verkada
To:	2022	
Duties:	Testifying Expert in Motorola Solutions matter	
Date	2021	Facebook
To:	2022	
Duties:	Consulting Expert in EyesMatch matter	
Date	2021	Videoconferencing company
To:	2023	
Duties:	Testifying Expert	
Date	2021	Canon

To:	2022	
Duties:		Consulting Expert in WSOU Investments/Brazos Licensing matter.
Date	2021	Axis
Duties:		Consulting Expert
Date	2021	nVIDIA
To:	2022	
Duties:		Consultant
Date	2020	Xiaomi
To:	2021	
Duties:		Consulting Expert in InterDigital matter
Date	2020	LG
To:	2021	
Duties:		Consulting Expert DivX matter
Date	2020	Vizio
To:	2023	
Duties:		Consulting Expert VDPP matter
Date	2020	Netflix
To:	2022	
Duties:		Consultant
Date	2020	Oppo
To:	Present	
Duties:		Consultant
Date	2020	IdeaHub
To:	Present	
Duties:		Preparation of declaration for Inter Partes Review proceedings. (Unified Patents matter)
Date	2019	Google
To:	2021	
Duties:		Preparation of declarations for Inter Partes Review proceedings (PMC matter)
Date	2019	Google
To:	2021	
Duties:		Consulting Expert (Multiple projects)
Date	2019	LG
To:	2020	

	Duties:	Preparation of declarations for Inter Partes Review proceedings. (Uniloc matter)
Date	2019	Klarquist, Sparkman
To:	2021	
	Duties:	Consulting Expert (Multiple projects)
Date	2019	Netflix, Hulu
To:	2021	
	Duties:	Preparation of declarations for Inter Partes Review proceedings. (DivX matter)
Date	2019	MediaTek
	Duties:	Consulting Expert in American Patents matter
Date	2019	AT&T
	Duties:	Consulting Expert
Date	2019	KAIST/KBS
To:	2021	
	Duties:	Consulting Expert for Inter Partes Review proceedings. (Unified Patents matter)
Date	2019	Vimeo
To:	2020	
	Duties:	Preparation of declarations for Inter Partes Review proceedings. (BT matter)
Date	2019	Apple
	Duties:	Preparation of declarations for Inter Partes Review proceedings. (Red.com matter)
Date	2019	Adobe
To:	2021	
	Duties:	Preparation of declarations for Inter Partes Review proceedings and consulting expert. (Realtime matter)
Date	2018	Toshiba
To:	2019	
	Duties:	Testifying expert concerning valuation of essential patents for ATSC standards
Date	2018	Hisense
	Duties:	Analysis of essential patents for AAC standards
Date	2018	HTC

To:	2020	
Duties:		Analysis of essential patents for the H.265 standard
Date	2018	Cisco
To:	2020	
Duties:		Consulting expert in Realtime matter
Date	2017	Dish Network
To:	2023	
Duties:		Consulting expert in ClearPlay matter
Date	2017	Apple
To:	2019	
Duties:		Preparation of declarations for Inter Partes Review proceedings. (Uniloc matter)
Date	2017	Dish Network
To:	2020	
Duties:		Testifying expert in Realtime matter
Date	2017	CustomPlay
To:	2020	
Duties:		Preparation of declaration for summary judgment in Amazon case.
Date	2017	Vizio, Funai, LG, MediaTek, MStar
Duties:		Testifying expert in Broadcom case.
Date	2017	Apple
Duties:		Preparation of declarations for Inter Partes Review proceedings. (Nokia matter)
Date	2017	Vizio
Duties:		Preparation of declarations for Inter Partes Review proceeding. (Lightside Technologies matter)
Date	2016	Dell, Riverbed, EchoStar, Dish Network
To:	2019	
Duties:		Testifying expert in Realtime matter
Date	2016	Sharp, Vizio, ON
To:	2018	
Duties:		Testifying expert in WiLAN matter
Date	2016	Avid
To:	2017	
Duties:		Testifying expert in Harmonic matter.

Date	2016	Apple
Duties:		Testifying expert in PUMA matter.
Date	2016	Vizio
Duties:		Testifying expert in PMC matter.
Date	2016	US Dept. of Justice, Dept. of Homeland Security, DoD, FBI, NSA, & Others
To:	2021	
Duties:		Consulting expert in Discovery Patents (3 rd Eye Surveillance) matter. Declarations in support of six Inter Partes Reviews.
Date	2015	ST Micro
To:	2016	
Duties:		Consulting expert in Avago matter.
Date	2015	AT&T
Duties:		Consulting expert in Raniere matter.
Date	2015	Motorola
To:	2016	
Duties:		Consulting expert in PUMA matter.
Date	2015	TPV
To:	2016	
Duties:		Consulting expert in Thomson licensing matter.
Date	2015	Tyco (Exacq, Johnson Controls)
To:	2019	
Duties:		Consulting expert in JDS Technologies matter.
Date	2015	Tyco
Duties:		Declaration in support of Inter Partes Review petition in Hawk Technology matter.
Date	2015	Sceptre
Duties:		Expert reports in licensing matter concerning MPEGLA MPEG2 pool patents.
Date	2015	Samsung
Duties:		Consultant and fact witness in case asserting Samsung patents of which I am a named inventor, against NVidia.
Date	2015	Nissim
To:	2016	

