IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of:	Nakamura et al.	
U.S. Patent No.:	8,139,150	Attorney Docket No.: 39843-0169IP1
Issue Date:	March 20, 2012	
Appl. Serial No.:	11/907,188	
Filing Date:	October 10, 2007	
Title:	METHOD AND APPARATUS FOR ENCODING AND DECODING MULTI-VIEW VIDEO SIGNAL, AND RELATED COMPUTER PROGRAMS	

DECLARATION OF JUNE ANN MUNFORD

SAMSUNG 1017

1. My name is June Ann Munford. I am over the age of 18, have personal knowledge of the facts set forth herein, and am competent to testify to the same.

2. I earned a Master of Library and Information Science (MLIS) degree from the University of Wisconsin-Milwaukee in 2009. I have over ten years of experience in the library/information science field. Beginning in 2004, I have served in various positions in the public library sector including Assistant Librarian, Youth Services Librarian and Library Director. I have attached my Curriculum Vitae as Appendix CV.

3. During my career in the library profession, I have been responsible for materials acquisition for multiple libraries. In that position, I have cataloged, purchased and processed incoming library works. That includes purchasing materials directly from vendors, recording publishing data from the material in question, creating detailed material records for library catalogs and physically preparing that material for circulation. In addition to my experience in acquisitions, I was also responsible for analyzing large collections of library materials, tailoring library records for optimal catalog search performance and creating lending agreements between libraries during my time as a Library Director.

4. I am fully familiar with the catalog record creation process in the library sector. In preparing a material for public availability, a library catalog record describing that material would be created. These records are typically written in Machine Readable Catalog (herein referred to as “MARC”) code and contain information such as a physical description of the material, metadata from the material’s publisher, and date of library acquisition. Library catalog software is used to organize this data into a format conducive for library patrons to interact with the library’s collection. Library catalog software ordinarily indexes MARC records on a field-by-field level, providing users with robust search capabilities via search features that function similarly to popular search engines. Common search features include the ability to search by title, author, topic, publisher, subject or ISBN as well as the ability to filter results by fields such as format or year of publication.

5. The 008 field of the MARC record is reserved for denoting the date of creation of the library record itself. As this typically occurs during the process of preparing materials for public access, it is my experience that an item’s MARC record indicates the date of an item’s public availability.

6. Typically, in creating a MARC record, a librarian would gather various bits of metadata such as book title, publisher and subject headings among others and assign each value to a relevant numerical field. For example, a book's physical description is tracked in field 300 while title/attribution is tracked in field 245. The 008 field of the MARC record is reserved for denoting the creation of the library record itself. As this is the only date reflecting the inclusion of said materials within the library's collection, it is my experience that an item's 008 field accurately indicates the date of an item's public availability.

7. I have reviewed Exhibit 1013, "Multiviewpoint Video Coding with MPEG-2 Compatibility" by Belle L. Tseng and Dimitris Anastassiou as published in *IEEE Transactions on Circuits and Systems for Video Technology*, August 1996.

8. Attached hereto as Appendix TSENG01 is a true and correct copy of the MARC record for *IEEE Transactions on Circuits and Systems for Video Technology* as held by the Penn State University library. I secured this record myself from the library's public catalog. The MARC record contained within Appendix TSENG01 accurately describes the title, author, publisher, and ISSN number of *IEEE Transactions on Circuits and Systems*

for Video Technology. The ‘Availability’ field of this record visible on page 3 indicates this collection includes the April 1996 edition of *IEEE Transactions on Circuits and Systems for Video Technology* containing “Multiviewpoint Video Coding with MPEG-2 Compatibility” by Belle L. Tseng and Dimitris Anastassiou.

9. Attached hereto as Appendix TSENG02 is a true and correct copy of “Multiviewpoint Video Coding with MPEG-2 Compatibility” as published in *IEEE Transactions on Circuits and Systems for Video Technology* as held by the Penn State University library. I secured these scans myself from the library’s collection. Page 4 of Appendix TSENG02 features a stamp reading ‘SHELVED IN BOUND PERIODICAL COLLECTION’, indicating Penn State University intended to include this journal within its publicly accessible library collection. In comparing Exhibit 1013 to Appendix TSENG02, it is my determination that Exhibit 1013 is a true and correct copy of “Multiviewpoint Video Coding with MPEG-2 Compatibility” by Belle L. Tseng and Dimitris Anastassiou as published in *IEEE Transactions on Circuits and Systems for Video Technology* August 1996.

10. The 008 field of the MARC record in Appendix TSENG01 indicates the date of record creation. The 008 field of Appendix TSENG01 indicates the Penn

State University library first acquired this journal as of May 15, 1991 and held the journal in perpetuity through at least October 2006. Page 5 of Appendix TSENG02, a cover page for the August 1996 edition, features a stamp reading 'Received AUG 15 1996 PENNSYLVANIA STATE UNIVERSITY LIBRARIES'. Considering these dates, it is my determination that *IEEE Transactions on Circuits and Systems for Video Technology* August 1996 and therefore "Multiviewpoint Video Coding with MPEG-2 Compatibility" was made available to the public at the Penn State University Library shortly after its initial acquisition in August 1996.

11. Attached hereto as Appendix KANADE01 is an IEEE website describing a paper entitled," "Virtualized Reality: Constructing Virtual Worlds from Real Scenes", published in *IEEE MultiMedia* January-March 1997 alongside a PDF copy of the paper itself. I secured these screen captures from the publisher's website, which can be found at https://www.computer.org/csdl/magazine/mu/1997/01/u1034/13rRUx0xPF9. Page 16 of Appendix KANADE01 contains a citation of "Multiviewpoint Video Coding with MPEG-2 Compatibility", indicating the Tseng paper's wider public availability as of early 1997.

12. Attached hereto as Appendix OHM01 is an SPIE website describing a paper entitled “Stereo/Multiview Video Encoding Using the MPEG Family of Standards”, published in *SPIE Proceedings Volume 3639, Stereoscopic Displays and Virtual Reality Systems VI* alongside a PDF copy of the paper itself. I secured these screen captures from the publisher’s website, which can be found at https://www.spiedigitallibrary.org/conference-proceedings-of-spie/3639/1/Stereomultiview-video-encoding-using-the-MPEG-family-of-standards/10.1117/12.349385.short?SSO=1. Page 1 of Appendix OHM01 indicates these *SPIE Proceedings* were published as of May 24, 1999. Page 16 of Appendix OHM01 contains a citation of “Multiviewpoint Video Coding with MPEG-2 Compatibility”, indicating the Tseng paper’s wider public availability as of Spring 1999.

13. Attached hereto as Appendix GUO01 is an IEEE website describing a paper entitled “Inter-View Direct Mode for Multiview Video Coding”, published in *IEEE Transactions on Circuits and Systems for Video Technology*, December 2006 alongside a PDF copy of the paper itself. I secured these screen captures from the publisher’s website, which can be found at https://ieeexplore.ieee.org/document/4016102/citations#citations. Page 1 of Appendix GUO01 indicates this volume of *IEEE Transactions on Circuits and Systems for Video Technology* was published as of November 30, 2006.

Page 12 of Appendix GUO01 contains a citation of "Multiviewpoint Video Coding with MPEG-2 Compatibility", indicating the Tseng paper's wider public availability as of Winter 2006.

14. Appendices KANADE01, OHM01 and GUO01 each indicate a broad public availability for "Multiviewpoint Video Coding with MPEG-2 Compatibility" after its publication in 1996. Considering these citations alongside the Penn State University's holdings, it is my determination that Tseng was publicly accessible and disseminated around August 1996 and certainly long before October 2006.

15. I have reviewed Exhibit 1006, *ITU-T H.262: Information Technology – Generic Coding of Moving Pictures and Associated Audio Information* by The International Telecommunication Union, 02/2000 edition.

16. Attached hereto as Appendix ITU01 is a screen capture of an ITU website describing *ITU-T H.262: Information Technology – Generic Coding of Moving Pictures and Associated Audio Information* as well as a PDF copy of that standard. I secured this appendix from the ITU's website at https://www.itu.int/itu-t/recommendations/rec.aspx?rec=11627. In comparing Exhibit 1006 to ITU01, it is my determination that Exhibit 1006

is a true and correct copy of *ITU-T H.262: Information Technology – Generic Coding of Moving Pictures and Associated Audio Information.* Both Exhibit 1006 and Appendix ITU01 bear a date of 02/2000 on their title pages and each contain a passage summarizing the paper which reads 'ITU-T Recommendation H.262 was approved on 17 February 2000. The identical text is also published as ISO/IEC International Standard 13818-2.'

17. Attached hereto as Appendix ITU02 is a true and correct copy of the MARC record for *ITU-T Recommendations on DVD-ROM* as held by the University of Maryland, Baltimore County library. I secured this record myself from the library's public catalog. The MARC record contained within Appendix ITU02 accurately describes the title, author, publisher, and ISBN number of *ITU-T Recommendations on DVD-ROM*. Based upon the 'notes' field visible on page 3 of Appendix ITU02, the University of Maryland, Baltimore County library's collection contains a copy of the September 2004 edition of this DVD.

18. Attached hereto as Appendix ITU03 are photos of the September 2004 edition of *ITU-T Recommendations on DVD-ROM* as held by the University of Maryland, Baltimore County library. These photos were provided to me

by reference staff at the University of Maryland, Baltimore County upon request. In comparing Appendix ITU02 to Appendix ITU03, it is my determination that the University of Maryland, Baltimore County library's copy of the September 2004 edition is a true and correct copy of *ITU-T Recommendations on DVD-ROM* by The International Telecommunication Union.

19. The 008 field of the MARC record in Appendix ITU02 indicates the date of record creation. The 008 field of Appendix ITU02 indicates the University of Maryland, Baltimore County library first acquired this book as of November 17, 2004. Considering this information, it is my determination that *ITU-T Recommendations on DVD-ROM* September 2004 edition was made available to the public shortly after its initial acquisition as of November 2004.

20. Attached hereto as Appendix ITU04 is a PDF file downloaded from The International Telecommunication Union website at https://www.itu.int/itudoc/gs/itutcd/86730.pdf. Appendix ITU04 is the table of contents for the September 2004 edition of *ITU-T Recommendations on DVD-ROM*, referred to as *ITU-T Recommendations on CD-ROM* as well.

Page 37 of Appendix ITU04 indicates that this compilation includes *ITU-T H.262: Information Technology – Generic Coding of Moving Pictures and Associated Audio Information* by The International Telecommunication Union, 02/2000 edition as well as amendments and errata related to that standard.

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

library recordskeeping practices such as MARC records, OCLC records and Dublin Core.

22. Attached hereto as Appendix ITU05 is a screen capture of the Internet Archive Wayback Machine entry for http://www.itu.int/publications/main_publ/itut.html. I secured these screen captures myself from http://web.archive.org/web/20230000000000*/http://www.itu.int/publications/main_publ/itut.html. This record contains a capture of the ITU website entitled 'ITU-T Recommendations', hosted by the ITU as of September 29, 2004. This page contains a description of the September 2004 edition of *ITU-T Recommendations on DVD-ROM.* According to page 4 of this appendix, the September 2004 edition of this standards collection contains all ITU-T recommendations alongside a search function. Page 4 of this appendix also indicates that this collection was regularly published as a CD-ROM until June 2004 as the size of the standard collection necessitated change in format to DVD – explaining any incongruities between disc titles present in Appendix ITU04. Page 4 also includes information on purchasing a single edition of this DVD, subscribing to an annual edition of this DVD and contains links to purchase via the ITU website store. Page 5 of this

document indicates that individual recommendations such as *ITU-T H.262: Information Technology – Generic Coding of Moving Pictures and Associated Audio Information* were also purchasable as a paper edition or digital PDF.

23. Attached hereto as Appendix ITU06 is a PDF file downloaded from the ITU website at https://www.itu.int/itudoc/gs/subscirc/itu-t/(197-04).pdf. This file is entitled "Publication Notice No. 197-04-Rev-04" and contains a description of *ITU-T Recommendations on DVD-ROM* – March, June, September and December 2004 editions. This publication notice is dated October 28, 2004 and page 1 of this document indicates that the September 2004 edition among others contains the current ITU-T Recommendations in full, which would include *ITU-T H.262: Information Technology – Generic Coding of Moving Pictures and Associated Audio Information*. Page 4 of this document includes a full order form for *ITU-T Recommendations on DVD-ROM*, indicating that ITU had intended to make these standards available via purchase as of October 28, 2004 if not earlier.

24. Attached hereto as Appendix PATENT01 is a disclosure statement submitted to the United States Patent and Trademark Office by Yuichi

Onami in U.S. Application Serial No. 10/659,393, which was obtained from the USPTO's Patent Center. Page 2 of this document indicates this disclosure statement was submitted as of March 7, 2005. Page 5 of this document directly references *ITU-T H.262: Information Technology – Generic Coding of Moving Pictures and Associated Audio Information*, indicating the standard's public availability as of March 7, 2005.

25. Attached hereto as Appendix PATENT02 is a disclosure statement submitted to the United States Patent and Trademark Office by John Sievers in U.S. Application Serial No. 10/798,519, which was obtained from the USPTO's Patent Center. Page 1 of this document indicates this disclosure statement was submitted as of June 14, 2004. Page 4 of this document directly references *ITU-T H.262: Information Technology – Generic Coding of Moving Pictures and Associated Audio Information*, indicating the standard's availability as of June 2004.

26. Appendix ITU02 indicates that the University of Maryland, Baltimore County library first secured *ITU-T Recommendations on DVD-ROM* as of November 17, 2004 and Appendix ITU03 confirms that their collection includes the September 2004 edition of this DVD-ROM. Appendix ITU04 indicates the September 2004 edition contains *ITU-T H.262: Information*

Technology – Generic Coding of Moving Pictures and Associated Audio Information. Appendix ITU05 and ITU06 both indicate The International Telecommunication Union solicited this September 2004 edition of *ITU-T Recommendations on DVD-ROM* for purchase as of October 2004 and also indicates this compiled edition includes all ITU recommendations including *ITU-T H.262: Information Technology – Generic Coding of Moving Pictures and Associated Audio Information*. Appendices PATENT01 and PATENT02 feature submission dates of March 2005 and June 2004, respectively. As such it is my determination that *ITU-T H.262: Information Technology – Generic Coding of Moving Pictures and Associated Audio Information* was made available to the public via *ITU-T Recommendations on DVD-ROM September 2004* and other sources as early as June 2004 and certainly no later than November 2004. Given the previous editions of *ITU-T Recommendations on CD-ROM* and *H.262*'s date of institution in 2000, it is likely that *ITU-T H.262: Information Technology – Generic Coding of Moving Pictures and Associated Audio Information* was available to the public prior to September 2004 via similar access methods.

27. I have been retained on behalf of the Petitioner to provide assistance in the above-illustrated matter in establishing the authenticity and public

availability of the documents discussed in this declaration. I am being compensated for my services in this matter at the rate of $200.00 per hour plus reasonable expenses. My statements are objective, and my compensation does not depend on the outcome of this matter.

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

Dated: 12/1/2023



June Ann Munford

APPENDIX CV

June A. Munford
Curriculum Vitae

Education

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

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

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

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

Professional Experience

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

- Material authentication and public accessibility determination. Declarations of authenticity and/or public accessibility provided upon research completion. Experienced with appeals and deposition process.

- Research provided on topics of public library operations, material publication history, digital database services and legacy web resources.

- Past clients include Alston & Bird, Arnold & Porter, Baker Botts, Fish & Richardson, Erise IP, Irell & Manella, O'Melveny & Myers, Perkins-Coie, Pillsbury Winthrop Shaw Pittman and Slayden Grubert Beard.

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

- Executive administrator of the Dowagiac District Library. Located in

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

● Developed careful budgeting guidelines to produce a 15% surplus during the 2013-2014 & 2014-2015 fiscal years while being audited.

● Using this budget surplus, oversaw significant library investments including the purchase of property for a future building site, demolition of existing buildings and building renovation projects on the current facility.

● Led the organization and digitization of the library's archival records.

● Served as the public representative for the library, developing business relationships with local school, museum and tribal government entities.

● Developed an objective-based analysis system for measuring library services - including a full collection analysis of the library's 50,000+ circulating items and their records.

November 2010 - January 2013
Librarian & Branch Manager, Anchorage Public Library ● Anchorage, Alaska

● Headed the 2013 Anchorage Reads community reading campaign including event planning, staging public performances and creating marketing materials for mass distribution.

● Co-led the social media department of the library's marketing team, drafting social media guidelines, creating original content and instituting long-term planning via content calendars.

● Developed business relationships with The Boys & Girls Club, Anchorage School District and the US Army to establish summer reading programs for children.

June 2004 - September 2005, September 2006 - October 2013
Library Assistant, Hart Area Public Library
Hart, MI

● Responsible for verifying imported MARC records and original MARC

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

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

Professional Involvement

Alaska Library Association - Anchorage Chapter
- Treasurer, 2012

Library Of Michigan
- Level VII Certification, 2008
- Level II Certification, 2013

Michigan Library Association Annual Conference 2014
- New Directors Conference Panel Member

Southwest Michigan Library Cooperative
- Represented the Dowagiac District Library, 2013-2015

Professional Development

Library Of Michigan Beginning Workshop, May 2008
Petoskey, MI
- Received training in cataloging, local history, collection management, children's literacy and reference service.

Public Library Association Intensive Library Management Training, October 2011
Nashville, TN
- Attended a five-day workshop focused on strategic planning, staff management, statistical analysis, collections and cataloging theory.

Alaska Library Association Annual Conference 2012 - Fairbanks, February 2012
Fairbanks, AK
- Attended seminars on EBSCO advanced search methods, budgeting, cataloging, database usage and marketing.

Depositions

2019 ● Fish & Richardson

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

2019 ● Erise IP

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

2019 ● Perkins-Coie

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

2020 ● O'Melveny & Myers

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

2021 ● Pillsbury Winthrop Shaw Pittman LLP

Intel v. SRC (IPR2020-1449)

2022 ● Perkins-Coie

Realtek v. Future Link (IPR2021-01182)

2023 ● Fish & Richardson

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

2023 ● Fish & Richardson

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

Limited Case History & Potential Conflicts

Alston & Bird

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

Arnold & Porter

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

Benesch Friedlander Coplan & Aronoff

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

Erise I.P.