	Duties:	Consultant expert for patent holder in 20 th Century Fox, MGM, and Paramount cases concerning patents related to DVD navigation. Testified at Markman hearings.
Date	2015	Nikon
To:	Present	
	Duties:	Consultant.
Date	2015	Humax
	Duties:	Search and analysis of prior art.
Date	2015	Apple
	Duties:	Analysis of patent portfolio potentially essential for the H.264 standard.
Date	2014	Haier
To:	2018	
	Duties:	Analysis of patent portfolios for smart consumer devices.
Date	2014	Cisco
To:	2021	
	Duties:	Consultant.
Date	2014	ZTE, Sony, LG, Samsung, Nokia, GoPro
To:	2015	
	Duties:	Consulting expert.
Date	2014	Tyco
To:	2015	
	Duties:	Expert reports; declaration in support of Inter Partes Review in Trover matter.
Date	2013	Humax
	Duties:	Consultant.
Date	2014	GE Licensing
To:	2015	
	Duties:	Consultant.
Date	2014	HikVision & Axis
To:	2015	
	Duties:	Declaration in support of Inter Partes Review. Expert reports in Trover matter.
Date	2014	Sharp
To:	2016	
	Duties:	Declaration in support of Inter Partes Review in Wi-Lan matter.

Date	2013	InterDigital
To:	2015	
Duties:	Consulting expert in support of licensing a patent portfolio.	
Date	2013	Apple
Duties:	Consulting expert in National Cheng Kung University matter.	
Date	2013	Acer, ASUS, TPV
To:	2014	
Duties:	Testifying expert in Florida Atlantic University matter.	
Date	2013	Toshiba
To:	2014	
Duties:	Testifying expert in WiLAN matter.	
Date	2013	Grass Valley Group
Duties:	Consulting expert for defense in FastVDO matter.	
Date	2013	TI
To:	Present	
Duties:	Consulting expert.	
Date	2012	Vizio
Duties:	Consulting expert in Innovus Prime matter.	
Date	2012	Haier & Shandong Provincial Government
To:	2014	
Duties:	Foreign expert advisor for developing and acquiring patent portfolios for innovative consumer products. Development of a patent pool for patents essential to standards for wireless power.	
Date	2012	Vizio
To:	2014	
Duties:	Consulting expert in MIT matter.	
Date	2012	Nokia
To:	2013	
Duties:	Consulting expert.	
Date	2012	TPV & Vizio
To:	2013	
Duties:	Testifying expert for defense in Hitachi matter.	
Date	2012	Samsung
Duties:	Consulting expert in Myport matter.	

Date	2012	Verizon Wireless (Cellco) & T-Mobile
To:	2013	
Duties:		Testifying expert for defense in Realtime Data matter.
Date	2011	Apple
Duties:		Consulting expert in Technicolor matter.
Date	2012	Microsoft
To:	2014	
Duties:		Consulting expert for plaintiff in Motorola matter.
Date	2012	Apple & LG
To:	2014	
Duties:		Testifying expert for defense in MPT matter.
Date	2011	Sanyo & Olympus
Duties:		Consulting expert for defense in FastVDO matter.
Date	2011	Apple
Duties:		Consulting expert for defense in FastVDO matter.
Date	2011	Sony
Duties:		Consulting expert for defense in FastVDO matter.
Date	2011	Philips
To:	2014	
Duties:		Consulting expert for licensing essential patents.
Date	2011	Apple
Duties:		Consulting expert for defense in MobileMediaIdeas matter.
Date	2011	Video264Innovations
Duties:		Consulting expert.
Date	2011	Nikon, Fujifilm & Panasonic
Duties:		Consulting expert for defense in FastVDO matter.
Date	2011	Haier
To:	2014	
Duties:		Consultant for standards, patent pools and patent licensing.
Date	2011	Susman Godfrey
Duties:		Consultant for patent analysis.
Date	2011	Vizio

	Duties:	Testifying expert for defense in MPT matter.
Date	2011	Tivo
	Duties:	Consulting expert.
Date	2011	Nikon
To:	2013	
	Duties:	Consulting expert for defense in MPT matter.
Date	2011	Broadcom
	Duties:	Consulting expert.
Date	2010	Lionsgate Entertainment
	Duties:	Consulting expert in MPEG licensing matter.
Date	2010	Verizon
To:	2012	
	Duties:	Testifying expert for defense in ActiveVideo Networks matter.
Date	2010	Lenovo
To:	2011	
	Duties:	Consulting expert for defense in licensor matter.
Date	2010	Sonic, Cyberlink & Joint Defense Team
	Duties:	Consulting expert for defense in Mediostream licensor matter.
Date	2010	Wistron
To:	2011	
	Duties:	Consulting expert for defense in Toshiba licensor matter.
Date	2010	Panasonic, Pioneer
To:	2011	
	Duties:	Consulting expert for defense in VES licensor matter.
Date	2010	Zoran
To:	2011	
	Duties:	Technical analysis of patents potentially related to video coding standards.
Date	2010	Intravizual
To:	2015	
	Duties:	Consulting expert for patent licensing.
Date	2009	Apple
	Duties:	Technical analysis of patents potentially related to video coding standards.