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

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

Fish & Richardson

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

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

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

Irell & Manella

- Curium

O'Melveny & Myers

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

Perkins-Coie

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

- Twitter Inc

  v. VOIP-Pal.com (Case No. 3:20-cv-02397-JD)

- TCL Industries

  v. Koninklijke Philips NV (IPR2021-00495, IPR2021-00496 and IPR2021-00497)

Pillsbury Winthrop Shaw Pittman

- Intel

  v. FG SRC LLC (Case No. 6:20-cv-00315)

- Gravel Rating Systems

  v. Costco (Case No. 4:21-cv-149)
  v. Lowe's Home Centers (Case No. 4:21-cv-150)
  v. T-Mobile USA (Case No. 4:21-cv-152)
  v. Kohl's Inc. (Case No. 4:21-cv-258)
  v. Under Armor (Case No. 4:21-cv-356)

APPENDIX GUO01

screenshot-ieeexplore.ieee.org-2023.11.30-12_00_51
https://ieeexplore.ieee.org/document/4016102/citations#citations
30.11.2023

Inter-View Direct Mode for Multiview Video Coding

Publisher: IEEE Cite This PDF

Xun Guo ; Yan Lu ; Feng Wu ; Wen Gao All Authors

31 Cites in Papers | 39 Cites in Patents | 403 Full Text Views

Abstract
Document Sections
I. Introduction
II. Inter-View Motion Model
III. Inter-View Direct Mode
IV. Experimental Results
V. Conclusions
Authors
Figures
References
Citations
Keywords
Metrics

Abstract:
Global disparity between views is usually caused by the displacement between cameras, which can be accurately represented by a global geometric transformation. In this paper, we first propose an inter-view motion model in terms of the global geometric transformation to represent the motion correlation between two adjacent views. Specifically, the motion vector of a pixel in one view may be directly derived from that in another view according to the inter-view motion model. Further, we propose an inter-view direct mode to signal the decoder that the motion of a macroblock (MB) can be achieved from the coded view without any coding bits. The proposed inter-view direct mode is further incorporated in the existing multiview video coding (MVC) schemes (i.e., AVC-based MVC and 4-D wavelet-based MVC), working together with the other classical coding modes. The mode selection at each MB is accomplished with the rate-distortion optimization technique. The proposed inter-view direct mode can significantly reduce bits to code motion vectors especially at low bit rates, thus improving the coding efficiency

Published in: IEEE Transactions on Circuits and Systems for Video Technology (Volume: 16 , Issue: 12, December 2006)

Page(s): 1527 - 1532

INSPEC Accession Number: 9207501

Date of Publication: 30 November 2006

DOI: 10.1109/TCSVT.2006.885724

Publisher: IEEE

ISSN Information:

I. Introduction

In modern video coding schemes, motion prediction is becoming more and more accurate for better coding efficiency. For example in MPEG-4 AVC/H.264 standard [1], a macroblock (MB) in P-picture may have up to 16 different motion vectors, while an MB in B-picture may even have up to 32 different motion vectors in the case of bidirectional prediction. However, it also implied that many bits have to be assigned to code these motion vectors. A[illegible]y efficiently coded, considering that they are differentially coded compared to a motion vector predictor

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Joint Optimization of Transform and Quantization for High Efficiency Video Coding
IEEE Access
Published: 2019

Motion optimized spatial-temporal video coding based on wavelet transform
Conference Record of the Thirty-Eighth Asilomar Conference on Signals, Systems and Computers, 2004.
Published: 2004

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Figures

References

Citations

By Papers | By Patents

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Cites in Papers - IEEE (18) | Other Publishers (13)

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Show Article Google Scholar

2. Ranjit Reddy Bayyapu, Ramana Reddy Patil, "A novel selection of inter-view reference frame based on the direction of motion", *2017 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET)*, pp.2566-2569, 2017.
Show Article Google Scholar

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Inter-View Direct Mode for Multiview Video Coding

Xun Guo, Yan Lu, Feng Wu, *Senior Member, IEEE*, and Wen Gao

***Abstract*—Global disparity between views is usually caused by the displacement between cameras, which can be accurately represented by a global geometric transformation. In this paper, we first propose an inter-view motion model in terms of the global geometric transformation to represent the motion correlation between two adjacent views. Specifically, the motion vector of a pixel in one view may be directly derived from that in another view according to the inter-view motion model. Further, we propose an inter-view direct mode to signal the decoder that the motion of a macroblock (MB) can be achieved from the coded view without any coding bits. The proposed inter-view direct mode is further incorporated in the existing multiview video coding (MVC) schemes (i.e., AVC-based MVC and 4-D wavelet-based MVC), working together with the other classical coding modes. The mode selection at each MB is accomplished with the rate-distortion optimization technique. The proposed inter-view direct mode can significantly reduce bits to code motion vectors especially at low bit rates, thus improving the coding efficiency.**

***Index Terms*—Direct mode, inter-view correlation, motion vector prediction, multiview video coding (MVC).**

I. Introduction

In MODERN video coding schemes, motion prediction is becoming more and more accurate for better coding efficiency. For example in MPEG-4 AVC/H.264 standard [1], a macroblock (MB) in P-picture may have up to 16 different motion vectors, while an MB in B-picture may even have up to 32 different motion vectors in the case of bidirectional prediction. However, it also implied that many bits have to be assigned to code these motion vectors. Although motion vectors are relatively efficiently coded considering that they are differentially coded compared to a motion vector predictor, taken as the median value of the motion vectors of the spatially adjacent blocks, MPEG-4 AVC/H.264 standard still introduces two direct modes: SKIP and DIRECT within P- and B-pictures respectively, for a further reduction to the amount of bits for coding motion vectors [2].

SKIP mode assumes that the current MB has motion vectors equal to the median predictor. Furthermore, no residual information is transmitted for a SKIP MB. DIRECT mode can infer motion in either spatial or temporal prediction. Spatial prediction for DIRECT MBs is relatively similar to that of SKIP MBs although in this case up to two different motion vectors are needed for bidirectional prediction. In the temporal prediction, motion is inferred through the consideration of motion data in previously decoded pictures and is based on the assumption that an object is moving with relatively constant speed. In this case motion vectors are derived by temporally interpolating the motion vectors of a co-located MB in the forward reference.

SKIP and DIRECT modes are also applicable in multiview video coding (MVC). Some MVC schemes based on H.264 have been proposed in [3]–[5], by virtue that the existing multiple reference structure in the standard can be borrowed to alternatively utilize motion-compensated prediction (MCP) and disparity-compensated prediction (DCP). Recently, MPEG has started the MVC standardization process. Accordingly, a number of MVC techniques have been proposed to MPEG [6]–[8]. In particular, an AVC-based MVC scheme with hierarchical B-prediction structure and inter-view texture prediction is developed in [6]. It has been selected as the reference solution in the forthcoming core experiments in MPEG 3-DAV group. Besides the investigation on AVC-based MVC schemes, several efforts have been invested in developing high dimensional wavelet coding for multiview video [9], where temporal and view filters replace MCP and DCP, respectively. These filters also need precise motion vectors between frames and between views so that the wavelet decomposition along motion trajectories can result in high energy-compacted sub-bands.

Then, a question arises here. Besides the traditional SKIP and DIRCT modes, do we have more efficient way to compress motion vectors in the MVC? The common idea in most of the investigations on MVC is how to efficiently exploit the correlations between adjacent views for pixel prediction [10], [11]. It enlightens us whether the view correlation can be also used to code the motion vectors. As we know, the disparity between views is caused by the locations and angles of two cameras. It can be accurately represented by a global geometric model. When the motion vectors in one view have been estimated and coded, the motion vectors in another view should be able to be derived from that in the coded view through a certain model supposing only simple local motion exists in the video.

Upon the above idea, in this paper we propose an inter-view motion model to describe the motion correlations between video sequences from different views, based on which the motion vector of a pixel in a view is directly calculated from that of a coded view. Since pixels are usually processed at MB unit in video coding schemes, we further propose an inter-view direct mode to signal the decoder that motion vectors of a MB can be generated from the coded view without any coding bits. The proposed mode is also applicable in MVC schemes containing the classical coding modes. Furthermore, we have incorporated the view direct mode into the AVC-based MVC scheme in [6] and the 4-D wavelet-based MVC scheme in [9], respectively. Both schemes demonstrate the advantages of the proposed technology.

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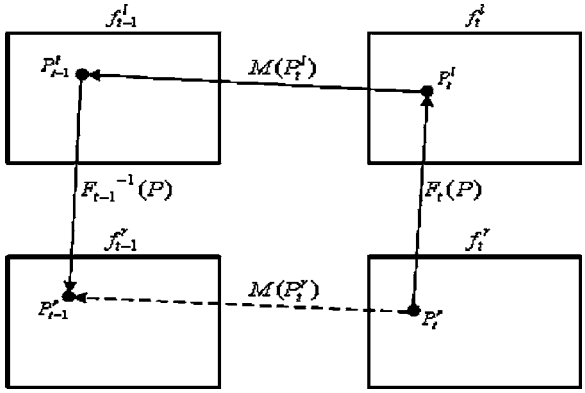


Fig. 1. Geometric relationship of pixels and motion vectors in two views.

The rest of this paper is organized as follows. Section II presents the inter-view motion model to derive the motion of a view from that of a coded view. Section III discusses the proposed inter-view direct mode and its applications in the MVC schemes. In Section IV, experimental results are given. Finally, Section V concludes this paper.

II. Inter-View Motion Model

In this section, we will model the relationship between the temporal motions at different views based on a geometric model. The motion of an object usually indicates the displacement of the object in two successive frames, which can be represented by such motion models as the block-based translational model with pixel matching between the two frames. Moreover, we know that a pair of frames at the same time instant but from different views also corresponds to the same content. Similar to the motion model, the disparity model is used to indicate the displacement of an object in two view frames. Therefore, it is possible to find all corresponding pixels with respect to the same content in both temporally and view neighboring frames. Intuitively, we can deduce the inter-view motion correlation based on the pixel mapping along both temporal and view directions.

We take the case of two-view video sequences (i.e., the stereoscopic video) as an example to describe the proposed inter-view motion model. Above all, we define some notations as used in Fig. 1. Let f_t^v, $v \in \{l, r\}$, represent the frame at time t in view v, and hence f_t^l and f_t^r indicate a stereo pair at time t. We assume that the temporal motion of every pixel in the view l is already known. Now the problem is how to derive the temporal motion of every pixel in the view r. In this paper, we still employ the translational model to represent the temporal motion because it has been extensively used in existing hybrid video coding schemes. Let $P_t^r = (x, y)^T$ represent the location of one pixel in f_t^r, and let P_t^l, P_{t-1}^r and P_{t-1}^l represent the locations of its corresponding pixels in f_t^l, f_{t-1}^r and f_{t-1}^l, respectively. As shown in Fig. 1, $M\left(P_t^l\right)$ denotes the motion vector of P_t^l in f_t^l pointing to P_{t-1}^l in f_{t-1}^l, i.e., $M\left(P_t^l\right) = P_{t-1}^l - P_t^l$. Then, the problem becomes how to derive $M\left(P_t^r\right)$ from $M\left(P_t^l\right)$, i.e., the motion vector of P_t^r in f_t^r.

Towards the above goal, we also need get the disparity-based pixel mapping in the stereo pair. Let $F_t(P)$ indicate the mapping of pixel P from f_t^r to f_t^l. It is well known that the disparity is usually very compact and can be represented by several global disparity models [12], [13]. In this paper, we employ the six-parameter affine transformation to represent the global disparity. Therefore, we define $F_t(P)$ as

$$F_t(P) = A_t P + C_t \tag{1}$$

where

$$A_t = \begin{pmatrix} a_{1,t} & a_{2,t} \\ b_{1,t} & b_{2,t} \end{pmatrix} \text{ and } C_t = \begin{pmatrix} c_{1,t} \\ c_{2,t} \end{pmatrix}. \tag{2}$$

Here A_t is a 2×2 transform matrix and C_t is an offset vector. Given the pixel P_t^r in f_t^r, we can get its corresponding pixel P_t^l in f_t^l through the above affine transformation, i.e., $P_t^l = F_t\left(P_t^r\right)$. Since the motion vector of P_t^l in f_t^l is already known, we can also easily find its corresponding pixel P_{t-1}^l in f_{t-1}^l by

$$P_{t-1}^l = M\left(P_t^l\right) + P_t^l. \tag{3}$$

In addition, we assume that the global disparity in the stereo pair at time $t-1$ is represented by the affine transformation $F_{t-1}(P)$ as well, which indicates the mapping of pixel P from f_{t-1}^r to f_{t-1}^l. $F_{t-1}(P)$ may have transform matrix and offset vector different to $F_t(P)$. Therefore, we define it as

$$F_{t-1}(P) = A_{t-1} P + C_{t-1}. \tag{4}$$

As for the pixel mapping from f_{t-1}^l to f_{t-1}^r, we need the inverse of $F_{t-1}(P)$, i.e.,

$$F_{t-1}^{-1}(P) = A_{t-1}^{-1} P - A_{t-1}^{-1} C_{t-1}. \tag{5}$$

Then, given pixel P_{t-1}^l in f_{t-1}^l, we can get its corresponding pixel P_{t-1}^r in f_{t-1}^r through the above affine transformation model, i.e., $P_{t-1}^r = F_{t-1}^{-1}\left(P_{t-1}^l\right)$. Thus, we can derive the motion vector of P_t^r in f_t^r from $M\left(P_t^r\right) = P_{t-1}^r - P_t^r$. Combining (1), (4), and (5), we have

$$M(P_t^r) = A_{t-1}^{-1} M\left(P_t^l\right) + A_{t-1}^{-1} C_t - A_{t-1}^{-1} C_{t-1} + A_{t-1}^{-1} A_t P_t^r - P_t^r. \tag{6}$$

Consider that the relative locations and angles of the cameras are usually fixed. In this case, the global disparity models of the two successive stereo pairs are almost identical. Then, $F_t(P)$ and $F_{t-1}(P)$ have the same parameters, i.e., $A_{t-1} = A_t$ and $C_{t-1} = C_t$. Thus, we can further simplify (6) as

$$M\left(P_t^r\right) = A_t^{-1} M\left(P_t^l\right). \tag{7}$$

Both (6) and (7) clearly indicate that we can deduce the temporal motion of one view from another if the disparity between views

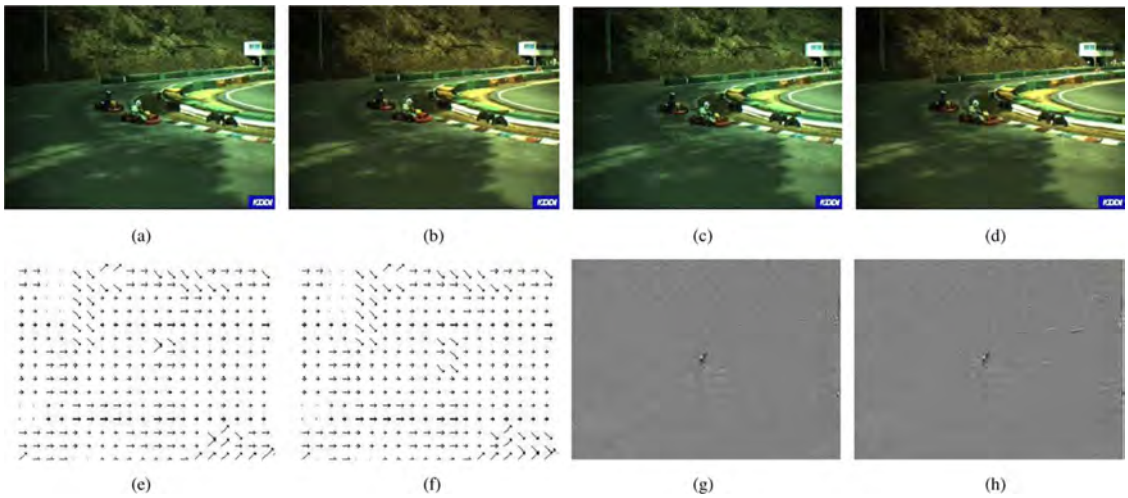


Fig. 2. Illustration of inter-view motion model. (a) First frame of the left view. (b) First frame of the right view. (c) Second frame of the left view. (d) Second frame of the right view. (e) Motion field from the block-based motion estimation. (f) Motion field from the inter-view motion model. (g) Prediction errors in terms of motion field in (e). (h) Prediction errors in terms of the motion field in (f). (Color version available online at: http://ieeexplore.ieee.org.)

and the temporal motion of the latter view are available. In particular in the case of (7), we can deduce the motion vector of every pixel in the view to be coded by simply scaling the motion vector of its corresponding pixel in the coded view.

Here we give an example to illustrate the accuracy of the derived motion vectors based on the proposed inter-view motion model. Above all, we explain some practical issues in the test of the inter-view motion model. We employ the block-based full-search motion estimation scheme to achieve the motion vector of every pixel in the left view. Secondly, we employ the global motion estimation algorithm proposed in [14] to calculate the affine transformation parameters between every stereo pair. Thirdly, since the location calculated in (1) may correspond to a fractional position or a position outside the image, we force the motion vector at this location to be the one at the closest integer pixel. Finally, we round the derived motion vector to quarter pixel precision due to the consideration of the tradeoff between prediction accuracy and complexity of interpolation.

Fig. 2 shows the original images, motion fields and prediction errors in terms of two successive stereo pairs in a multiview video. Note that the distributions of the prediction errors from the inter-view motion model and from the direct motion estimation are very similar. The corresponding PSNR is also calculated in terms of the motion-compensated prediction errors. The PSNR from the inter-view motion model is 32.16 dB, and the PSNR from the direct motion estimation is 32.34. In other words, the objective evaluation in terms of PSNR also shows the accuracy of the inter-view motion model. Note further, that the relatively larger prediction errors from the inter-view motion model are usually clustered in some local regions where complicated motion exists.

III. Inter-View Direct Mode

As discussed above, the motion of a view can be derived from another view through (6) or (7), depending on whether the parameters of the global geometric model in two successive frame pairs are equivalent or not. However, in the practical

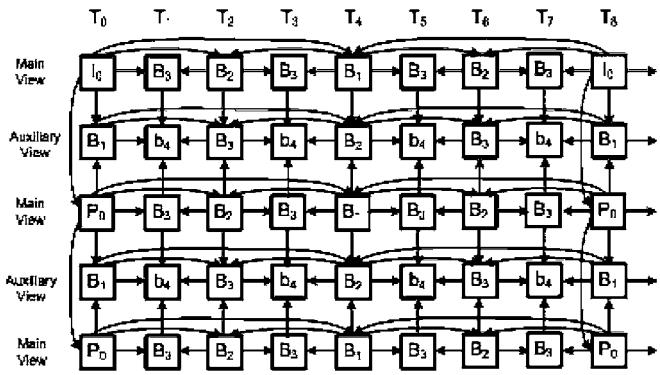


Fig. 3. Employed MVC structure based on [6].

MVC schemes, obviously not all pixels can derive their motion vectors with the inter-view motion model. It is no doubt that the proposed method should be jointly utilized with some existing methods. Accordingly, we propose a new direct mode namely inter-view direct mode for MVC. The proposed coding mode is integrated into the AVC-based MVC scheme and the 4-D wavelet-based MVC scheme, respectively.

A. AVC-Based MVC

In recent years, a number of MVC algorithms based on the AVC standard have been proposed [4]–[8]. They have the common feature of adaptively using MCP and DCP for predictive coding. In particular, the scheme in [6] has shown significant coding gains over the simulcast anchors, in which a prediction structure with hierarchical B-pictures is employed. Since the inter-view motion correlation has not been utilized in this scheme, we further extend it by incorporating the proposed inter-view direct mode. Above all, we give a brief overview of the employed AVC-based MVC scheme. As shown in Fig. 3, the basic coding scheme uses the hierarchical B-prediction structure for each view. The inter-view texture prediction is also applied to every second view. In summary, this MVC scheme mainly uses the existing AVC techniques to exploit temporal and inter-view dependencies.

TABLE I
USAGE PERCENTAGES OF MCP AND DCP MODES

	with DCP modes			w/o DCP modes	
	inter-view direct	other MCP	DCP	inter-view direct	other MCP
Race1	34.0%	50.3%	15.7%	35.7%	64.3%
Flamenco2	13.3%	78%	8.7%	14%	86%

In terms of the above MVC scheme, all MB coding modes can be classified into two categories: MCP and DCP. In fact, the MCP modes are often selected, especially when the luminance and/or chrominance variance across views exists and the multiview video is not rectified. In the original scheme in [6], only the temporal texture correlation is utilized when an MCP mode is selected. As discussed previously, even in the case of temporal MCP, the corresponding motion vector can possibly be derived from the other views due to the existence of inter-view motion correlation. Therefore, the proposed inter-view direct mode can be taken as a new MCP mode and be incorporated into the above MVC scheme. The rate-distortion optimization technique in [15] can be employed for coding mode selection. In addition, the proposed new coding mode used in an auxiliary view references another coded view (i.e., the main view) for motion vector derivation. Accordingly, we classify all views into two categories, e.g., taking every second view as an auxiliary view as shown in Fig. 3.

Some practical issues about how to derive the motion vectors in terms of the inter-view motion model have been addressed in Section II. Here we only address some practical issues about how to derive the prediction directions when the inter-view direct mode is used. For an MB coded with inter-view direct mode in a P-picture, every pixel in the MB only corresponds to the forward prediction. For an MB coded with inter-view direct mode in a B-picture, every pixel corresponds to a pixel (after rounding) in the main view. Thus, the pixel in the current MB has the same prediction directions as the corresponding pixel in the main view, including forward, backward, and bidirectional predictions. Note further, that it is unnecessary to code the prediction directions when it is coded with inter-view direct mode, because they are also derived from the main view.

B. 4-D Wavelet-Based MVC

In our previous work, a 4-D wavelet-based MVC algorithm has been proposed [9]. The basic idea is to decompose the multiview video using the lifting-based high dimensional wavelet transform. An example decomposition structure is shown in Fig. 4. Since the temporal correlation is usually stronger than the inter-view one, several levels of motion-compensated temporal filtering (MCTF) are performed first, followed by a few levels of disparity-compensated view filtering (DCVF). The coefficient frames in every temporal-view subband are further decomposed using the 2D spatial digital wavelet transform (DWT). As shown in Fig. 4, the 2-level MCTF, 1-level DCVF, and 2-level 2D spatial DWT are subsequently performed. The decomposed temporal-view-spatial subbands are coded with the entropy coding algorithm developed from 3-D-ESCOT in [16].

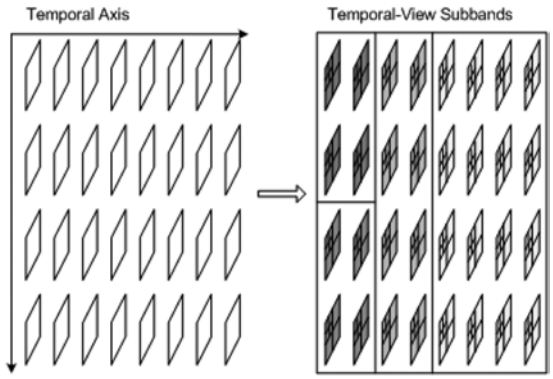


Fig. 4. Illustration of the 4-D wavelet decomposition.

In general, the MCTF dominates the overall coding performance, even though the DCVF can further improve the coding efficiency. The original MCTF only exploits the temporal texture correlation. To jointly utilize the inter-view motion correlation and the temporal texture correlation, we propose to incorporate the inter-view direct mode in MCTF in MVC. The motion vector derivation process for a MB with inter-view direct mode is the same as before. After the motion vectors are derived, the prediction and updating steps in the lifting-based MCTF are performed on the view video along motion trajectories in the temporal direction. Thanks to the energy-distributed updating (EDU) technique [17] adopted in the MCTF, the derived motion vector need not be inversed in the updating step. For more details about the other parts of the 4-D wavelet-based MVC scheme, we refer to [9].

IV. EXPERIMENTAL RESULTS

In this section, we evaluate the proposed inter-view direct mode in terms of the AVC-based MVC scheme and the 4-D wavelet-based MVC scheme, respectively. The results on *Race1*, *Flamenco2*, and *Flamenco1* sequences provided by KDDI Lab [18] are shown in this paper. All multiview videos have the frame size of 320×240 and frame rate of 30 fps, representing the simple and complex local disparities, respectively. The testing results are presented as follows.

A. AVC-Based MVC

The performance of the original AVC-based MVC scheme has been reported in [6]. In this section, we only present the improvement of the proposed coding technique. For each multiview video, all views are coded with the hierarchical B structure as shown in Fig. 3, and the overall performance is given in terms of the rate-distortion curves. Above all, we get some statistics on the usage percentages of the MCP and DCP modes. Since the proposed inter-view direct mode is only used in auxiliary

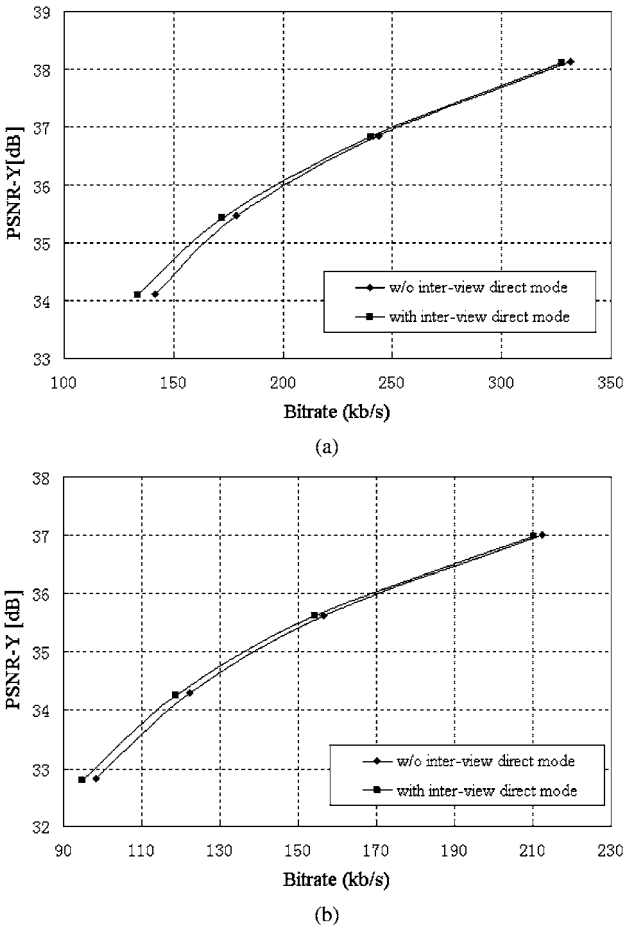


Fig. 5. Results of the AVC-based MVC. (a) *Race1*. (b) *Flamenco2*.

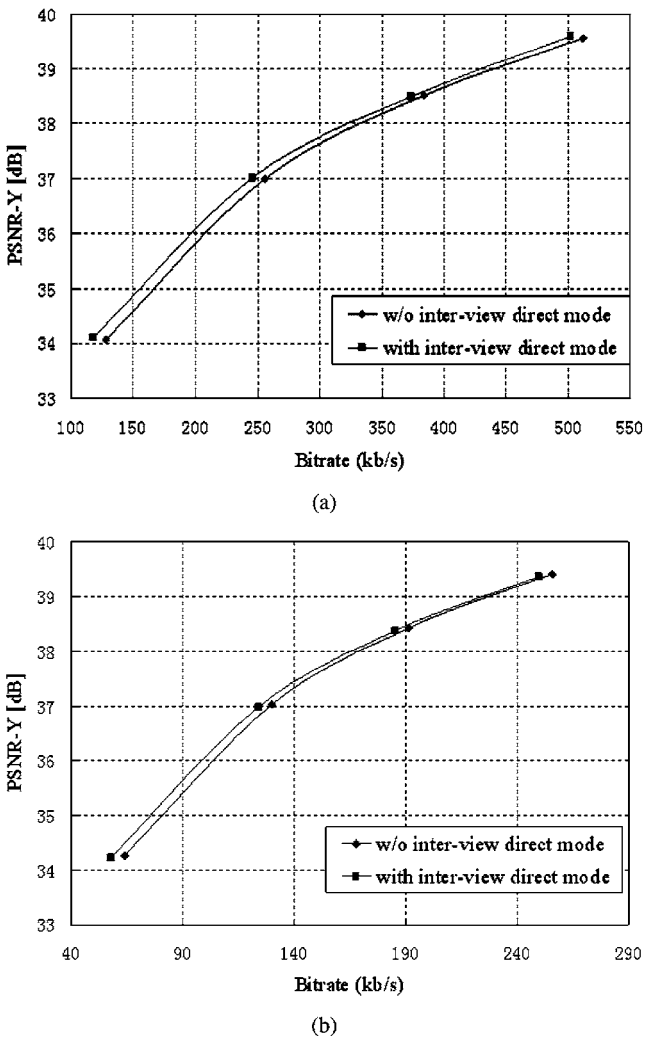


Fig. 6. Results of the 4-D wavelet-based MVC. (a) *Race1*. (b) *Flamenco1*.

views, the statistics is done on all auxiliary views. The statistics in Table I shows that the MCP modes are selected with a large ratio. For example, for *Race1*, 84.3% MBs are coded with MCP modes, including 34.0% MBs coded with inter-view direct mode. The multiview video has not been rectified, which may more or less decrease the number of DCP MBs. However, the major reason is that the inter-view texture correlation is usually not as strong as the temporal one. In addition, the percentages of MBs coded with inter-view direct mode change little between the MVC with and without DCP modes, which indicates that the inter-view direct mode has most probably replaced some traditional MCP modes rather than the DCP modes.

Fig. 5 shows the overall coding results. We can observe that the proposed inter-view direct mode can always improve the coding efficiency. The bit rate saving is up to 6% for *Race1* and 4% for *Flamenco2*. Note that the coding gain depends on the percentage of the bits for coding motion vectors and the prediction structures. As shown in Fig. 5, the coding gain at the high bit rate is not as obvious as that at the low bit rate, because the amount of bits for coding motion vectors increases slower than that for coding prediction errors. Furthermore, as shown in Fig. 5, the inter-view direct mode works better for *Race1* rather than for *Flamenco2*. The reason lies in that the global disparity is less effective for the regions with local disparity. In this case, the derived motion vectors in terms of the inter-view direct mode may not be accurate enough. The complex motion field may also influence the accuracy of global disparity estimation.

B. 4-D Wavelet-Based MVC

Although the 4-D wavelet-based MVC framework supports the content-adaptive wavelet decomposition structure, we employ the fixed decomposition structure in our test, i.e., 4-level MCTP followed by 2-level DCVF, as used in [9]. Considering the efficiency of the DCVF decomposition, all eight views are coded for each multiview video. The performance of the original 4-D wavelet-based MVC scheme compared with the H.264-based simulcast coding has been reported in [9]. In this paper, we only present the evaluation of the proposed inter-view direct mode in the 4-D wavelet-based MVC scheme. In particular, the coding results of the 4-D wavelet-based MVC with and without inter-view direct mode are reported, respectively.

Since the 4-D wavelet-based MVC scheme supports the SNR scalability, we create only a single bitstream for each test and get the coding results by truncating the bitstream at the targeted bit rates. To evaluate the saving of bit rate, the selection of the targeted bit rates aims at achieving the similar PSNR in terms of the two coding schemes. Fig. 6 shows the rate-distortion (R-D) curves. We can observe that the proposed inter-view direct mode can achieve up to up to 8% bit rate saving for *Race1* and 9% bit rate saving for *Flamenco1*. Note further, that the same set of motion bits has been used in decoding the bitstream truncated

at any targeted bit rate. In other words, the portion of motion bits also decreases at high bit rates, which leads to the coding gain not as obvious as that at the low bit rates. Nevertheless, the coding results have shown that the proposed inter-view direct mode can achieve coding gains in all cases.

C. Discussion of Complexity

The complexity issues in terms of the proposed inter-view direct mode in both the AVC-extension and 4-D wavelet-based MVC schemes are discussed as follows. At the encoder, the proposed algorithm does increase the complexity to some extent due to the following two aspects. First, the global disparity estimation between two adjacent views is performed in addition to the traditional block-based disparity estimation, which increases the complexity in disparity and motion search. As we know, the global disparity information is also helpful for enhancing inter-view texture prediction accuracy. Second, the proposed algorithm adds a new candidate coding mode (i.e., the proposed one), which increases the complexity in coding mode selection. However, the complexity of a typical AVC encoder is inherently high due to the adoption of some efficient coding techniques. Therefore, the increased encoding complexity due to the proposed coding mode is acceptable. At the decoder, the complexity introduced by the proposed coding mode is comparable to the traditional temporal direct mode in H.264. The only difference lies in the methods of deriving the motion vectors. With the proposed coding mode, the block-level motion vector is derived after being scaled twice. Actually, the temporal direct mode in H.264 also involves the scaling operations. Therefore, the decoding complexities with and without the proposed mode almost remain the same.

V. Conclusions

In this paper, the temporal motion correlation between views in the multiview video has been investigated, based on which an inter-view motion model is proposed. In particular, the affine transformation model is employed to represent the global disparity between any two views. Thus, the temporal motion of one view can be derived from that in another view supposing the affine transformation parameters are known. Due to the consideration of the bit saving of motion information in coding, we further propose an inter-view direct mode based on the inter-view motion model. The proposed new coding mode has been incorporated in the existing MVC schemes, including the AVC-based MVC and the 4-D wavelet-based MVC. Experimental results have shown that the proposed inter-view direct mode can achieve coding gains in all cases in both MVC schemes

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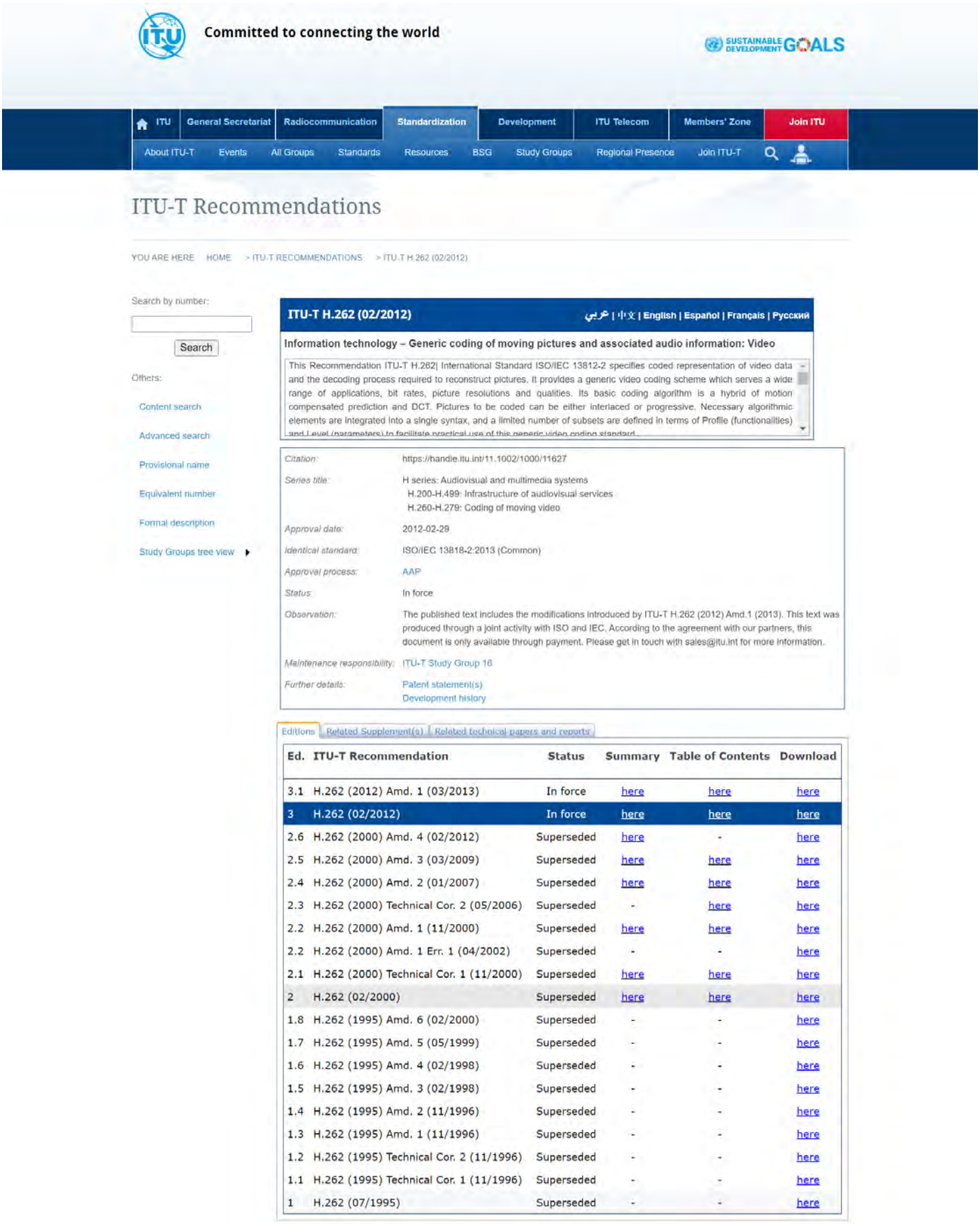
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APPENDIX ITU01

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ITU-T H.262 (02/2012)

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Information technology – Generic coding of moving pictures and associated audio information: Video

This Recommendation ITU-T H.262| International Standard ISO/IEC 13812-2 specifies coded representation of video data and the decoding process required to reconstruct pictures. It provides a generic video coding scheme which serves a wide range of applications, bit rates, picture resolutions and qualities. Its basic coding algorithm is a hybrid of motion compensated prediction and DCT. Pictures to be coded can be either interlaced or progressive. Necessary algorithmic elements are integrated into a single syntax, and a limited number of subsets are defined in terms of Profile (functionalities) and Level (parameters) to facilitate practical use of this generic video coding standard.