Date	2009	SanDisk
Duties:		Consulting expert re Audio and Video coding patents
Date	2009	Lenovo
To:	2011	
Duties:		Consulting expert for defense in MPEGLA licensor matter.
Date	2009	Polycom
To:	2010	
Duties:		Consulting expert for defense in MPT matter.
Date	2009	DirecTV
To:	2011	
Duties:		Consulting expert for defense in MPT matter.
Date	2009	EchoStar
To:	2010	
Duties:		Consulting expert for defense in MPT matter.
Date	2009	Vizio
Duties:		Consulting expert for defense in Sony matter.
Date	2009	Vizio
To:	2010	
Duties:		Consulting expert for defense in LG matter.
Date	2009	Vizio, TPV, Amtran
To:	2010	
Duties:		Technical report & video presentation to US Customs on design issues related to Funai matter. Testified in ITC hearing, March 2010.
Date	2008	Humax (Korea)
To:	2009	
Duties:		Audio patent and prior art review.
Date	2008	IC Media (Canada)
To:	2009	
Duties:		Design of digital signage.
Date	2008	AVS Patent Pool Administration (China)
To:	Present	
Duties:		Co-Director, leading license negotiations among domestic and multinational licensors.

Date	2008	DirecTV
Duties:		Prior art search for DirecTV's appeal against Finisar.
Date	2008	Pure Digital
Duties:		Prior art research and analysis.
Date	2008	Wragge (UK)
Duties:		Prior art review for two video coding patents.
Date	2008	Microsoft
Duties:		Extensive non-infringement analysis for patents asserted by Multimedia Patent Trust (MPT).
Date	2008	iPotential
To:	2010	
Duties:		Technical analysis of patents potentially related to video coding standards.
Date	2008	Alba (UK) aka Harvard Research
To:	2009	
Duties:		General education on essential patents, licensing, prior art related to the MPEG2 video standard.
Date	2008	Philips (Holland)
Duties:		Review of patents for essentiality.
Date	2008	Proview
Duties:		Prior art search for TV display features.
Date	2008	Nissim
To:	2014	
Duties:		Consultant expert for plaintiff in Time-Warner case concerning patents related to DVD navigation.
Date	2008	Comcast
Duties:		Technical analysis of MPEG2 systems, DSM-CC, and carousel operation in the cable TV network environment. Contribution to expert's report in Comcast's successful litigation against Finisar.
Date	2007	Sun Microsystems
To:	2009	
Duties:		Chief architect of royalty-free video codec: OMS Video. Extensive supporting patent analysis and technical publication analysis for prior art review.
Date	2008	SanDisk

	Duties:	Technical analysis of patents and prior art searching for audio coding.
Date	2008	Stammberger (Munich)
	Duties:	Technical analysis of patents potentially related to video coding standards.
Date	2008	Trigem America Liquidating Trust
	Duties:	Preparation of expert reports concerning litigation between Toshiba and Trigem.
Date	2007	Susman-Godfrey
	Duties:	Technical analysis of patents potentially related to video coding standards.
Date:	2007	Wong-Cabello
	Duties:	Technical analysis of patents potentially related to video coding standards.
Date:	2007	Sisvel
	Duties:	Technical assistance in licensing audio patents to a third party.
Date:	2007	Quanta
	Duties:	Technical assistance in litigation related to DVD.
Date:	2006	CCTV (China Central TV)
	Duties:	Technical analysis of patents potentially related to MPEG2, H.264, AVS and VC-1 video coding standards and MPEG-AAC and Dolby audio coding standards.
Date:	2006	MediaTek
	Duties:	Technical analysis of MediaTek patents potentially related to video coding standards.
Date:	2006	Alcatel
	Duties:	Technical analysis of Alcatel patents potentially related to video coding standards.
Date:	2006	Motorola
	Duties:	Analysis of technologies contributed to the H.264 standard.
Date:	2005	Nokia
	Duties:	Analysis of technologies contributed to the H.264 standard.
Date:	2005	Avid
	Duties:	Technical analysis of patents potentially related to coding standards.

Date:	2005	IBM
Duties:		Analysis of technologies contributed to the H.264 standard.
Date:	2005	HP
Duties:		Analysis of selected audio coding patents.
Date:	2005	ComVentures
Duties:		Due diligence review of a start-up company in the video semiconductor business.
Date:	2005	nVidia
Duties:		Prior art search for a set of third-party patents.
Date:	2004	Microsoft
Duties:		<ul style="list-style-type: none"> Working with a major financial services company, developed a procurement model for managing licensing costs. Assisting development of non-infringement positions for a set of patents. (Not in suit).
From:	2004	SAGEM (France)
To:	2005	
Duties:		Technical analysis of potential infringement by SAGEM of a set of third-party patents.
From:	2004	Polycom Inc.
To:	2005	
Duties:		Technical analysis of Polycom patents potentially related to video coding standards.
From:	2004	Sony Corp.
To:	2006	
Duties:		<ul style="list-style-type: none"> Technical analysis of potential infringement by Sony of a set of third-party patents. The parties settled without litigation. Analysis of a third-party patent per Sony's direction.
Date:	2004	On2 Inc
Duties:		Delivery of the comprehensive set of reports on IPR potentially related to the emerging H.264 standard.
Date:	2004	Matsushita Avionics
Duties:		Technical analysis of potential infringement of Matsushita patents by a third party.
Date:	2004	Connex Inc.
Duties:		Teaching the details of key complex algorithms in the H.264 standard.