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H.262

(02/2000)

SERIES H: AUDIOVISUAL AND MULTIMEDIA SYSTEMS

Infrastructure of audiovisual services – Coding of moving video

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Information technology – Generic coding of moving pictures and associated audio information: Video

ITU-T Recommendation H.262

(Previously CCITT Recommendation)

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INTERNATIONAL STANDARD 13818-2

ITU-T RECOMMENDATION H.262

INFORMATION TECHNOLOGY – GENERIC CODING OF MOVING PICTURES AND ASSOCIATED AUDIO INFORMATION: VIDEO

Summary

This Recommendation | International Standard specifies coded representation of video data and the decoding process required to reconstruct pictures. It provides a generic video coding scheme which serves a wide range of applications, bit rates, picture resolutions and qualities. Its basic coding algorithm is a hybrid of motion compensated prediction and DCT. Pictures to be coded can be either interlaced or progressive. Necessary algorithmic elements are integrated into a single syntax, and a limited number of subsets are defined in terms of Profile (functionalities) and Level (parameters) to facilitate practical use of this generic video coding standard.

This second edition of this Recommendation | International Standard consists of ITU-T Rec. H.262 (1995) | ISO/IEC 13818-2:1996, subsequently altered by two corrigenda and six amendments:

1. A first corrigendum adding a slice picture identifier, allowing an application to define default colour description parameters, removing a prohibition of field-structured DCT coding in progressive frames, clarifying ambiguity on restricted range of reconstructed motion vectors, clarifying ambiguity of VBV at boundaries of sequences, and making various minor corrections.
2. A second corrigendum altering the inverse discrete cosine transform requirements, altering temporal_reference for low delay, and making various minor corrections.
3. A first amendment providing a method of obtaining and registering copyright identifiers.
4. A second amendment defining a 4:2:2 profile.
5. A third amendment adding a camera parameters extension and a multi-view profile.
6. A fourth amendment adding an ITU-T extension.
7. A fifth amendment adding a high level to the 4:2:2 profile.
8. A sixth amendment reducing the upper bound for the number of lines per frame in the high level of all profiles from 1152 to 1088.

Source

ITU-T Recommendation H.262 was approved on 17 February 2000. The identical text is also published as ISO/IEC International Standard 13818-2.

This edition of ITU-T H.262 consolidates H.262 (07/1995) and its Amendments 1 and 2 (11/1996), 3 and 4 (02/1998), 5 (05/1999), 6 (02/2000) and Corrigenda 1 and 2 (11/1996).

FOREWORD

ITU (International Telecommunication Union) is the United Nations Specialized Agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of the ITU. The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Conference (WTSC), which meets every four years, establishes the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

INTELLECTUAL PROPERTY RIGHTS

The ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. The ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, the ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

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Intro. 1 Purpose

This Part of this Recommendation | International Standard was developed in response to the growing need for a generic coding method of moving pictures and of associated sound for various applications such as digital storage media, television broadcasting and communication. The use of this Specification means that motion video can be manipulated as a form of computer data and can be stored on various storage media, transmitted and received over existing and future networks and distributed on existing and future broadcasting channels.

Intro. 2 Application

The applications of this Specification cover, but are not limited to, such areas as listed below:

BSS	Broadcasting Satellite Service (to the home)
CATV	Cable TV Distribution on optical networks, copper, etc.
CDAD	Cable Digital Audio Distribution
DSB	Digital Sound Broadcasting (terrestrial and satellite broadcasting)
DTTB	Digital Terrestrial Television Broadcasting
EC	Electronic Cinema
ENG	Electronic News Gathering (including SNG, Satellite News Gathering)
FSS	Fixed Satellite Service (e.g. to head ends)
HTT	Home Television Theatre
IPC	Interpersonal Communications (videoconferencing, videophone, etc.)
ISM	Interactive Storage Media (optical disks, etc.)
MMM	Multimedia Mailing
NCA	News and Current Affairs
NDB	Networked Database Services (via ATM, etc.)
RVS	Remote Video Surveillance
SSM	Serial Storage Media (digital VTR, etc.)

Intro. 3 Profiles and levels

This Specification is intended to be generic in the sense that it serves a wide range of applications, bitrates, resolutions, qualities and services. Applications should cover, among other things, digital storage media, television broadcasting and communications. In the course of creating this Specification, various requirements from typical applications have been considered, necessary algorithmic elements have been developed, and they have been integrated into a single syntax. Hence, this Specification will facilitate the bitstream interchange among different applications.

Considering the practicality of implementing the full syntax of this Specification, however, a limited number of subsets of the syntax are also stipulated by means of "profile" and "level". These and other related terms are formally defined in clause 3.

A "profile" is a defined subset of the entire bitstream syntax that is defined by this Specification. Within the bounds imposed by the syntax of a given profile it is still possible to require a very large variation in the performance of encoders and decoders depending upon the values taken by parameters in the bitstream. For instance, it is possible to specify frame sizes as large as (approximately) 2^{14} samples wide by 2^{14} lines high. It is currently neither practical nor economic to implement a decoder capable of dealing with all possible frame sizes.

In order to deal with this problem, "levels" are defined within each profile. A level is a defined set of constraints imposed on parameters in the bitstream. These constraints may be simple limits on numbers. Alternatively they may take the form of constraints on arithmetic combinations of the parameters (e.g. frame width multiplied by frame height multiplied by frame rate).

Bitstreams complying with this Specification use a common syntax. In order to achieve a subset of the complete syntax, flags and parameters are included in the bitstream that signal the presence or otherwise of syntactic elements that occur later in the bitstream. In order to specify constraints on the syntax (and hence define a profile), it is thus only necessary to constrain the values of these flags and parameters that specify the presence of later syntactic elements.

Intro. 4 The scalable and the non-scalable syntax

The full syntax can be divided into two major categories: One is the non-scalable syntax, which is structured as a super set of the syntax defined in ISO/IEC 11172-2. The main feature of the non-scalable syntax is the extra compression tools for interlaced video signals. The second is the scalable syntax, the key property of which is to enable the reconstruction of useful video from pieces of a total bitstream. This is achieved by structuring the total bitstream in two or more layers, starting from a standalone base layer and adding a number of enhancement layers. The base layer can use the non-scalable syntax, or in some situations conform to the ISO/IEC 11172-2 syntax.

Intro. 4.1 Overview of the non-scalable syntax

The coded representation defined in the non-scalable syntax achieves a high compression ratio while preserving good image quality. The algorithm is not lossless as the exact sample values are not preserved during coding. Obtaining good image quality at the bitrates of interest demands very high compression, which is not achievable with intra picture coding alone. The need for random access, however, is best satisfied with pure intra picture coding. The choice of the techniques is based on the need to balance a high image quality and compression ratio with the requirement to make random access to the coded bitstream.

A number of techniques are used to achieve high compression. The algorithm first uses block-based motion compensation to reduce the temporal redundancy. Motion compensation is used both for causal prediction of the current picture from a previous picture, and for non-causal, interpolative prediction from past and future pictures. Motion vectors are defined for each 16-sample by 16-line region of the picture. The prediction error, is further compressed using the Discrete Cosine Transform (DCT) to remove spatial correlation before it is quantised in an irreversible process that discards the less important information. Finally, the motion vectors are combined with the quantised DCT information, and encoded using variable length codes.

Intro. 4.1.1 Temporal processing

Because of the conflicting requirements of random access and highly efficient compression, three main picture types are defined. Intra Coded Pictures (I-Pictures) are coded without reference to other pictures. They provide access points to the coded sequence where decoding can begin, but are coded with only moderate compression. Predictive Coded Pictures (P-Pictures) are coded more efficiently using motion compensated prediction from a past intra or predictive coded picture and are generally used as a reference for further prediction. Bidirectionally-predictive Coded Pictures (B-Pictures) provide the highest degree of compression but require both past and future reference pictures for motion compensation. Bidirectionally-predictive coded pictures are never used as references for prediction (except in the case that the resulting picture is used as a reference in a spatially scalable enhancement layer). The organisation of the three picture types in a sequence is very flexible. The choice is left to the encoder and will depend on the requirements of the application. Figure Intro. 1 illustrates an example of the relationship among the three different picture types.

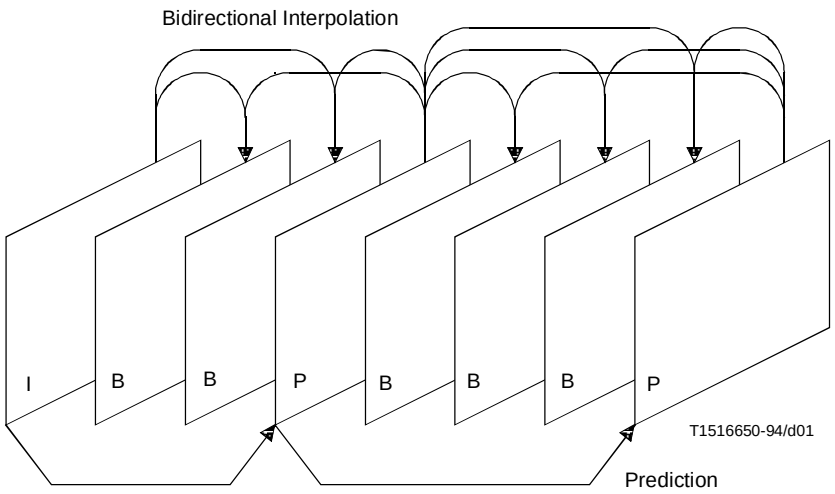


Figure Intro. 1 – Example of temporal picture structure

Intro. 4.1.2 Coding interlaced video

Each frame of interlaced video consists of two fields which are separated by one field-period. The Specification allows either the frame to be encoded as picture or the two fields to be encoded as two pictures. Frame encoding or field encoding can be adaptively selected on a frame-by-frame basis. Frame encoding is typically preferred when the video scene contains significant detail with limited motion. Field encoding, in which the second field can be predicted from the first, works better when there is fast movement.

Intro. 4.1.3 Motion representation – Macroblocks

As in ISO/IEC 11172-2, the choice of 16 by 16 macroblocks for the motion-compensation unit is a result of the trade-off between the coding gain provided by using motion information and the overhead needed to represent it. Each macroblock can be temporally predicted in one of a number of different ways. For example, in frame encoding, the prediction from the previous reference frame can itself be either frame-based or field-based. Depending on the type of the macroblock, motion vector information and other side information is encoded with the compressed prediction error in each macroblock. The motion vectors are encoded differentially with respect to the last encoded motion vectors using variable length codes. The maximum length of the motion vectors that may be represented can be programmed, on a picture-by-picture basis, so that the most demanding applications can be met without compromising the performance of the system in more normal situations.

It is the responsibility of the encoder to calculate appropriate motion vectors. This Specification does not specify how this should be done.

Intro. 4.1.4 Spatial redundancy reduction

Both source pictures and prediction errors have high spatial redundancy. This Specification uses a block-based DCT method with visually weighted quantisation and run-length coding. After motion compensated prediction or interpolation, the resulting prediction error is split into 8 by 8 blocks. These are transformed into the DCT domain where they are weighted before being quantised. After quantisation many of the DCT coefficients are zero in value and so two-dimensional run-length and variable length coding is used to encode the remaining DCT coefficients efficiently.

Intro. 4.1.5 Chrominance formats

In addition to the 4:2:0 format supported in ISO/IEC 11172-2 this Specification supports 4:2:2 and 4:4:4 chrominance formats.

Intro. 4.2 Scalable extensions

The scalability tools in this Specification are designed to support applications beyond that supported by single layer video. Among the noteworthy applications areas addressed are video telecommunications, video on Asynchronous Transfer Mode (ATM) networks, interworking of video standards, video service hierarchies with multiple spatial, temporal and quality resolutions, HDTV with embedded TV, systems allowing migration to higher temporal resolution HDTV, etc. Although a simple solution to scalable video is the simulcast technique which is based on transmission/storage of multiple independently coded reproductions of video, a more efficient alternative is scalable video coding, in which the bandwidth allocated to a given reproduction of video can be partially re-utilised in coding of the next reproduction of video. In scalable video coding, it is assumed that given a coded bitstream, decoders of various complexities can decode and display appropriate reproductions of coded video. A scalable video encoder is likely to have increased complexity when compared to a single layer encoder. However, this Recommendation | International Standard provides several different forms of scalabilities that address non-overlapping applications with corresponding complexities. The basic scalability tools offered are:

- data partitioning;
- SNR scalability;
- spatial scalability; and
- temporal scalability.

Moreover, combinations of these basic scalability tools are also supported and are referred to as *hybrid scalability*. In the case of basic scalability, two layers of video referred to as the *lower layer* and the *enhancement layer* are allowed, whereas in hybrid scalability up to three layers are supported. Tables Intro. 1 to Intro. 3 provide a few example applications of various scalabilities.

Table Intro. 1 – Applications of SNR scalability

Lower layer	Enhancement layer	Application
Recommendation ITU-R BT.601	Same resolution and format as lower layer	Two quality service for Standard TV (SDTV)
High Definition	Same resolution and format as lower layer	Two quality service for HDTV
4:2:0 high definition	4:2:2 chroma simulcast	Video production / distribution

Table Intro. 2 – Applications of spatial scalability

Base	Enhancement	Application
Progressive (30 Hz)	Progressive (30 Hz)	Compatibility or scalability CIF/SCIF
Interlace (30 Hz)	Interlace (30 Hz)	HDTV/SDTV scalability
Progressive (30 Hz)	Interlace (30 Hz)	ISO/IEC 11172-2/compatibility with this Specification
Interlace (30 Hz)	Progressive (60 Hz)	Migration to high resolution progressive HDTV

Table Intro. 3 – Applications of temporal scalability

Base	Enhancement	Higher	Application
Progressive (30 Hz)	Progressive (30 Hz)	Progressive (60 Hz)	Migration to high resolution progressive HDTV
Interlace (30 Hz)	Interlace (30 Hz)	Progressive (60 Hz)	Migration to high resolution progressive HDTV

Intro. 4.2.1 Spatial scalable extension

Spatial scalability is a tool intended for use in video applications involving telecommunications, interworking of video standards, video database browsing, interworking of HDTV and TV, etc., i.e. video systems with the primary common feature that a minimum of two layers of spatial resolution are necessary. Spatial scalability involves generating two spatial resolution video layers from a single video source such that the lower layer is coded by itself to provide the basic spatial resolution and the enhancement layer employs the spatially interpolated lower layer and carries the full spatial resolution of the input video source. The lower and the enhancement layers may either both use the coding tools in this Specification, or the ISO/IEC 11172-2 Standard for the lower layer and this Specification for the enhancement layer. The latter case achieves a further advantage by facilitating interworking between video coding standards. Moreover, spatial scalability offers flexibility in choice of video formats to be employed in each layer. An additional advantage of spatial scalability is its ability to provide resilience to transmission errors as the more important data of the lower layer can be sent over channel with better error performance, while the less critical enhancement layer data can be sent over a channel with poor error performance.

Intro. 4.2.2 SNR scalable extension

SNR scalability is a tool intended for use in video applications involving telecommunications, video services with multiple qualities, standard TV and HDTV, i.e. video systems with the primary common feature that a minimum of two layers of video quality are necessary. SNR scalability involves generating two video layers of same spatial resolution but different video qualities from a single video source such that the lower layer is coded by itself to provide the basic video quality and the enhancement layer is coded to enhance the lower layer. The enhancement layer when added back to the

lower layer regenerates a higher quality reproduction of the input video. The lower and the enhancement layers may either use this Specification or ISO/IEC 11172-2 Standard for the lower layer and this Specification for the enhancement layer. An additional advantage of SNR scalability is its ability to provide high degree of resilience to transmission errors as the more important data of the lower layer can be sent over channel with better error performance, while the less critical enhancement layer data can be sent over a channel with poor error performance.

Intro. 4.2.3 Temporal scalable extension

Temporal scalability is a tool intended for use in a range of diverse video applications from telecommunications to HDTV for which migration to higher temporal resolution systems from that of lower temporal resolution systems may be necessary. In many cases, the lower temporal resolution video systems may be either the existing systems or the less expensive early generation systems, with the motivation of introducing more sophisticated systems gradually. Temporal scalability involves partitioning of video frames into layers, whereas the lower layer is coded by itself to provide the basic temporal rate and the enhancement layer is coded with temporal prediction with respect to the lower layer, these layers when decoded and temporal multiplexed to yield full temporal resolution of the video source. The lower temporal resolution systems may only decode the lower layer to provide basic temporal resolution, whereas more sophisticated systems of the future may decode both layers and provide high temporal resolution video while maintaining interworking with earlier generation systems. An additional advantage of temporal scalability is its ability to provide resilience to transmission errors as the more important data of the lower layer can be sent over channel with better error performance, while the less critical enhancement layer can be sent over a channel with poor error performance.

Intro. 4.2.4 Data partitioning extension

Data partitioning is a tool intended for use when two channels are available for transmission and/or storage of a video bitstream, as may be the case in ATM networks, terrestrial broadcast, magnetic media, etc. The bitstream is partitioned between these channels such that more critical parts of the bitstream (such as headers, motion vectors, low frequency DCT coefficients) are transmitted in the channel with the better error performance, and less critical data (such as higher frequency DCT coefficients) is transmitted in the channel with poor error performance. Thus, degradation to channel errors are minimised since the critical parts of a bitstream are better protected. Data from neither channel may be decoded on a decoder that is not intended for decoding data partitioned bitstreams.

INTERNATIONAL STANDARD

ITU-T RECOMMENDATION

INFORMATION TECHNOLOGY – GENERIC CODING OF MOVING PICTURES AND ASSOCIATED AUDIO INFORMATION: VIDEO

1 Scope

This Recommendation | International Standard specifies the coded representation of picture information for digital storage media and digital video communication and specifies the decoding process. The representation supports constant bitrate transmission, variable bitrate transmission, random access, channel hopping, scalable decoding, bitstream editing, as well as special functions such as fast forward playback, fast reverse playback, slow motion, pause and still pictures. This Recommendation | International Standard is forward compatible with ISO/IEC 11172-2 and upward or downward compatible with EDTV, HDTV, SDTV formats.

This Recommendation | International Standard is primarily applicable to digital storage media, video broadcast and communication. The storage media may be directly connected to the decoder, or via communications means such as busses, LANs, or telecommunications links.

2 Normative references

The following Recommendations and International Standards contain provisions which, through reference in this text, constitute provisions of this Recommendation | International Standard. At the time of publication, the editions indicated were valid. All Recommendations and Standards are subject to revision, and parties to agreements based on this Recommendation | International Standard are encouraged to investigate the possibility of applying the most recent edition of the Recommendations and Standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards. The Telecommunication Standardization Bureau of ITU maintains a list of currently valid ITU-T Recommendations.

- Recommendation ITU-R BT.601-3 (1992), *Encoding parameters of digital television for studios.*
- Recommendation ITU-R BR.648 (1986), *Digital recording of audio signals.*
- Report ITU-R 955-2 (1990), *Satellite sound broadcasting with portable receivers and receivers in automobiles.*
- ISO/IEC 11172-1:1993, *Information technology – Coding of moving pictures and associated audio for digital storage media at up to about 1,5 Mbit/s – Part 1 : Systems.*
- ISO/IEC 11172-2:1993, *Information technology – Coding of moving pictures and associated audio for digital storage media at up to about 1,5 Mbit/s – Part 2 : Video.*
- ISO/IEC 11172-3:1993, *Information technology – Coding of moving pictures and associated audio for digital storage media at up to about 1,5 Mbit/s – Part 3 : Audio.*
- IEEE 1180:1990, Standard Specifications for the Implementations of 8 by 8 Inverse Discrete Cosine Transform.
- IEC 60908 (1999), *Audiorecording – Compact disc digital audio system.*
- IEC 60461 (1986), *Time and control code for video tape recorders.*
- ITU-T Recommendation H.261 (1993), *Video codec for audiovisual services at p ×64 kbit/s.*
- ITU-T Recommendation H.320 (1999), *Narrow-band visual telephone systems and terminal equipment.*
- CCITT Recommendation T.81 (1992) ISO/IEC 10918-1:1994, *Information technology – Digital compression and coding of continuous-tone still images – Requirements and guidelines.* (JPEG.)

3 Definitions

For the purposes of this Recommendation | International Standard, the following definitions apply.

3.1 AC coefficient: Any DCT coefficient for which the frequency in one or both dimensions is non-zero.

3.2 big picture: A coded picture that would cause VBV buffer underflow as defined in C.7. Big pictures can only occur in sequences where low_delay is equal to 1. "Skipped picture" is a term that is sometimes used to describe the same concept.

3.3 B-field picture: A field structure B-Picture.

3.4 B-frame picture: A frame structure B-Picture.

3.5 B-picture; **bidirectionally predictive-coded picture**: A picture that is coded using motion compensated prediction from past and/or future reference fields or frames.

3.6 backward compatibility: A newer coding standard is backward compatible with an older coding standard if decoders designed to operate with the older coding standard are able to continue to operate by decoding all or part of a bitstream produced according to the newer coding standard.

3.7 backward motion vector: A motion vector that is used for motion compensation from a reference frame or reference field at a later time in display order.

3.8 backward prediction: Prediction from the future reference frame (field).

3.9 base layer: First, independently decodable layer of a scalable hierarchy.

3.10 bitstream; stream: An ordered series of bits that forms the coded representation of the data.

3.11 bitrate: The rate at which the coded bitstream is delivered from the storage medium to the input of a decoder.

3.12 block: An 8-row by 8-column matrix of samples, or 64 DCT coefficients (source, quantised or dequantised).

3.13 bottom field: One of two fields that comprise a frame. Each line of a bottom field is spatially located immediately below the corresponding line of the top field.

3.14 byte aligned: A bit in a coded bitstream is byte-aligned if its position is a multiple of 8 bits from the first bit in the stream.

3.15 byte: Sequence of 8 bits.

3.16 channel: A digital medium that stores or transports a bitstream constructed according to ITU-T Rec. H.262 | ISO/IEC 13818-2.

3.17 chrominance format: Defines the number of chrominance blocks in a macroblock.

3.18 chroma simulcast: A type of scalability (which is a subset of SNR scalability) where the enhancement layer(s) contain only coded refinement data for the DC coefficients, and all the data for the AC coefficients, of the chrominance components.

3.19 chrominance component: A matrix, block or single sample representing one of the two colour difference signals related to the primary colours in the manner defined in the bitstream. The symbols used for the chrominance signals are Cr and Cb.

3.20 coded B-frame: A B-frame picture or a pair of B-field pictures.

3.21 coded frame: A coded frame is a coded I-frame, a coded P-frame or a coded B-frame.

3.22 coded I-frame: An I-frame picture or a pair of field pictures, where the first field picture is an I-picture and the second field picture is an I-picture or a P-picture.

3.23 coded P-frame: A P-frame picture or a pair of P-field pictures.

3.24 coded picture: A coded picture is made of a picture header, the optional extensions immediately following it, and the following picture data. A coded picture may be a coded frame or a coded field.

3.25 coded video bitstream: A coded representation of a series of one or more pictures as defined in ITU-T Rec. H.262 | ISO/IEC 13818-2.

3.26 coded order: The order in which the pictures are transmitted and decoded. This order is not necessarily the same as the display order.

3.27 coded representation: A data element as represented in its encoded form.

3.28 coding parameters: The set of user-definable parameters that characterise a coded video bitstream. Bitstreams are characterised by coding parameters. Decoders are characterised by the bitstreams that they are capable of decoding.

3.29 component: A matrix, block or single sample from one of the three matrices (luminance and two chrominance) that make up a picture.

3.30 compression: Reduction in the number of bits used to represent an item of data.

3.31 constant bitrate coded video: A coded video bitstream with a constant bitrate.

3.32 constant bitrate: Operation where the bitrate is constant from start to finish of the coded bitstream.

3.33 data element: An item of data as represented before encoding and after decoding.

3.34 data partitioning: A method for dividing a bitstream into two separate bitstreams for error resilience purposes. The two bitstreams have to be recombined before decoding.

3.35 D-Picture: A type of picture that shall not be used except in ISO/IEC 11172-2.

3.36 DC coefficient: The DCT coefficient for which the frequency is zero in both dimensions.

3.37 DCT coefficient: The amplitude of a specific cosine basis function.

3.38 decoder input buffer: The First-In First-Out (FIFO) buffer specified in the video buffering verifier.

3.39 decoder: An embodiment of a decoding process.

3.40 decoding (process): The process defined in ITU-T Rec. H.262 | ISO/IEC 13818-2 that reads an input coded bitstream and produces decoded pictures.

3.41 dequantisation: The process of rescaling the quantised DCT coefficients after their representation in the bitstream has been decoded and before they are presented to the inverse DCT.

3.42 digital storage media (DSM): A digital storage or transmission device or system.

3.43 discrete cosine transform (DCT): Either the forward discrete cosine transform or the inverse discrete cosine transform. The DCT is an invertible, discrete orthogonal transformation. The inverse DCT is defined in Annex A of ITU-T Rec. H.262 | ISO/IEC 13818-2.

3.44 display aspect ratio: The ratio height/width (in spatial measurement units such as centimeters) of the intended display.

3.45 display order: The order in which the decoded pictures are displayed. Normally this is the same order in which they were presented at the input of the encoder.

3.46 display process: The (non-normative) process by which reconstructed frames are displayed.

3.47 dual-prime prediction: A prediction mode in which two forward field-based predictions are averaged. The predicted block size is 16×16 luminance samples.

3.48 editing: The process by which one or more coded bitstreams are manipulated to produce a new coded bitstream. Conforming edited bitstreams must meet the requirements defined in ITU-T Rec. H.262 | ISO/IEC 13818-2.

3.49 encoder: An embodiment of an encoding process.

3.50 encoding (process): A process, not specified in ITU-T Rec. H.262 | ISO/IEC 13818-2, that reads a stream of input pictures and produces a valid coded bitstream as defined in ITU-T Rec. H.262 | ISO/IEC 13818-2.

3.51 enhancement layer: A relative reference to a layer (above the base layer) in a scalable hierarchy. For all forms of scalability, its decoding process can be described by reference to the lower layer decoding process and the appropriate additional decoding process for the enhancement layer itself.

3.52 fast forward playback: The process of displaying a sequence, or parts of a sequence, of pictures in display-order faster than real-time.

3.53 fast reverse playback: The process of displaying the picture sequence in the reverse of display order faster than real-time.

3.54 **field**: For an interlaced video signal, a "field" is the assembly of alternate lines of a frame. Therefore an interlaced frame is composed of two fields, a top field and a bottom field.

3.55 **field-based prediction**: A prediction mode using only one field of the reference frame. The predicted block size is 16×16 luminance samples.

3.56 **field period**: The reciprocal of twice the frame rate.

3.57 **field picture; field structure picture**: A field structure picture is a coded picture with picture_structure is equal to "Top field" or "Bottom field".

3.58 **flag**: A one bit integer variable which may take one of only two values (zero and one).

3.59 **forbidden**: The term "forbidden" when used in the clauses defining the coded bitstream indicates that the value shall never be used. This is usually to avoid emulation of start codes.

3.60 **forced updating**: The process by which macroblocks are intra-coded from time-to-time to ensure that mismatch errors between the inverse DCT processes in encoders and decoders cannot build up excessively.

3.61 **forward compatibility**: A newer coding standard is forward compatible with an older coding standard if decoders designed to operate with the newer coding standard are able to decode bitstreams of the older coding standard.

3.62 **forward motion vector**: A motion vector that is used for motion compensation from a reference frame or reference field at an earlier time in display order.

3.63 **forward prediction**: Prediction from the past reference frame (field).

3.64 **frame**: A frame contains lines of spatial information of a video signal. For progressive video, these lines contain samples starting from one time instant and continuing through successive lines to the bottom of the frame. For interlaced video, a frame consists of two fields, a top field and a bottom field. One of these fields will commence one field period later than the other.

3.65 **frame-based prediction**: A prediction mode using both fields of the reference frame.

3.66 **frame period**: The reciprocal of the frame rate.

3.67 **frame picture; frame structure picture**: A frame structure picture is a coded picture with picture_structure is equal to "Frame".

3.68 **frame rate**: The rate at which frames are output from the decoding process.

3.69 **future reference frame (field)**: A future reference frame (field) is a reference frame (field) that occurs at a later time than the current picture in display order.

3.70 **frame re-ordering**: The process of re-ordering the reconstructed frames when the coded order is different from the display order. Frame re-ordering occurs when B-frames are present in a bitstream. There is no frame re-ordering when decoding low delay bitstreams.

3.71 **group of pictures**: A notion defined only in ISO/IEC 11172-2 (MPEG-1 Video). In ITU-T Rec. H.262 | ISO/IEC 13818-2, a similar functionality can be achieved by the mean of inserting group of pictures headers.

3.72 **header**: A block of data in the coded bitstream containing the coded representation of a number of data elements pertaining to the coded data that follow the header in the bitstream.

3.73 **hybrid scalability**: Hybrid scalability is the combination of two (or more) types of scalability.

3.74 **interlace**: The property of conventional television frames where alternating lines of the frame represent different instances in time. In an interlaced frame, one of the field is meant to be displayed first. This field is called the first field. The first field can be the top field or the bottom field of the frame.

3.75 **I-field picture**: A field structure I-Picture.

3.76 **I-frame picture**: A frame structure I-Picture.

3.77 **I-picture; intra-coded picture**: A picture coded using information only from itself.

3.78 **intra coding**: Coding of a macroblock or picture that uses information only from that macroblock or picture.

3.78.1 **Inverse DCT, IDCT**: Inverse discrete cosine transform, as defined in Annex A.

3.79 **level**: A defined set of constraints on the values which may be taken by the parameters of ITU-T Rec. H.262 | ISO/IEC 13818-2 within a particular profile. A profile may contain one or more levels. In a different context, level is the absolute value of a non-zero coefficient (see "run").

3.80 **layer**: In a scalable hierarchy denotes one out of the ordered set of bitstreams and (the result of) its associated decoding process (implicitly including decoding of **all** layers below this layer).

3.81 **layer bitstream**: A single bitstream associated to a specific layer (always used in conjunction with layer qualifiers, e. g. "enhancement layer bitstream").

3.82 **lower layer**: A relative reference to the layer immediately below a given enhancement layer (implicitly including decoding of **all** layers below this enhancement layer).

3.83 **luminance component**: A matrix, block or single sample representing a monochrome representation of the signal and related to the primary colours in the manner defined in the bitstream. The symbol used for luminance is Y.

3.84 **Mbit**: 1 000 000 bits.

3.85 **macroblock**: The four 8 by 8 blocks of luminance data and the two (for 4:2:0 chrominance format), four (for 4:2:2 chrominance format) or eight (for 4:4:4 chrominance format) corresponding 8 by 8 blocks of chrominance data coming from a 16 by 16 section of the luminance component of the picture. Macroblock is sometimes used to refer to the sample data and sometimes to the coded representation of the sample values and other data elements defined in the macroblock header of the syntax defined in ITU-T Rec. H.262 | ISO/IEC 13818-2. The usage is clear from the context.

3.86 **motion compensation**: The use of motion vectors to improve the efficiency of the prediction of sample values. The prediction uses motion vectors to provide offsets into the past and/or future reference frames or reference fields containing previously decoded sample values that are used to form the prediction error.

3.87 **motion estimation**: The process of estimating motion vectors during the encoding process.

3.88 **motion vector**: A two-dimensional vector used for motion compensation that provides an offset from the coordinate position in the current picture or field to the coordinates in a reference frame or reference field.

3.89 **non-intra coding**: Coding of a macroblock or picture that uses information both from itself and from macroblocks and pictures occurring at other times.

3.90 **opposite parity**: The opposite parity of top is bottom, and vice versa.

3.91 **P-field picture**: A field structure P-Picture.

3.92 **P-frame picture**: A frame structure P-Picture.

3.93 **P-picture; predictive-coded picture**: A picture that is coded using motion compensated prediction from past reference fields or frame.

3.94 **parameter**: A variable within the syntax of ITU-T Rec. H.262 | ISO/IEC 13818-2 which may take one of a range of values. A variable which can take one of only two values is called a flag.

3.95 **parity (of field)**: The parity of a field can be top or bottom.

3.96 **past reference frame (field)**: A past reference frame (field) is a reference frame (field) that occurs at an earlier time than the current picture in display order.

3.97 **picture**: Source, coded or reconstructed image data. A source or reconstructed picture consists of three rectangular matrices of 8-bit numbers representing the luminance and two chrominance signals. A "coded picture" is defined in 3.21 of ITU-T Rec. H.262 | ISO/IEC 13818-2. For progressive video, a picture is identical to a frame, while for interlaced video, a picture can refer to a frame, or the top field or the bottom field of the frame depending on the context.

3.98 **picture data**: In the VBV operations, picture data is defined as all the bits of the coded picture, all the header(s) and user data immediately preceding it if any (including any stuffing between them) and all the stuffing following it, up to (but not including) the next start code, except in the case where the next start code is an end of sequence code, in which case it is included in the picture data.

3.99 **prediction**: The use of a predictor to provide an estimate of the sample value or data element currently being decoded.

3.100 **prediction error**: The difference between the actual value of a sample or data element and its predictor.

3.101 **predictor**: A linear combination of previously decoded sample values or data elements.

3.102 **profile**: A defined subset of the syntax of ITU-T Rec. H.262 | ISO/IEC 13818-2.

NOTE – In ITU-T Rec. H.262 | ISO/IEC 13818-2, the word "profile" is used as defined above. It should not be confused with other definitions of "profile" and in particular it does not have the meaning that is defined by JTC1/SGFS.

3.103 progressive: The property of film frames where all the samples of the frame represent the same instances in time.

3.104 quantisation matrix: A set of sixty-four 8-bit values used by the dequantiser.

3.105 quantised DCT coefficients: DCT coefficients before dequantisation. A variable length coded representation of quantised DCT coefficients is transmitted as part of the coded video bitstream.

3.106 quantiser scale: A scale factor coded in the bitstream and used by the decoding process to scale the dequantisation.

3.107 random access: The process of beginning to read and decode the coded bitstream at an arbitrary point.

3.108 reconstructed frame: A reconstructed frame consists of three rectangular matrices of 8-bit numbers representing the luminance and two chrominance signals. A reconstructed frame is obtained by decoding a coded frame.

3.109 reconstructed picture: A reconstructed picture is obtained by decoding a coded picture. A reconstructed picture is either a reconstructed frame (when decoding a frame picture), or one field of a reconstructed frame (when decoding a field picture). If the coded picture is a field picture, then the reconstructed picture is the top field or the bottom field of the reconstructed frame.

3.110 reference field: A reference field is one field of a reconstructed frame. Reference fields are used for forward and backward prediction when P-pictures and B-pictures are decoded. Note that when field P-pictures are decoded, prediction of the second field P-picture of a coded frame uses the first reconstructed field of the same coded frame as a reference field.

3.111 reference frame: A reference frame is a reconstructed frame that was coded in the form of a coded I-frame or a coded P-frame. Reference frames are used for forward and backward prediction when P-pictures and B-pictures are decoded.

3.112 re-ordering delay: A delay in the decoding process that is caused by frame re-ordering.

3.113 reserved: The term "reserved" when used in the clauses defining the coded bitstream, indicates that the value may be used in the future for ITU-T | ISO/IEC defined extensions.

3.114 sample aspect ratio (SAR): This specifies the relative distance between samples. It is defined (for the purposes of ITU-T Rec. H.262 | ISO/IEC 13818-2), as the vertical displacement of the lines of luminance samples in a frame divided by the horizontal displacement of the luminance samples. Thus, its units are (metres per line) ÷ (metres per sample).

3.115 scalable hierarchy: Coded video data consisting of an ordered set of more than one video bitstream.

3.116 scalability: Scalability is the ability of a decoder to decode an ordered set of bitstreams to produce a reconstructed sequence. Moreover, useful video is output when subsets are decoded. The minimum subset that can thus be decoded is the first bitstream in the set which is called the base layer. Each of the other bitstreams in the set is called an enhancement layer. When addressing a specific enhancement layer, "lower layer" refer to the bitstream which precedes the enhancement layer.

3.117 side information: Information in the bitstream necessary for controlling the decoder.

3.118 16 × 8 prediction: A prediction mode similar to field-based prediction but where the predicted block size is 16×8 luminance samples.