Date:	2004	DoCoMo (Japan)
Duties:		Delivery of the comprehensive set of reports on IPR potentially related to the emerging H.264 standard.
From:	2004	DivX Inc.
To:	2006	
Duties:		Analysis of technologies contributed to the H.264 standard
Date:	2004	Cues, Inc
Duties:		Assisted evaluation of infringement by Cues' products of a patent asserted by a third party. The parties settled without litigation.
From:	2003	GE Licensing
To:	2004	
Duties:		Working with a major financial services company, developed a business, market and financial model for valuation of a portfolio of patents through their expiration.
From:	2003	Institute of Computing Technology, Chinese Academy of Sciences
To:	Present	
Duties:		<ul style="list-style-type: none"> • Preparation of IPR Report for IPR potentially related to the AVS Video standard. This effort involved review of over 2500 abstracts and over 450 patents. • IPR Subgroup Chairman of AVS. Formed an IPR Experts group to establish a legal foundation for AVS IPR. This group comprised approximately 20 attorneys and business development managers from eight multinational companies representing the PC, consumer, semiconductor and communication industries. (Broadcom, IBM, Intel, Matsushita, Microsoft, Nokia, Sony, Sun Microsystems). The group drafted a member agreement, bylaws and a formal IPR policy governing licensing commitments, disclosure obligations, and protection of license holder rights. AVS Members approved these documents in September 2004. • Co-Director of AVS Patent Pool. Leading the drafting and negotiation of patent pool management and licensing agreements. • Adjunct Professor, supervising a graduate student project on deinterlacing algorithm development.
Date:	2003	Yahoo
Duties:		Prior art search to provide background information per Yahoo's request.
Date:	2002	Gateway, Inc.
To:	2007	
Duties:		Extensive prior art search and assistance with claim construction in a litigation matter with Lucent Technologies.

From:	2002	Apple Computer
To:	2007	
Duties:		<ul style="list-style-type: none"> • Technical analysis of Apple patents potentially related to H.264. • Prior art search for various patents per Apple's request.
Date:	2002	Siemens (Germany)
Duties:		<ul style="list-style-type: none"> • Technical analysis of Siemens patents potentially related to H.264. • Delivery of the comprehensive set of reports on IPR potentially related to the emerging H.264 standard.
Date:	2002	JVT Committee (Apple, Cisco, Nokia, Polycom, Sun Microsystems, Tandberg, Teles, Texas Instruments, UBVideo, VideoLocus)
Duties:		Developed a comprehensive set of reports on IPR potentially related to the emerging H.264 standard. The reports included a technical review of legacy and new patents for video coding, and analysis of the patent statements provided by all companies whose contributions were adopted into H.264.
Date	2002	Intervideo
Duties:		Advised on market opportunities in the emerging MPEG4 marketplace.
Date:	2001	Proskauer Rose LLP
Duties:		Provided background support in MPEGLA's (successful) effort to license MPEG2 to the major PC manufacturers.
Date	2001	Pixonics
Duties:		Developed marketing plan and marketing support materials for this incubator-stage company.
Date	2001	Eltron, (Taiwan)
Duties:		Provided overview of the digital video semiconductor market.
Date	1999	nDSP Corporation
Duties:		Drafted the sales and marketing plan for this early-stage company. Joined nDSP full-time.
Date:	1998	IBM Corp.
Duties:		Assisted with participation in the ATSC DASE (datacasting) standard.
Date	1998	Spruce Technologies
Duties:		Assisted with transition of Cagent MPEG encoder product after it was sold to Spruce.
From:	1997	Samsung Advanced Institute of Technology
To:	1999	

Duties: Supported Samsung researchers in MPEG4 standard development. Led effort to provide error-resilient 3D-mesh coding.

Date 1997 **MPEGLA LLC**
Duties: Review of opportunity for an MPEG4 patent pool

From: 1993 **CableLabs**
To: 1994
Duties: Teamed with a patent attorney to develop the initial essential patent list for MPEG2. Reviewed approximately 10,000 abstracts and 1,000 patents for the MPEG2 Video and MPEG2 Systems standards. This effort led to the MPEGLA patent pool.

Litigation Support Experience

Quinn Emanuel Urquhart & Sullivan, LLP, San Francisco, CA
Case Motorola Solutions vs. Verkada, Investigation No. 337-TA-1281
Project: Expert report, deposition and trial testimony on invalidity of Motorola patents.
Status: Final determination found Verkada not infringed
Filed: August, 2021
Location: United States International Trade Commission, Washington DC

Orrick, Herrington & Sutcliffe, LLP, New York, NY
Case ClearPlay vs. Dish Network & EchoStar Technologies, Case No. : 2:14-cv-00191
Project: Expert report, deposition and trial testimony on invalidity of ClearPlay patents.
Status: ClearPlay patents not infringed
Filed: March 13, 2014
Location: United States District Court for the District of Utah

Akin Gump, Fish & Richardson, Finnegan, Baker Hostetler, Washington, DC
Case Broadcom vs. Vizio, LG, Funai, MediaTek, MStar, Investigation No. 337-TA-1047
Project: Expert report and deposition on non-infringement of Broadcom's patent.
Status: Final Determination in favor of Respondants.

Jones Day, Cleveland, OH
Case Avid Technology vs. Harmonic, Case No. C.A. No. 12-627-GMS
Project: Expert reports and deposition on infringement of Avid's patent.

Status: Parties settled before trial.

Haynes and Boone, Dallas, TX
Case Realtime vs. Riverbed, Case No. 6:1S-CV-463-RWS-JDL
Project: Expert report, deposition and trial testimony (E. District Texas) on
invalidity of Realtime patent.
Status: Jury found Realtime patent invalid at trial.

Akin Gump, LLP, Irvine, CA
Case Personalized Media Communications “PMC” vs. TPV et al, Case No.
2:15-cv-01366-JRG-RSP
Project: Declaration in support of claim construction brief.
Status: Parties settled.

Feinberg, Day, LLP, Menlo Park, CA
Case Parthenon Unified Memory Architecture “PUMA” vs. Apple, Case No.
9:12-cv-80701
Project: Expert report and deposition concerning unified memory architecture.
Status: Trial stayed at request of PUMA. Parties settled.