3.119 run: The number of zero coefficients preceding a non-zero coefficient, in the scan order. The absolute value of the non-zero coefficient is called "level".

3.120 saturation: Limiting a value that exceeds a defined range by setting its value to the maximum or minimum of the range as appropriate.

3.121 skipped macroblock: A macroblock for which no data is encoded.

3.122 slice: A consecutive series of macroblocks which are all located in the same horizontal row of macroblocks.

3.123 SNR scalability: A type of scalability where the enhancement layer(s) contain only coded refinement data for the DCT coefficients of the lower layer.

3.124 source; **input**: Term used to describe the video material or some of its attributes before encoding.

3.125 spatial prediction: Prediction derived from a decoded frame of the lower layer decoder used in spatial scalability.

3.126 spatial scalability: A type of scalability where an enhancement layer also uses predictions from sample data derived from a lower layer without using motion vectors. The layers can have different frame sizes, frame rates or chrominance formats.

3.127 start codes (system and video): 32-bit codes embedded in that coded bitstream that are unique. They are used for several purposes including identifying some of the structures in the coding syntax.

3.128 stuffing (bits); **stuffing (bytes)**: Code-words that may be inserted into the coded bitstream that are discarded in the decoding process. Their purpose is to increase the bitrate of the stream which would otherwise be lower than the desired bitrate.

3.129 temporal prediction: Prediction derived from reference frames or fields other than those defined as spatial prediction.

3.130 temporal scalability: A type of scalability where an enhancement layer also uses predictions from sample data derived from a lower layer using motion vectors. The layers have identical frame size, and chrominance formats, but can have different frame rates.

3.131 top field: One of two fields that comprise a frame. Each line of a top field is spatially located immediately above the corresponding line of the bottom field.

3.132 top layer: The topmost layer (with the highest layer_id) of a scalable hierarchy.

3.133 variable bitrate: Operation where the bitrate varies with time during the decoding of a coded bitstream.

3.134 variable length coding (VLC): A reversible procedure for coding that assigns shorter code-words to frequent events and longer code-words to less frequent events.

3.135 video buffering verifier (VBV): A hypothetical decoder that is conceptually connected to the output of the encoder. Its purpose is to provide a constraint on the variability of the data rate that an encoder or editing process may produce.

3.136 video sequence: The highest syntactic structure of coded video bitstreams. It contains a series of one or more coded frames.

3.137 xxx profile decoder: Decoder able to decode one or a scalable hierarchy of bitstreams of which the top layer conforms to the specifications of the xxx profile (with xxx being any of the defined Profile names).

3.138 xxx profile scalable hierarchy: Set of bitstreams of which the top layer conforms to the specifications of the xxx profile.

3.139 xxx profile bitstream: A bitstream of a scalable hierarchy with a profile indication corresponding to xxx. Note that this bitstream is only decodable together with all its lower layer bitstreams (unless it is a base layer bitstream).

3.140 zigzag scanning order: A specific sequential ordering of the DCT coefficients from (approximately) the lowest spatial frequency to the highest.

4 Abbreviations and symbols

The mathematical operators used to describe this Specification are similar to those used in the C programming language. However, integer divisions with truncation and rounding are specifically defined. Numbering and counting loops generally begin from zero.

4.1 Arithmetic operators

+	Addition
–	Subtraction (as a binary operator) or negation (as a unary operator)
++	Increment, i.e. *x*++ is equivalent to x = x + 1
––	Decrement, i.e. *x*–– is equivalent to x = x – 1
× *	Multiplication

^ Power

/ Integer division with truncation of the result toward zero. For example, 7/4 and –7/–4 are truncated to 1 and –7/4 and 7/–4 are truncated to –1.

// Integer division with rounding to the nearest integer. Half-integer values are rounded away from zero unless otherwise specified. For example 3//2 is rounded to 2, and –3//2 is rounded to –2.

DIV Integer division with truncation of the result toward minus infinity. For example 3 DIV 2 is rounded to 1, and –3 DIV 2 is rounded to –2.

÷ Used to denote division in mathematical equations where no truncation or rounding is intended.

% Modulus operator. Defined only for positive numbers.

Sign( ) $\text{Sign}(x) = \begin{cases} 1 & x > 0 \\ 0 & x == 0 \\ -1 & x < 0 \end{cases}$

Abs( ) $\text{Abs}(x) = \begin{cases} x & x >= 0 \\ -x & x < 0 \end{cases}$

$\sum_{i=a}^{i<b} f(i)$ The summation of the $f(i)$ with i taking integral values from a up to, but not including b.

4.2 Logical operators

|| Logical OR

&& Logical AND

! Logical NOT

4.3 Relational operators

> Greater than

>= Greater than or equal to

< Less than

<= Less than or equal to

== Equal to

!= Not equal to

max [, … ,] The maximum value in the argument list

min [, … ,] The minimum value in the argument list

4.4 Bitwise operators

& AND

| OR

>> Shift right with sign extension

<< Shift left with zero fill

4.5 Assignment

= Assignment operator

4.6 Mnemonics

The following mnemonics are defined to describe the different data types used in the coded bitstream.

bslbf Bit string, left bit first, where "left" is the order in which bit strings are written in this Specification. Bit strings are generally written as a string of 1s and 0s within single quote marks, e.g. '1000 0001'. Blanks within a bit string are for ease of reading and have no significance. For convenience, large strings are occasionally written in hexadecimal; in this case, conversion to a binary in the conventional manner will yield the value of the bit string. Thus, the left most hexadecimal digit is first and in each hexadecimal digit the most significant of the four bits is first.

uimsbf Unsigned integer, most significant bit first.

simsbf Signed integer, in twos complement format, most significant (sign) bit first.

vlclbf Variable length code, left bit first, where "left" refers to the order in which the VLC codes are written. The byte order of multibyte words is the most significant byte first.

In the clauses describing the syntax, any syntactic element that can only take positive or unsigned values (such as a flag that can be equal to 0 or 1) is described with the mnemonic 'uimsbf'. If the syntactic element can have a negative value, it is described with the mnemonic 'simsbf'. If the syntactic element has a constant value (e.g. marker_bit) then it is described with the mnemonic 'bslbf'. If the syntactic element represents a variable-length code, it is described with the mnemonic 'vlclbf'.

4.7 Constants

π 3,141 592 653 58...

e 2,718 281 828 45...

5 Conventions

5.1 Method of describing bitstream syntax

The bitstream retrieved by the decoder is described in 6.2. Each data item in the bitstream is in bold type. It is described by its name, its length in bits, and a mnemonic for its type and order of transmission.

The action caused by a decoded data element in a bitstream depends on the value of that data element and on data elements previously decoded. The decoding of the data elements and definition of the state variables used in their decoding are described in 6.3. The following constructs are used to express the conditions when data elements are present, and are in normal type:

while (condition) {
  data_element
  . . .
}
	If the condition is true, then the group of data elements occurs next in the data stream. This repeats until the condition is not true.

do { **data_element** . . . } while (condition)	The data element always occurs at least once. The data element is repeated until the condition is not true.

if (condition) {
  data_element
  . . .
} else {
  data_element
  . . .
}
	If the condition is true, then the first group of data elements occurs next in the data stream.
	
	If the condition is not true, then the second group of data elements occurs next in the data stream.

for (i = m; i < n; i++) {
  data_element
  . . .
}
	The group of data elements occurs (m – n) times. Conditional constructs within the group of data elements may depend on the value of the loop control variable i, which is set to zero for the first occurrence, incremented by one for the second occurrence, and so forth.

/* comment ... */	Explanatory comment that may be deleted entirely without in any way altering the syntax.

This syntax uses the 'C-code' convention that a variable or expression evaluating to a non-zero value is equivalent to a condition that is true and a variable or expression evaluating to a zero value is equivalent to a condition that is false. In many cases a literal string is used in a condition. For example:

if (scalable_mode == "spatial scalability") …

In such cases the literal string is that used to describe the value of the bitstream element in 6.3. In this example, we see that "spatial scalability" is defined in Table 6-10 to be represented by the two bit binary number '01'.

As noted, the group of data elements may contain nested conditional constructs. For compactness, the {} are omitted when only one data element follows:

data_element [n] data_element [n] is the n + 1th element of an array of data.

data_element [m][n] data_element [m][n] is the m + 1, n + 1th element of a two-dimensional array of data.

data_element [l][m][n] data_element [l][m][n] is the l + 1, m + 1, n + 1th element of a three-dimensional array of data.

While the syntax is expressed in procedural terms, it should not be assumed that 6.2 implements a satisfactory decoding procedure. In particular, it defines a correct and error-free input bitstream. Actual decoders must include means to look for start codes in order to begin decoding correctly, and to identify errors, erasures or insertions while decoding. The methods to identify these situations, and the actions to be taken, are not standardised.

5.2 Definition of functions

Several utility functions for picture coding algorithm are defined as follows.

5.2.1 Definition of bytealigned() function

The function bytealigned () returns 1 if the current position is on a byte boundary, that is the next bit in the bitstream is the first bit in a byte. Otherwise it returns 0.

5.2.2 Definition of nextbits() function

The function nextbits () permits comparison of a bit string with the next bits to be decoded in the bitstream.

5.2.3 Definition of next_start_code() function

The next_start_code() function removes any zero bit and zero byte stuffing and locates the next start code.

next_start_code() {	No. of bits	Mnemonic
while (!bytealigned())		
zero_bit	1	'0'
while (nextbits() != '0000 0000 0000 0000 0000 0001')		
zero_byte	8	'0000 0000'
}		

This function checks whether the current position is byte aligned. If it is not, zero stuffing bits are present. After that any number of zero stuffing bytes may be present before the start code. Therefore, start codes are always byte aligned and may be preceded by any number of zero stuffing bits.

5.3 Reserved, forbidden and marker_bit

The terms "reserved" and "forbidden" are used in the description of some values of several fields in the coded bitstream.

The term "reserved" indicates that the value may be used in the future for ITU-T | ISO/IEC defined extensions.

The term "forbidden" indicates a value that shall never be used (usually in order to avoid emulation of start codes).

The term "marker_bit" indicates a one bit integer in which the value zero is forbidden (and it therefore shall have the value '1'). These marker bits are introduced at several points in the syntax to avoid start code emulation.

5.4 Arithmetic precision

In order to reduce discrepancies between implementations of this Specification, the following rules for arithmetic operations are specified:

a) Where arithmetic precision is not specified, such as in the calculation of the IDCT, the precision shall be sufficient so that significant errors do not occur in the final integer values.

b) Where ranges of values are given by a colon, the end points are included if a bracket is present, and excluded if the 'less than' (<) and 'greater than' (>) characters are used. For example, [a : b > means from *a* to *b*, including *a* but excluding *b*.

6 Video bitstream syntax and semantics

6.1 Structure of coded video data

Coded video data consists of an ordered set of video bitstreams, called layers. If there is only one layer, the coded video data is called non-scalable video bitstream. If there are two layers or more, the coded video data is called a scalable hierarchy.

The first layer (of the ordered set) is called base layer, and it can always be decoded independently. See 7.1 to 7.6 and 7.12 for a description of the decoding process for the base layer, except in the case of Data partitioning, described in 7.10.

Other layers are called enhancement layers, and can only be decoded together with all the lower layers (previous layers in the ordered set), starting with the base layer. See 7.7 to 7.11 for a description of the decoding process for scalable hierarchy.

See Rec. ITU-T H.222.0 | ISO/IEC 13818-1 for a description of the way layers may be multiplexed together.

The base layer of a scalable hierarchy may conform to this Specification or to other standards such as ISO/IEC 11172-2. See details in 7.7 to 7.11. Enhancement layers shall conform to this Specification.

In all cases apart from Data partitioning, the base layer does not contain a sequence_scalable_extension(). Enhancement layers always contain sequence_scalable_extension().

In general, the video bitstream can be thought of as a syntactic hierarchy in which syntactic structures contain one or more subordinate structures. For instance, the structure "picture_data()" contains one or more of the syntactic structure "slice()" which in turn contains one or more of the structure "macroblock()".

This structure is very similar to that used in ISO/IEC 11172-2.

6.1.1 Video sequence

The highest syntactic structure of the coded video bitstream is the video sequence.

A video sequence commences with a sequence header which may optionally be followed by a group of pictures header and then by one or more coded frames. The order of the coded frames in the coded bitstream is the order in which the decoder processes them, but not necessarily in the correct order for display. The video sequence is terminated by a sequence_end_code. At various points in the video sequence, a particular coded frame may be preceded by either a repeat sequence header or a group of pictures header or both. (In the case that both a repeat sequence header and a group of pictures header immediately precede a particular picture, the group of pictures header shall follow the repeat sequence header.)

6.1.1.1 Progressive and interlaced sequences

This Specification deals with coding of both progressive and interlaced sequences.

The output of the decoding process, for interlaced sequences, consists of a series of reconstructed fields that are separated in time by a field period. The two fields of a frame may be coded separately (field-pictures). Alternatively the two fields may be coded together as a frame (frame-pictures). Both frame pictures and field pictures may be used in a single video sequence.

In progressive sequences each picture in the sequence shall be a frame picture. The sequence, at the output of the decoding process, consists of a series of reconstructed frames that are separated in time by a frame period.

6.1.1.2 Frame

A frame consists of three rectangular matrices of integers: a luminance matrix (Y), and two chrominance matrices (Cb and Cr).

The relationship between these Y, Cb and Cr components and the primary (analogue) Red, Green and Blue Signals (E'_R, E'_G and E'_B), the chromaticity of these primaries and the transfer characteristics of the source frame may be specified in the bitstream (or specified by some other means). This information does not affect the decoding process.

6.1.1.3 Field

A field consists of every other line of samples in the three rectangular matrices of integers representing a frame.

A frame is the union of a top field and a bottom field. The top field is the field that contains the top-most line of each of the three matrices. The bottom field is the other one.

6.1.1.4 Picture

A coded picture is made of a picture header, the optional extensions immediately following it and the following picture data. A coded picture may be a coded frame or a coded field.

An I-frame picture or a pair of field pictures, where the first field picture is an I-picture and the second field picture is an I-picture or a P-picture, is called a coded I-frame.

A P-frame picture or a pair of P-field pictures is called a coded P-frame.

A B-frame picture or a pair of B-field pictures is called a coded B-frame.

A coded I-frame, a coded P-frame or a coded B-frame is called a coded frame.

A reconstructed picture is obtained by decoding a coded picture, i.e. a picture header, the optional extensions immediately following it, and the picture data. A coded picture may be a frame picture or a field picture. A reconstructed picture is either a reconstructed frame (when decoding a frame picture), or one field of a reconstructed frame (when decoding a field picture).

6.1.1.4.1 Field pictures

If field pictures are used, then they shall occur in pairs (one top field followed by one bottom field, or one bottom field followed by one top field) and together constitute a coded frame. The two field pictures that comprise a coded frame shall be encoded in the bitstream in the order in which they shall occur at the output of the decoding process.

When the first picture of the coded frame is a P-field picture, then the second picture of the coded frame shall also be a P-field picture. Similarly when the first picture of the coded frame is a B-field picture the second picture of the coded frame shall also be a B-field picture.

When the first picture of the coded frame is a I-field picture, then the second picture of the frame shall be either an I-field picture or a P-field picture. If the second picture is a P-field picture, then certain restrictions apply (see 7.6.3.5).

6.1.1.4.2 Frame pictures

When coding interlaced sequences using frame pictures, the two fields of the frame shall be interleaved with one another and then the entire frame is coded as a single frame-picture.

6.1.1.5 Picture types

There are three types of pictures that use different coding methods:

- an **Intra-coded (I) picture** is coded using information only from itself;
- a **Predictive-coded (P) picture** is a picture which is coded using motion compensated prediction from a past reference frame or past reference field;
- a **Bidirectionally predictive-coded (B) picture** is a picture which is coded using motion compensated prediction from a past and/or future reference frame(s).

6.1.1.6 Sequence header

A video sequence header commences with a sequence_header_code and is followed by a series of data elements. In this Specification, sequence_header() shall be followed by sequence_extension() which includes further parameters beyond those used by ISO/IEC 11172-2. When sequence_extension() is present, the syntax and semantics defined in ISO/IEC 11172-2 do not apply, and the present Specification applies.

In repeat sequence headers all of the data elements with the permitted exception of those defining the quantisation matrices (load_intra_quantiser_matrix, load_non_intra_quantiser_matrix and optionally intra_quantiser_matrix and non_intra_quantiser_matrix) shall have the same values as in the first sequence header. The quantisation matrices may be redefined each time that a sequence header occurs in the bitstream (note that quantisation matrices may also be updated using quant_matrix_extension()).

All of the data elements in the sequence_extension() that follows a repeat sequence_header() shall have the same values as in the first sequence_extension().

If a sequence_scalable_extension() occurs after the first sequence_header() all subsequent sequence headers shall be followed by sequence_scalable_extension() in which all data elements are the same as in the first sequence_scalable_extension(). Conversely if no sequence_scalable_extension() occurs between the first sequence_header() and the first picture_header(), then sequence_scalable_extension() shall not occur in the bitstream.

If a sequence_display_extension() occurs after the first sequence_header() all subsequent sequence headers shall be followed by sequence_display_extension() in which all data elements are the same as in the first sequence_display_extension(). Conversely if no sequence_display_extension() occurs between the first sequence_header() and the first picture_header(), then sequence_display_extension() shall not occur in the bitstream.

Repeating the sequence header allows the data elements of the initial sequence header to be repeated in order that random access into the video sequence is possible.

In the coded bitstream, the first picture following a sequence header or a repeated sequence header shall be either an I-picture or a P-picture, but not a B-picture. In the case that an interlaced frame is coded as two separate field pictures, a repeat sequence header shall not precede the second of these two field pictures.

If a bitstream is edited so that all of the data preceding any of the repeat sequence headers is removed (or alternatively random access is made to that sequence header), then the resulting bitstream shall be a legal bitstream that complies with this Specification. In the case that the first picture of the resulting bitstream is a P-picture, it is possible that it will contain non-intra macroblocks. Since the reference picture(s) required by the decoding process are not available, the reconstructed picture may not be fully defined. The time taken to fully refresh the entire frame depends on the refresh techniques employed.

6.1.1.7 I-pictures and group of pictures header

I-pictures are intended to assist random access into the sequence. Applications requiring random access, fast-forward playback, or fast reverse playback may use I-pictures relatively frequently.

I-pictures may also be used at scene cuts or other cases where motion compensation is ineffective.

Group of picture header is an optional header that can be used immediately before a coded I-frame to indicate to the decoder if the first consecutive B-pictures immediately following the coded I-frame can be reconstructed properly in the case of a random access. In effect, if the preceding reference frame is not available, those B-pictures, if any, cannot be reconstructed properly unless they only use backward prediction or intra coding. This is more precisely defined in the clause describing closed_gop and broken_link. A group of picture header also contains a time code information that is not used by the decoding process.

In the coded bitstream, the first coded frame following a group of pictures header shall be a coded I-frame.

6.1.1.8 4:2:0 format

In this format the Cb and Cr matrices shall be one half the size of the Y-matrix in both horizontal and vertical dimensions. The Y-matrix shall have an even number of lines and samples.

> NOTE – When interlaced frames are coded as field pictures, the picture reconstructed from each of these field pictures shall have a Y-matrix with half the number of lines as the corresponding frame. Thus, the total number of lines in the Y-matrix of an entire frame shall be divisible by four.

The luminance and chrominance samples are positioned as shown in Figure 6-1.

In order to further specify the organisation, Figures 6-2 and 6-3 show the vertical and temporal positioning of the samples in an interlaced frame. Figure 6-4 shows the vertical and temporal positioning of the samples in a progressive frame.

In each field of an interlaced frame, the chrominance samples do not lie (vertically) midway between the luminance samples of the field, this is so that the spatial location of the chrominance samples in the frame is the same whether the frame is represented as a single frame-picture or two field-pictures.

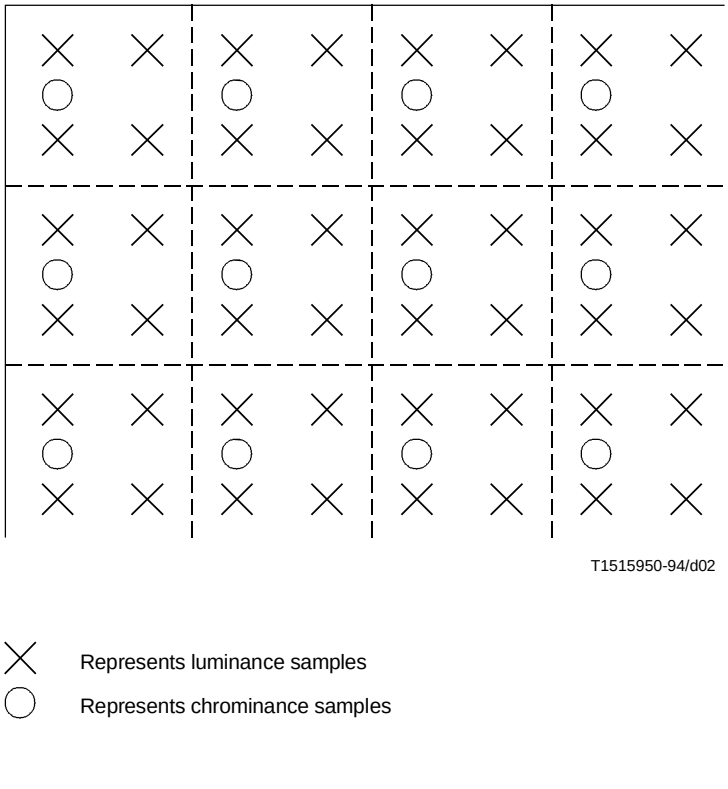


Figure 6-1 – The position of luminance and chrominance samples – 4:2:0 data

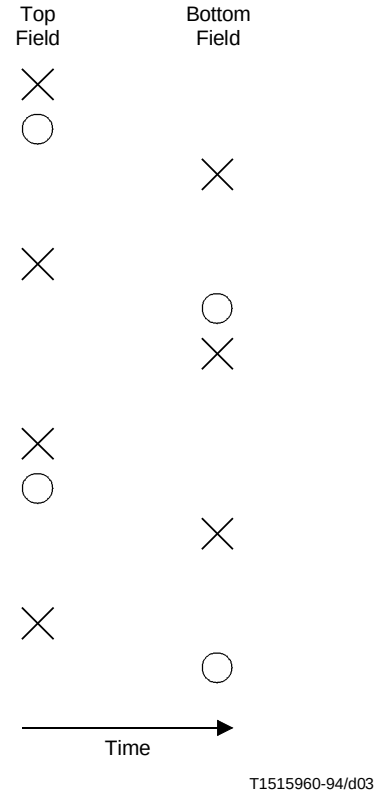


Figure 6-2 – Vertical and temporal positions of samples in an interlaced frame with top_field_first = 1

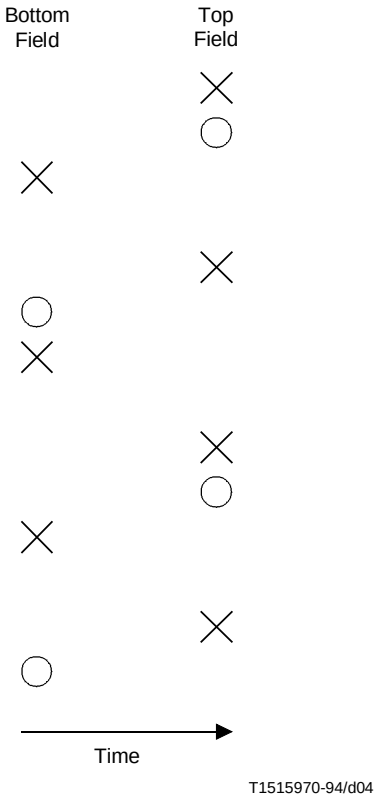


Figure 6-3 – Vertical and temporal positions of samples in an interlaced frame with top_field_first = 0

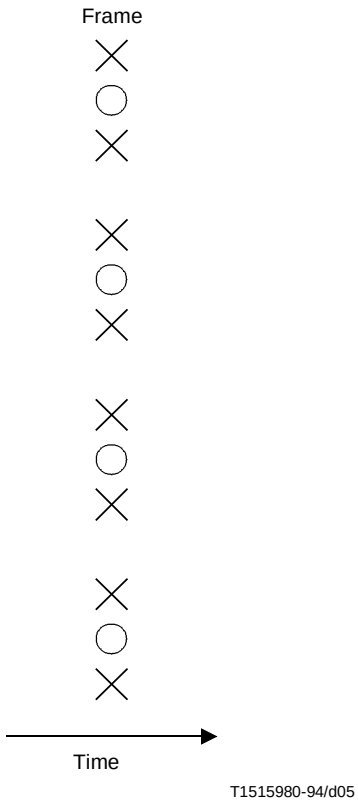


Figure 6-4 – Vertical and temporal positions of samples in a progressive frame

6.1.1.9 4:2:2 format

In this format the Cb and Cr matrices shall be one half the size of the Y-matrix in the horizontal dimension and the same size as the Y-matrix in the vertical dimension. The Y-matrix shall have an even number of samples.

NOTE – When interlaced frames are coded as field pictures, the picture reconstructed from each of these field pictures shall have a Y-matrix with half the number of lines as the corresponding frame. Thus the total number of lines in the Y-matrix of an entire frame shall be divisible by two.

The luminance and chrominance samples are positioned as shown in Figure 6-5.

In order to clarify the organisation, Figure 6-6 shows the (vertical) positioning of the samples when the frame is separated into two fields.

6.1.1.10 4:4:4 format

In this format the Cb and Cr matrices shall be the same size as the Y-matrix in the horizontal and the vertical dimensions.

NOTE – When interlaced frames are coded as field pictures, the picture reconstructed from each of these field pictures shall have a Y-matrix with half the number of lines as the corresponding frame. Thus the total number of lines in the Y-matrix of an entire frame shall be divisible by two.

The luminance and chrominance samples are positioned as shown in Figures 6-6 and 6-7.

6.1.1.11 Frame re-ordering

When the sequence contains coded B-frames, the number of consecutive coded B-frames is variable and unbounded. The first coded frame after a sequence header shall not be a B-frame.

A sequence may contain no coded P-frames. A sequence may also contain no coded I-frames in which case some care is required at the start of the sequence and within the sequence to effect both random access and error recovery.

The order of the coded frames in the bitstream, also called coded order, is the order in which a decoder reconstructs them. The order of the reconstructed frames at the output of the decoding process, also called the display order, is not always the same as the coded order and this subclause defines the rules of frame re-ordering that shall happen within the decoding process.

When the sequence contains no coded B-frames, the coded order is the same as the display order. This is true in particular always when low_delay is one.

When B-frames are present in the sequence, re-ordering is performed according to the following rules:

- If the current frame in coded order is a B-frame, the output frame is the frame reconstructed from that B-frame.
- If the current frame in coded order is a I-frame or P-frame, the output frame is the frame reconstructed from the previous I-frame or P-frame if one exists. If none exists, at the start of the sequence, no frame is output.

The frame reconstructed from the final I-frame or P-frame is output immediately after the frame reconstructed when the last coded frame in the sequence was removed from the VBV buffer.

The following is an example of frames taken from the beginning of a video sequence. In this example there are two coded B-frames between successive coded P-frames and also two coded B-frames between successive coded I- and P-frames and all pictures are frame-pictures. Frame '1I' is used to form a prediction for frame '4P'. Frames '4P' and '1I' are both used to form predictions for frames '2B' and '3B'. Therefore the order of coded frames in the coded sequence shall be '1I', '4P', '2B', '3B'. However, the decoder shall display them in the order '1I', '2B', '3B', '4P'.

At the encoder input:

1	2	3	4	5	6	7	8	9	10	11	12	13
I	B	B	P	B	B	P	B	B	I	B	B	P

At the encoder output, in the coded bitstream, and at the decoder input:

1	4	2	3	7	5	6	10	8	9	13	11	12
I	P	B	B	P	B	B	I	B	B	P	B	B

At the decoder output:

1	2	3	4	5	6	7	8	9	10	11	12	13

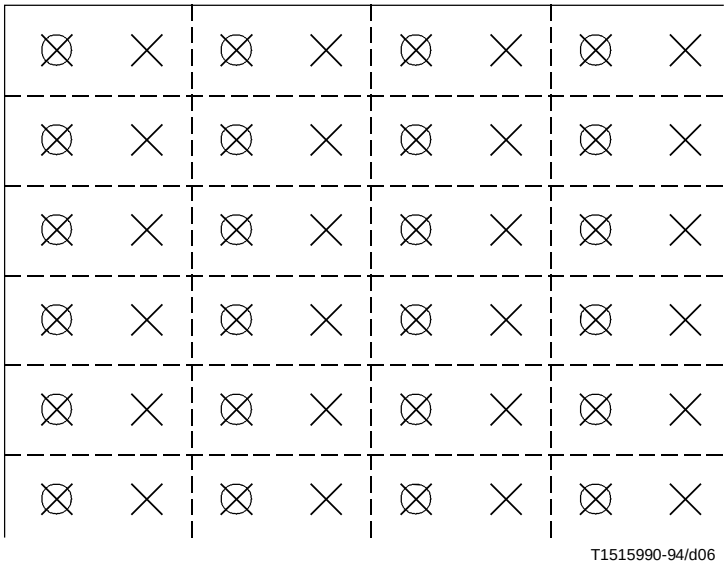


Figure 6-5 – The position of luminance and chrominance samples – 4:2:2 data

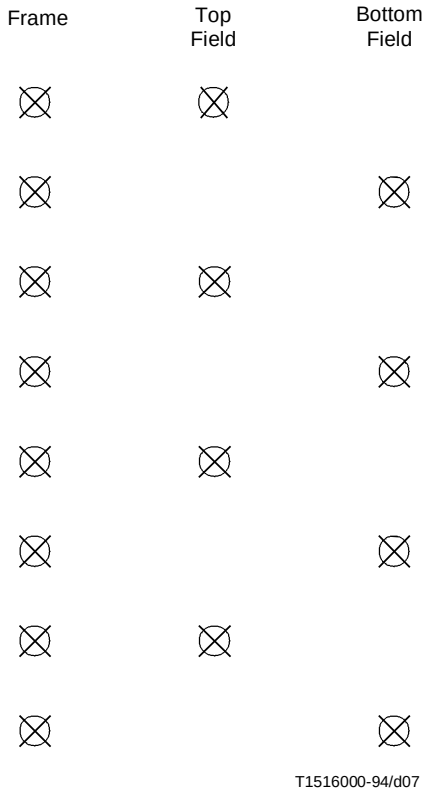


Figure 6-6 – Vertical positions of samples with 4:2:2 and 4:4:4 data



Figure 6-7 – The position of luminance and chrominance samples – 4:4:4 data

6.1.2 Slice

A **slice** is a series of an arbitrary number of consecutive macroblocks. The first and last macroblocks of a slice shall not be skipped macroblocks. Every slice shall contain at least one macroblock. Slices shall not overlap. The position of slices may change from picture to picture.

The first and last macroblock of a slice shall be in the same horizontal row of macroblocks.

Slices shall occur in the bitstream in the order in which they are encountered, starting at the upper-left of the picture and proceeding by raster-scan order from left to right and top to bottom (illustrated in Figures 6-8 and 6-9 as alphabetical order).

6.1.2.1 The general slice structure

In the most general case it is not necessary for the slices to cover the entire picture. Figure 6-8 shows this case. Those areas that are not enclosed in a slice are not encoded and no information is encoded for such areas (in the specific picture).

If the slices do not cover the entire picture, then it is a requirement that if the picture is subsequently used to form predictions, then predictions shall only be made from those regions of the picture that were enclosed in slices. It is the responsibility of the encoder to ensure this.

This Specification does not define what action a decoder shall take in the regions between the slices.

6.1.2.2 Restricted slice structure

In certain defined levels of defined profiles a restricted slice structure illustrated in Figure 6-9 shall be used. In this case every macroblock in the picture shall be enclosed in a slice.

Where a defined level of a defined profile requires that the slice structure obeys the restrictions detailed in this subclause, the term "restricted slice structure" may be used.

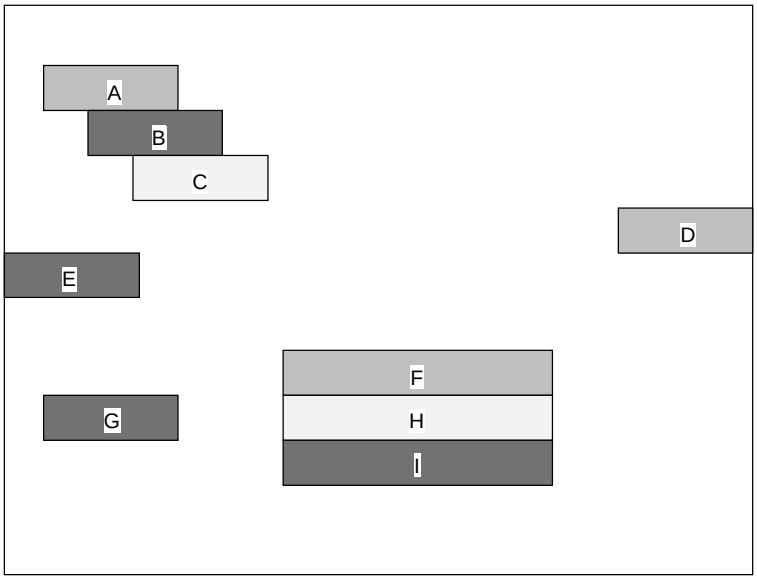


Figure 6-8 – The most general slice structure

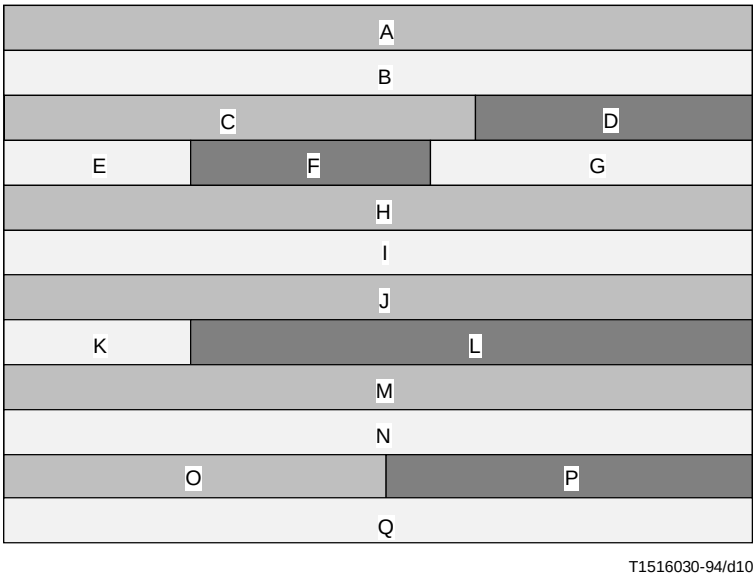


Figure 6-9 – Restricted slice structure

6.1.3 Macroblock

A **macroblock** contains a section of the luminance component and the spatially corresponding chrominance components. The term macroblock can either refer to source and decoded data or to the corresponding coded data elements. A skipped macroblock is one for which no information is transmitted (see 7.6.6). There are three chrominance formats for a macroblock, namely, 4:2:0, 4:2:2 and 4:4:4 formats. The orders of blocks in a macroblock shall be different for each different chrominance format and are illustrated below.

A 4:2:0 Macroblock consists of 6 blocks. This structure holds 4 Y, 1 Cb and 1 Cr Blocks and the block order is depicted in Figure 6-10.

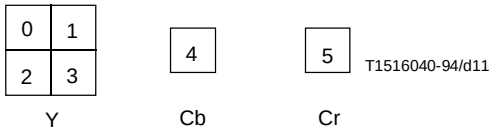


Figure 6-10 – 4:2:0 Macroblock structure

A 4:2:2 Macroblock consists of 8 blocks. This structure holds 4 Y, 2 Cb and 2 Cr Blocks and the block order is depicted in Figure 6-11.

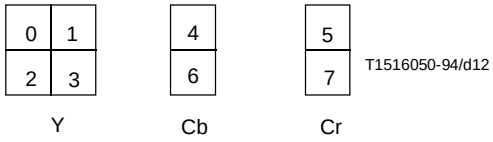


Figure 6-11 – 4:2:2 Macroblock structure

A 4:4:4 Macroblock consists of 12 blocks. This structure holds 4 Y, 4 Cb and 4 Cr Blocks and the block order is depicted in Figure 6-12.

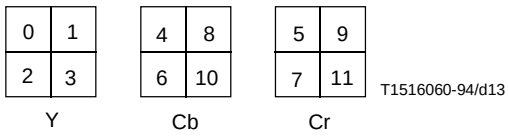


Figure 6-12 – 4:4:4 Macroblock structure

In frame pictures, where both frame and field DCT coding may be used, the internal organisation within the macroblock is different in each case.