Carey, Rodriguez, LLP, Miami
Case *Twentieth Century Fox Home Entertainment, LLC, Paramount Pictures
Corp., vs. Nissim Corp., Case No. 14-81349/813450-cv-MARRA
Project: Expert witness for patent owner in counterclaims for infringement.
Declaration and expert testimony at Markman Hearings concerning DVD
standards essential patents.
Status: Parties settled before trial.

*Nissim asserted its patents against Twentieth Century Fox and
Paramount. The latter filed a complaint seeking a declaratory judgment
of non-infringement and invalidity.

**TechKnowledge Law Group, Turner Boyd LLP & O’Melveny &
Myers LLP, Los Angeles,**
Case Florida Atlantic University Research Corporation vs. Acer, ASUS &
TPV, Case No. 9:12-cv-80701
Project: Expert testimony at Markman Hearings concerning scan converter
design. Expert reports and deposition testimony.
Status: Parties settled before trial.

Finnegan, Henderson, Farabow, Garrett & Dunner, LLP
Case WiLAN vs. Toshiba, Case No. 1:12-Civ-23744
Project: Expert reports & deposition testimony concerning digital television
design.
Status: Parties settled before trial.

O’Melveny & Myers LLP, Los Angeles & Akin Gump LLP, Dallas

Case Hitachi vs. TPV, Case No. 2:10-CV-260-JRG
Project: Expert reports, depositions & trial testimony (E. District Texas) concerning digital television design.
Status: Jury found no infringement of Hitachi's patents by TPV and found Hitachi's patents invalid. (Partially reversed by JMOL)

Fish & Richardson P.C. San Diego
Case Multimedia Patent Trust vs. Apple & LG, Case No. 10-cv-2618 H
Project: Expert report, & deposition testimony concerning development of technology, standards and patents for video coding.
Status: Jury found no infringement of MPT's patents and found MPT's patents invalid.

Gibson Dunn LLP, Palo Alto
Case Realtime Data vs. Verizon Wireless & T-Mobile, Case No. 6:10-cv-00493-LED
Project: Expert reports, depositions and testifying expert in jury trial (E. District Texas) concerning infringement and validity of patents related to data transmission.
Status: Jury found no infringement of Realtime Data's patents by T-Mobile, and found Realtime Data's patents invalid.

O'Melveny & Myers LLP, San Francisco
Case MobileMediaIdeas vs. Apple, Case No. 10-258-SLR
Project: Expert reports and deposition, concerning infringement and validity of patents related to MPEG Audio Layer III ("mp3") coding.
Status: Trial bifurcated.

Jones Day, Cleveland
Case Multimedia Patent Trust Vs. Vizio, Case No. 09-CV-0278-H (CAB)
Project: Expert report, concerning infringement of patents related to H.264 video coding. (Slated for deposition and jury trial)
Status: Parties settled on the day before my deposition.

Kellog, Huber, et al, Washington, DC
Case Active Video Vs. Verizon, No. 2:10-cv-00248-RAJ-FBS; 2011
Project: Expert report, deposition and testifying expert in jury trial concerning infringement of patents related to video-on-demand
Status: Jury finding of infringement with significantly reduced damages and no finding of willful infringement.

Jones Day, Washington, DC
Case Funai Vs. Vizio, et al, ITC Investigation No. 337-TA-617; 2010
Project: Expert report, deposition and testifying expert in ITC hearing concerning infringement of a patent related to ATSC broadcast standards
Status: Parties settled after the hearing following reports adverse to complainant.

Wilson Sonsini, Goodrich and Rosati, Palo Alto, CA.

Case Terayon vs. RGB Networks; 2007
Project: Expert report for defendant in a contract dispute alleging violation of a non-compete agreement.
Status: Mediation hearing resolved the dispute to the satisfaction of both parties.

Wilmer Cutler Pickering Hale and Dorr, Boston, MA

Case Qualcomm Inc. vs. Broadcom Corp. No. 05 CV 1958 B (BLM); 2007
Project: Expert report and deposition on behalf of Broadcom against assertions of infringement of patents concerning video encoding and decoding, and on Qualcomm's compliance with the policies and procedures for IPR policy in the H.264 standards committee (JVT of ITU-ISO/IEC).
Status: Broadcom found not guilty of infringing Qualcomm's patents. The patents were determined to be not essential for implementing the H.264 standard. Qualcomm found guilty of inequitable behavior in the manner of their participation in the H.264 standards committee. Qualcomm's patents held unenforceable against H.264.

Greenberg Glusker Fields Claman Machtinger & Kinsella.

Case DTS vs. MediaTek; 2005
Project: Expert report for defendant in a contract dispute related to hacking into semiconductor chips to enable functionality for which a license fee was payable.
Status: Mediation hearing resolved the dispute to the satisfaction of both parties. The Mediator personally thanked me for the clarity of my report, which covered technical, business and licensing issues.

Arvay Finley Barristers, Victoria, BC, Canada.

Case AVT Audio Visual Telecommunications vs. University of British Columbia; 2005
Project: Expert report and testimony on behalf of AVT in a contract dispute related to mobile video communication including failure to disclose intellectual property.
Status: Arbitration hearing resulted in adverse ruling to AVT.

Thelen Reid & Priest, San Jose, CA.

Case Toshiba Corp. vs. Trigem Computer Inc. & Trigem America Corp. Case No. CV-03-4558-GHK(AJWx); 2005
Project: Expert report on behalf of Trigem regarding invalidity of patents relating to video and sub-picture data in multimedia computer systems.
Status: Suspended due to insolvency of Trigem.

Morrison & Foerster LLP, San Francisco, CA.

Case	<u>Tivo Inc. vs. Echostar Communications Corp., Echostar DBS Corp., Echostar Technologies Corp., & EchoStar LLC, Case No. 2-04CV-01; 2005</u>
Project:	Expert report and deposition on behalf of Echostar against assertions of infringement of a patent concerning personal video recorders (PVR).
Status:	Adverse ruling to Echostar.
	Pinsent Curtis Biddle, Leeds, UK
Case	<u>Thomson Licensing S.A. and Deutsche Thomson Brandt GmbH vs. Pace Micro Technology PLC. Case No. HC 2000 No. 1584; 2001</u>
Project:	Expert report and slated to testify on behalf of Pace arguing invalidity of patent and defending against assertions infringement of a patent concerning interlaced video coding.
Status:	Parties agreed to settlement on the second day of trial. Settlement terms were very favorable to defendant, and shortly after the trial, Thomson joined the MPEGLA patent pool.

Education

1974	University of Sussex, England	Ph.D., Applied Sciences (EE/CS) Thesis on “Orthogonal Transform Coding of Still and Moving Pictures”. All research performed in residence at the Image Processing Institute, USC Los Angeles, CA.
1970	University of Liverpool, England	Bachelor of Engineering with Honours, Physical Electronics

Publications (Partial List)

C Reader, “Orthogonal Transform Coding of Still and Moving Pictures”, Ph.D. thesis, U. Sussex, England, 1973.

C. Reader, “Intraframe and Interframe Adaptive Transform Coding.” SPIE Vol. 66, pp. 108-117, *Efficient Transmission of Pictorial Information* (1975).

C. Reader, W.H. Chen, “Local Retransmission of Compressed Imagery Data”, SPIE Vol. 149 pp. 196-204, *Applications of Digital Image Processing* (1978).

L. Hubble, C. Reader, “State of the Art in Image Display Systems”, SPIE Vol. 199, pp 2-8, *Advances in Display Technology* (1979).

C. Reader, W. D. Flanagan, “Design Considerations for Real-Time Image Processing”, SPIE Vol. 180, *Real-Time Signal Processing II*, (1979).

C. Reader, L. Hubble, “Trends in Image Display Systems”, Proc. IEEE, Vol. 69, No. 5, pp. 606-614, (1981).

J. Adams, C. Patton, C. Reader, D. Zamora, “Hardware for Geometric Warping”, Electronic Imaging, April 1984.

Digital Image Processing Techniques (Computational Techniques), Michael P. Ekstrom (Editor), Chapter describing hardware for real-time image processing and display systems, Academic Press, 1984, pp. 289-360.

C. Reader, et al, “A New Architecture for Real-Time Image Processing,” SPIE Vol. 534, pp. 72-78, *Architectures and Algorithms for Digital Image Processing II* (1985).

B. Thacker, R. Rinaldi, C. Reader, “Multiwindow Displays of Text, Graphics and Images”, SPIE Vol. 757, pp. 104-110, *Methods of Handling and Processing Imagery* (1987).

Keynote opening speech at IEEE Conference on Image Processing, 1994.

C. Reader, “MPEG4: Coding for Content, Interactivity, and Universal Accessibility,” Optical Engineering, Vol. 35, No. 1 pp. 104-108 (1996).

C. Reader, P. Schirling, A. Puri, MPEG Tutorial paper at IEC – NCF/Infovision '97.

O. Avaro, P.A. Chou, A. Eleftheriadis, C. Herpel, C. Reader, J. Signes, “The MPEG4 Systems and Description Languages: a Way Ahead in Audio Visual Information Representation”, Signal Processing: Image Communication, Vol. 9, No. 4, pp. 385-431 (1997).

C Reader, “What MPEG-4 means to me”, Sig. Proc.: Image Comm. 9(4): 467, 1997

MPEG Video Compression Standard, Edited by Mitchell, Pennebaker, Fogg, Le Gall. Chapman & Hall, 1997. Chapter describing the process of establishing the MPEGLA patent pool, Chapter 16, *MPEG Patents*, pp.357-362.

W Gao, C Reader, F Wu, Y He, L Yu, H Lu, S Yang, T Huang, X Pan, “AVS - The Chinese Next-Generation Video Coding Standard”, Proc. NAB Conf., 1994.

C Reader, “Origins of the performance of H.264/AVC: an account of the development of H.263 and H.264 coding tools”, SPIE Vol. 5909, pp59090W-1-8 Applications of Digital Image Processing XXVIII (2005).

C Reader, “AVS Intellectual Property Rights (IPR) Policy, J. Comput. Sci. & Technol., Co. 21, No. 3 (May 2006).

Q Huang, W Gao, D Zhao, C Reader, “A Real-Time Video Deinterlacing Scheme for MPEG-2 to AVS Transcoding”, Advances in Multimedia Information Processing - PCM 2006, Vol. 4261/2006, Springer Berlin / Heidelberg.

W Gao, S Ma, C Reader, “An End-to-End Application System of AVS: AVS-IPTV in China”. PCM 2007: 50-57

C Reader, “Technical design & IPR analysis for royalty-free video codecs”. PCS 2010: 102-105

J Chen, F Xu, Y He, J D Villasenor, Y Han, Y Xu, Y Rong, C Reader, J Wen, “Efficient Video Coding Using Legacy Algorithmic Approaches”. IEEE Trans. Multimedia 14(1): 111-120 (2012)

W Gao, T Huang, C Reader, W Dou, X Chen, "IEEE Standards for Advanced Audio and Video Coding in Emerging Applications", Computer, vol.47, no. 5, pp. 81-83, May 2014.

Ma S, Huang T, Reader C, Gao W, AVS2-Making video coding smarter [Standards in a Nutshell], IEEE Signal Processing Magazine, vol. 32, no. 2, pp. 172 - 182, 2015.

Wang R, Huang T, Park S-H, Kim J-G, Jang E S, Reader C, Gao W, The MPEG Internet Video-Coding Standard [Standards in a Nutshell], IEEE Signal Processing Magazine, Vol. 33, No. 5, pp. 164-172, Sep. 2016.

Reader C, Patent Landscape for Royalty-Free Video Coding, SPIE Vol. 9971, Sep., 2016

Patents

<u>Patent Number</u>	<u>Date Issued</u>	<u>Title</u>
6,192,073	2000	Methods and apparatus for processing video data
5,845,112	2000	Method for performing dead-zone quantization in a single processor instruction.

Academic Positions

Taught “early bird” classes at Santa Clara University in Image Processing and Digital Signal Processing

Adjunct Professor of the National Engineering Laboratory for Video Technology, in the Computer Science Department at Peking University, Beijing, China.

Professional Associations and Achievements

- ISO/IEC Certificate of appreciation for development of the MPEG4 standard.
 - Senior Member IEEE.
 - Member SPIE.
 - Member ACM.
 - Member AES.
 - Member SMPTE.
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APPENDIX C

Expert Witness, CTO

Technology industry veteran with electronics/software/hardware/video/audio/data expertise.

IoT | Consumer Electronics | Telecommunications | Cable | Satellite | Broadband | Wireless

- Expert witness testimony (PTAB, ITC), technical consulting, and expert reports for renowned patent law firms such as Fish & Richardson and Banner Witcoff.
- 117 Patents and Patent publications. Served on corporate patent boards and as 30(b)(6) witness.
- Uniquely broad hardware/software/systems technical understanding.
- Award winning design and development including Best of Show, Technology Emmy, and Best of Innovations of over 100 million shipped products, responsible for \$1.3B annual revenue.
- Industries: Consumer Electronics, Cable, Satellite, Internet of Things (IoT), Telematics, Smart Truck Logistics, Transportation, Alarm Systems, Smart Tank monitoring & fulfillment, Smart Home, Television, Telecommunications, Video, Audio, Wireless, Broadband, OTT Video, IPTV, Payments
- Technical: hardware design, software design, systems design, mechanical design, embedded systems, cloud computing, AWS, Azure, Oracle Cloud Infrastructure (OCI), SaaS, edge computing, high speed digital, C, Java, Python, Linux, mobile applications (iOS, Android, cross-platform), web applications (Java, JavaScript, HTML), firmware, RTOS, user interfaces, UI/UX, video, audio, data, RF, DSP, communications, cybersecurity, encryption, error correction coding, real-time systems, cable, CATV, DOCSIS, broadband, satellite, satcom, IPTV, OTT video, video streaming, image processing, wireless, cellular, 3G, 4G, LTE, LTE-M, 5G, NB-IoT, Cat-M1, WiFi, ZigBee, Z-Wave, Bluetooth, BLE, LoRa, Internet of Things (IoT), IIoT, sensors, Machine-to-Machine (M2M), Telematics, AI, ML, networks, payments, consumer electronics, and telecommunications.

EXPERIENCE

Nov. 2016-present, **Expert Witness/CTO**, Independent Consultant

Technology, product development, organizational, & intellectual property consulting

- Expert Witness Reports and Testimony - Declarations, Opinions, PTAB Inter Partes Review (IPR) Petitions and Defense, Depositions
- Intellectual Property/Patent assistance, prosecution/defense strategy, search
- Technical Consulting

Jul. 2019 – June 2022, **Chief Technology Officer (CTO)**, **Telular**, an Ametek Company, Greater Atlanta Area

- Responsible for global engineering, corporate technical strategy, and technical representation.
- Developed SaaS, mobile, and hardware products for Industrial IoT (IIoT) businesses including transportation, tank monitoring, petroleum logistics, and facility alarm monitoring with 1.4M+ subscribers, sold under the SkyBitz and Telguard brands.
- Led the development of an IoT Toolkit (scalable platform and APIs) to extend the Telular IoT platform for all 60+ (and growing) AMETEK companies, enabling development of high- value IIoT recurring revenue web and mobile applications.
- SaaS, Cellular, 3G, 4G, LTE, LTE-M, 5G, NB-IoT, Cat-M1, BLE, Satellite, cloud, distributed systems, Azure, Oracle Cloud, IoT, telematics, AI, ML, M2M, hardware, GPS, solar, low-power design, broadband, firmware, software, systems, architecture, video, image processing, mobile apps, web apps.

Aug. 2011 – Oct. 2016, **Vice President of Engineering, Head of the Atlanta R & D Center, EchoStar Technologies**, Greater Atlanta Area (\$3B revenue, Engineering for Dish Network with a common controlling stockholder)

- Developed products for Dish Network and international customers including highest volume set-top boxes, H.265, HEVC, 3D, Satellite, MoCA, transcoding, Embedded C Linux applications, mobile applications (iOS and Android), SaaS, and web applications (Javascript, HTML). Provided product lifecycle support of contract manufacturers, test methodologies, customer service, QA, marketing, and sales.

- Led the architecture and global development of a huge end-to-end secure IoT cloud/fog/edge Platform for the consumer security & smart home market and other adjacent markets. Established the unique TV and mobile UI and MyLocal911 patented self-monitored security paradigm. System architecture consisted of 32 cloud systems and 24 CPE products. Systems included BSS/OSS, AWS cloud storage, 2-way video/audio streaming, authentication, provisioning, software download, command and control, customer service, online storefront, 911 emergency VoIP, logistics, CPE, and mobile applications. Represented the platform at trade shows.
- Functioned as a general manager in roles and responsibilities including vision, operations, business results, product management, program management, complex projects and services, hardware/software/systems product development of video, Internet of Things (IoT), and mobile application products.
- **Winner of the prestigious Best of Show award at the 2013 CES for the Hopper** because of the Hopper Transfers functionality and mobile applications.
- **Won 2015 CSI award “Best smart home product, technology or service”.**

Aug. 1990 – July 2011, **Vice President of Engineering, Cisco / Scientific Atlanta**, Greater Atlanta Area (\$35B / \$1.9B revenue companies respectively. Cisco acquired Scientific Atlanta Feb. 2006)

- Intellectual property – served on the corporate patent board, provided patent assistance, and testified in patent litigation cases including as a 30(b)(6) witness representing the corporation.
- Responsible for the hardware/firmware/software/mechanical/systems/architecture/ASIC requirements design and development of several generations of high volume set top boxes and other products with extensive data communications and multimedia capabilities and advanced features including DOCSIS 1/2/3 and hybrid gateways, 802.11, IPTV, DVR, cable modems, ADSL, VDSL, DVB-T/C/S, bootloaders, factory diagnostics, application frameworks, Nagra, DRMs, conditional access, secure microprocessors, device management, Android, Adobe Flash, Linux, DVD play/record, MPEG-4, MPEG-2, H.264, NTSC, PAL, DAVIC, MoCA, high-performance CPUs, cablecards, network processors, HDMI, multiple video/audio display interfaces, 2D/3D graphics, multiple RF tuners, and full spectrum tuners.
- Products developed supported worldwide video, audio, power supply, and regulatory standards.
- Developed products manufactured in company factories, contract manufacturers (CMs), Original Design Manufacturers (ODMs), and Joint Design Manufacturers (JDMs).
- Developed processes and practices to ensure success in high quality, high volume, low cost, and fast time-to-market product development.
- Architected Video-On-Demand (VOD) systems.
- Architected robust software download system to ensure network disaster recovery to avoid truck rolls. Received some of the **industries’ first downloadable software patents and an electronic program guide patent**. Developed the downloadable software system, enabling the applications software development business which evolved into a major corporate strategic business objective.
- Responsible for the total value proposition strategy internally in the organization through process design and externally facing customers to propose innovative solutions that add value and differentiate our offering.
- Established and managed department capex and opex budgets and manpower planning.
- Achieved unprecedented 3%/qtr product cost reductions for all products during the product lifecycle.
- Highly reliable products never had a field recall, which would have been disastrous to the business due to truck roll costs.
- Established software development department and software development practices including software processes, code reviews, networked version control and defect tracking, unit test teams, coding standards, and release processes.
- Reduced product development time to market for set top boxes from 14 months to 6 months through continuous process improvement
- Scaled organization from supporting \$10M to \$1.3B in sales
- Accounted for more than **70% of the revenues for Cisco’s Service Provider Video Technology Group and for Scientific Atlanta Corporation**.
- Award winning design and development of over 100 million shipped products
- **Winner of Technology Emmy in 2012 for Pioneering Development of Multi-Room DVR.**

- **Winner of 2006 CES "Best of Innovations" award for DVR/DVD Recorder/Player.**
- **Winner of Motorola/EE Times Excellence in Innovation Award** in 1994.

Nov. 1985 - July 1990, **Hardware Engineering Manager / Senior Engineer, Wegener Communications, Inc.,** Greater Atlanta Area

- Managed product development of video, audio, and data satellite receivers, modulators, graphics display systems, DSP-based companders, FSK and PSK satellite modems, multiplexers, forward error correction (FEC) codecs, RF upconverters and downconverters, and baseband analog and digital processing components. Disciplines managed included hardware, ASICs, FPGAs, RF, digital, microprocessors, analog, mechanical, and embedded software.
- Architected and designed forward error correction (FEC) coding systems, PSK modems, and analog control systems for RF modulators and PSK demodulators.

Mar. 1983 - June 1985 (while working at Scientific Atlanta), Assistant Professor, **DeVry Institute of Technology,** Greater Atlanta Area

- Taught evening school courses in microprocessor hardware/software and Electronics

June 1982 – Oct. 1985, **Scientific-Atlanta, Engineer II/Engineer I,** Greater Atlanta Area

- Designed software and hardware including addressable data transmitters, video sync suppression scramblers, transaction format converters, and data channel monitors for addressable Cable Television systems and Set Top Boxes.

EDUCATION

- MSEE course work in Electrical Engineering, Georgia Institute of Technology, Atlanta, Georgia
- BSEE, University of Tennessee, Knoxville, Tennessee, with High Honors. Specialization in Computer Engineering. GPA: 3.53/4.00.
- Georgia Institute of Technology Scrum Leadership Certificate, Certified Scrum Master (CSM), Certified Scrum Product Owner (CSPO), Certified Large Scale Scrum (LeSS) Practitioner
- Many short courses in business and engineering.