- In the case of frame DCT coding, each block shall be composed of lines from the two fields alternately. This is illustrated in Figure 6-13.
- In the case of field DCT coding, each block shall be composed of lines from only one of the two fields. This is illustrated in Figure 6-14.

In the case of chrominance blocks the structure depends upon the chrominance format that is being used. In the case of 4:2:2 and 4:4:4 formats (where there are two blocks in the vertical dimension of the macroblock) the chrominance blocks are treated in exactly the same manner as the luminance blocks. However, in the 4:2:0 format the chrominance blocks shall always be organised in frame structure for the purposes of DCT coding. It should, however, be noted that field based predictions may be made for these blocks which will, in the general case, require that predictions for 8×4 regions (after half-sample filtering) must be made.

In field pictures, each picture only contains lines from one of the fields. In this case each block consists of lines taken from successive lines in the picture as illustrated by Figure 6-13.

6.1.4 Block

The term "**block**" can refer either to source and reconstructed data or to the DCT coefficients or to the corresponding coded data elements.

When "block" refers to source and reconstructed data it refers to an orthogonal section of a luminance or chrominance component with the same number of lines and samples. There are 8 lines and 8 samples in the block.

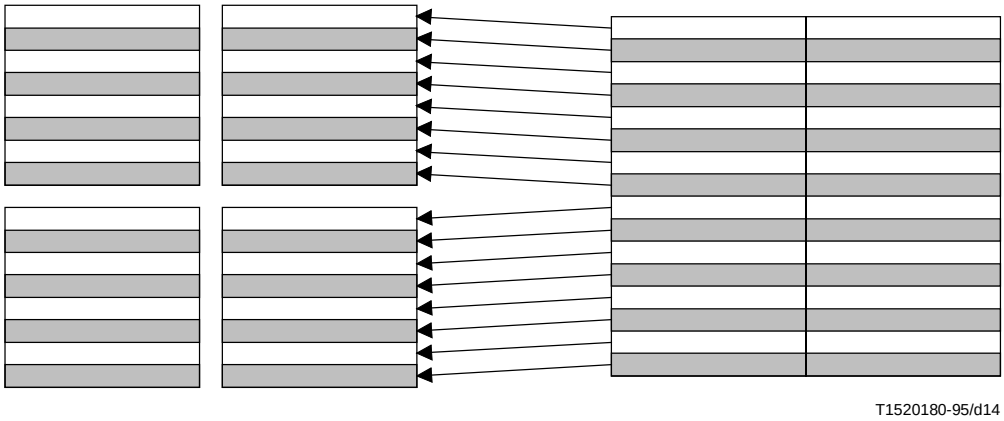


Figure 6-13 – Luminance macroblock structure in frame DCT coding

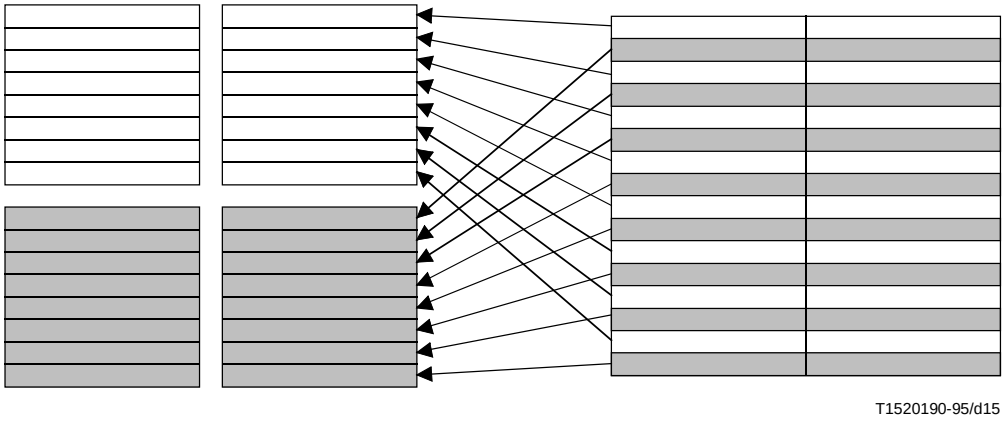


Figure 6-14 – Luminance macroblock structure in field DCT coding

6.2 Video bitstream syntax

6.2.1 Start codes

Start codes are specific bit patterns that do not otherwise occur in the video stream.

Each start code consists of a start code prefix followed by a start code value. The start code prefix is a string of twenty three bits with the value zero followed by a single bit with the value one. The start code prefix is thus the bit string '0000 0000 0000 0000 0000 0001'.

The start code value is an eight bit integer which identifies the type of start code. Most types of start code have just one start code value. However, slice_start_code is represented by many start code values, in this case the start code value is the slice_vertical_position for the slice.

All start codes shall be byte aligned. This shall be achieved by inserting bits with the value zero before the start code prefix such that the first bit of the start code prefix is the first (most significant) bit of a byte.

Table 6-1 defines the start code values for the start codes used in the video bitstream.

The use of the start codes is defined in the following syntax description with the exception of the sequence_error_code. The sequence_error_code has been allocated for use by a media interface to indicate where uncorrectable errors have been detected.

Table 6-1 – Start code values

Name	Start code value (hexadecimal)
picture_start_code	00
slice_start_code	01 through AF
reserved	B0
reserved	B1
user_data_start_code	B2
sequence_header_code	B3
sequence_error_code	B4
extension_start_code	B5
reserved	B6
sequence_end_code	B7
group_start_code	B8
system start codes (Note)	B9 through FF
NOTE – System start codes are defined in Part 1 of this Specification.	

6.2.2 Video Sequence

video_sequence() {	No. of bits	Mnemonic
next_start_code()		
sequence_header()		
if (nextbits() == extension_start_code) {		
sequence_extension()		
do {		
extension_and_user_data(0)		
do {		
if (nextbits() == group_start_code) {		
group_of_pictures_header()		
extension_and_user_data(1)		
}		
picture_header()		
picture_coding_extension()		
extensions_and_user_data(2)		
picture_data()		
} while ((nextbits() == picture_start_code) ||		
(nextbits() == group_start_code))		
if (nextbits() != sequence_end_code) {		
sequence_header()		
sequence_extension()		
}		
} while (nextbits() != sequence_end_code)		
} else {		
/* ISO/IEC 11172-2 */		
}		
sequence_end_code	32	bslbf
}		

6.2.2.1 Sequence header

sequence_header() {	No. of bits	Mnemonic
sequence_header_code	32	bslbf
horizontal_size_value	12	uimsbf
vertical_size_value	12	uimsbf
aspect_ratio_information	4	uimsbf
frame_rate_code	4	uimsbf
bit_rate_value	18	uimsbf
marker_bit	1	bslbf
vbv_buffer_size_value	10	uimsbf
constrained_parameters_flag	1	bslbf
load_intra_quantiser_matrix	1	uimsbf
if (load_intra_quantiser_matrix)		
intra_quantiser_matrix[64]	8*64	uimsbf
load_non_intra_quantiser_matrix	1	uimsbf
if (load_non_intra_quantiser_matrix)		
non_intra_quantiser_matrix[64]	8*64	uimsbf
next_start_code()		
}		

6.2.2.2 Extension and user data

extension_and_user_data(i) {	No. of bits	Mnemonic
while ((nextbits()== extension_start_code) ||		
(nextbits()== user_data_start_code)) {		
if ((i != 1) && (nextbits()== extension_start_code))		
extension_data(i)		
if (nextbits()== user_data_start_code)		
user_data()		
}		
}		

6.2.2.2.1 Extension data

extension_data(i) {	No. of bits	Mnemonic
while (nextbits()== extension_start_code) {		
extension_start_code	32	bslbf
if (i == 0) { /* follows sequence_extension() */		
if (nextbits()== "Sequence Display Extension ID")		
sequence_display_extension()		
else if (nextbits()		
== "Sequence Scalable Extension ID")		
sequence_scalable_extension()		
}		
/* NOTE – i never takes the value 1 because extension_data()		
never follows a group_of_pictures_header() */		
if (i == 2) { /* follows picture_coding_extension() */		
if (nextbits() == "Quant Matrix Extension ID")		
quant_matrix_extension()		
else if (nextbits() == "Copyright Extension ID")		
copyright_extension()		
else if (nextbits() == "Picture Display Extension ID")		
picture_display_extension()		
else if (nextbits()		
== "Picture Spatial Scalable Extension ID")		
picture_spatial_scalable_extension()		
else if (nextbits()		
== "Picture Temporal Scalable Extension ID")		
picture_temporal_scalable_extension()		
else if (nextbits()		
== "Camera Parameters Extension ID")		
camera_parameters_extension()		
else if (nextbits()		
== "ITU-T Extension ID")		
ITU-T_extension()		
}		
}		
}		

6.2.2.2.2 User data

user_data() {	No. of bits	Mnemonic
user_data_start_code	32	bslbf
while(nextbits() != '0000 0000 0000 0000 0000 0001') {		
user_data	8	uimsbf
}		
next_start_code()		
}		

6.2.2.3 Sequence extension

sequence_extension() {	No. of bits	Mnemonic
extension_start_code	32	bslbf
extension_start_code_identifier	4	uimsbf
profile_and_level_indication	8	uimsbf
progressive_sequence	1	uimsbf
chroma_format	2	uimsbf
horizontal_size_extension	2	uimsbf
vertical_size_extension	2	uimsbf
bit_rate_extension	12	uimsbf
marker_bit	1	bslbf
vbv_buffer_size_extension	8	uimsbf
low_delay	1	uimsbf
frame_rate_extension_n	2	uimsbf
frame_rate_extension_d	5	uimsbf
next_start_code()		
}		

6.2.2.4 Sequence display extension

sequence_display_extension() {	No. of bits	Mnemonic
extension_start_code_identifier	4	uimsbf
video_format	3	uimsbf
colour_description	1	uimsbf
if (colour_description) {		
colour_primaries	8	uimsbf
transfer_characteristics	8	uimsbf
matrix_coefficients	8	uimsbf
}		
display_horizontal_size	14	uimsbf
marker_bit	1	bslbf
display_vertical_size	14	uimsbf
next_start_code()		
}		

6.2.2.5 Sequence scalable extension

sequence_scalable_extension() {	No. of bits	Mnemonic
extension_start_code_identifier	4	uimsbf
scalable_mode	2	uimsbf
layer_id	4	uimsbf
if (scalable_mode == "spatial scalability") {		
lower_layer_prediction_horizontal_size	14	uimsbf
marker_bit	1	bslbf
lower_layer_prediction_vertical_size	14	uimsbf
horizontal_subsampling_factor_m	5	uimsbf
horizontal_subsampling_factor_n	5	uimsbf
vertical_subsampling_factor_m	5	uimsbf
vertical_subsampling_factor_n	5	uimsbf
}		
if (scalable_mode == "temporal scalability") {		
picture_mux_enable	1	uimsbf
if (picture_mux_enable)		
mux_to_progressive_sequence	1	uimsbf
picture_mux_order	3	uimsbf
picture_mux_factor	3	uimsbf
}		
next_start_code()		
}		

6.2.2.6 Group of pictures header

group_of_pictures_header() {	No. of bits	Mnemonic
group_start_code	32	bslbf
time_code	25	uimsbf
closed_gop	1	uimsbf
broken_link	1	uimsbf
next_start_code()		
}		

6.2.3 Picture header

picture_header() {	No. of bits	Mnemonic
picture_start_code	32	bslbf
temporal_reference	10	uimsbf
picture_coding_type	3	uimsbf
vbv_delay	16	uimsbf
if (picture_coding_type == 2 || picture_coding_type == 3) {		
full_pel_forward_vector	1	bslbf
forward_f_code	3	bslbf
}		
if (picture_coding_type == 3) {		
full_pel_backward_vector	1	bslbf
backward_f_code	3	bslbf
}		
while (nextbits() == '1') {		
extra_bit_picture /* with the value '1' */	1	uimsbf
extra_information_picture	8	uimsbf
}		
extra_bit_picture /* with the value '0' */	1	uimsbf
next_start_code()		
}		

6.2.3.1 Picture coding extension

picture_coding_extension() {	No . of bits	Mnemonic
extension_start_code	32	bslbf
extension_start_code_identifier	4	uimsbf
f_code[0][0] /* forward horizontal */	4	uimsbf
f_code[0][1] /* forward vertical */	4	uimsbf
f_code[1][0] /* backward horizontal */	4	uimsbf
f_code[1][1] /* backward vertical */	4	uimsbf
intra_dc_precision	2	uimsbf
picture_structure	2	uimsbf
top_field_first	1	uimsbf
frame_pred_frame_dct	1	uimsbf
concealment_motion_vectors	1	uimsbf
q_scale_type	1	uimsbf
intra_vlc_format	1	uimsbf
alternate_scan	1	uimsbf
repeat_first_field	1	uimsbf
chroma_420_type	1	uimsbf
progressive_frame	1	uimsbf
composite_display_flag	1	uimsbf
if (composite_display_flag) {		
v_axis	1	uimsbf
field_sequence	3	uimsbf
sub_carrier	1	uimsbf
burst_amplitude	7	uimsbf
sub_carrier_phase	8	uimsbf
}		
next_start_code()		
}		

6.2.3.2 Quant matrix extension

quant_matrix_extension() {	No. of bits	Mnemonic
extension_start_code_identifier	4	uimsbf
load_intra_quantiser_matrix	1	uimsbf
if (load_intra_quantiser_matrix)		
intra_quantiser_matrix[64]	8 * 64	uimsbf
load_non_intra_quantiser_matrix	1	uimsbf
if (load_non_intra_quantiser_matrix)		
non_intra_quantiser_matrix[64]	8 * 64	uimsbf
load_chroma_intra_quantiser_matrix	1	uimsbf
if (load_chroma_intra_quantiser_matrix)		
chroma_intra_quantiser_matrix[64]	8 * 64	uimsbf
load_chroma_non_intra_quantiser_matrix	1	uimsbf
if (load_chroma_non_intra_quantiser_matrix)		
chroma_non_intra_quantiser_matrix[64]	8 * 64	uimsbf
next_start_code()		
}		

6.2.3.3 Picture display extension

picture_display_extension() {	No. of bits	Mnemonic
extension_start_code_identifier	4	uimsbf
for (i = 0; i < number_of_frame_centre_offsets; i ++) {		
frame_centre_horizontal_offset	16	simsbf
marker_bit	1	bslbf
frame_centre_vertical_offset	16	simsbf
marker_bit	1	bslbf
}		
next_start_code()		
}		

6.2.3.4 Picture temporal scalable extension

picture_temporal_scalable_extension() {	No. of bits	Mnemonic
extension_start_code_identifier	4	uimsbf
reference_select_code	2	uimsbf
forward_temporal_reference	10	uimsbf
marker_bit	1	bslbf
backward_temporal_reference	10	uimsbf
next_start_code()		
}		

6.2.3.5 Picture spatial scalable extension

picture_spatial_scalable_extension() {	No. of bits	Mnemonic
extension_start_code_identifier	4	uimsbf
lower_layer_temporal_reference	10	uimsbf
marker_bit	1	bslbf
lower_layer_horizontal_offset	15	simsbf
marker_bit	1	bslbf
lower_layer_vertical_offset	15	simsbf
spatial_temporal_weight_code_table_index	2	uimsbf
lower_layer_progressive_frame	1	uimsbf
lower_layer_deinterlaced_field_select	1	uimsbf
next_start_code()		
}		

6.2.3.6 Copyright extension

copyright_extension() {	No. of bits	Mnemonic
extension_start_code_identifier	4	uimsbf
copyright_flag	1	uimsbf
copyright_identifier	8	uimsbf
original_or_copy	1	uimsbf
reserved	7	bslbf
marker_bit	1	bslbf
copyright_number_1	20	uimsbf
marker_bit	1	bslbf
copyright_number_2	22	uimsbf
marker_bit	1	bslbf
copyright_number_3	22	uimsbf
next_start_code()		
}		

6.2.3.7 Picture data

picture_data() {	No. of bits	Mnemonic
do {		
slice()		
} while (nextbits() == slice_start_code)		
next_start_code()		
}		

6.2.3.7.1 Camera parameters extension

camera_parameters_extension() {	No. of bits	Mnemonic
extension_start_code_identifier	4	uimsbf
reserved	1	uimsbf
camera_id	7	simsbf
marker_bit	1	bslbf
height_of_image_device	22	uimsbf
marker_bit	1	bslbf
focal_length	22	uimsbf
marker_bit	1	bslbf
f_number	22	uimsbf
marker_bit	1	bslbf
vertical_angle_of_view	22	uimsbf
marker_bit	1	bslbf
camera_position_x_upper	16	simsbf
marker_bit	1	bslbf
camera_position_x_lower	16	
marker_bit	1	bslbf
camera_position_y_upper	16	simsbf
marker_bit	1	bslbf
camera_position_y_lower	16	
marker_bit	1	bslbf
camera_position_z_upper	16	simsbf
marker_bit	1	bslbf
camera_position_z_lower	16	
marker_bit	1	bslbf
camera_direction_x	22	simsbf
marker_bit	1	bslbf
camera_direction_y	22	simsbf
marker_bit	1	bslbf
camera_direction_z	22	simsbf
marker_bit	1	bslbf
image_plane_vertical_x	22	simsbf
marker_bit	1	bslbf
image_plane_vertical_y	22	simsbf
marker_bit	1	bslbf
image_plane_vertical_z	22	simsbf
marker_bit	1	bslbf
reserved	32	bslbf
next_start_code()		
}		

NOTE – The parameters marked 'reserved' in the camera parameters extension shall be equal to zero. Other values are reserved for future use by ITU-T | ISO/IEC.

6.2.3.7.2 ITU-T extension

ITU-T_extension() {	No. of bits	Mnemonic
extension_start_code_identifier	4	uimsbf
while(nextbits() != '0000 0000 0000 0000 0000 0001') {		
ITU-T_data	1	uimsbf
}		
next_start_code()		
}		
NOTE – The construct with the while-statement prevents start code emulation.		

6.2.4 Slice

slice() {	No. of bits	Mnemonic
slice_start_code	32	bslbf
if (vertical_size > 2800)		
slice_vertical_position_extension	3	uimsbf
if (<*sequence_scalable_extension() is present in the bitstream*>) {		
if (scalable_mode == 'data partitioning')		
priority_breakpoint	7	uimsbf
}		
quantiser_scale_code	5	uimsbf
if (nextbits() == '1') {		
slice_extension_flag	1	bslbf
intra_slice	1	uimsbf
slice_picture_id_enable	1	uimsbf
slice_picture_id	6	uimbsf
while (nextbits() == '1') {		
extra_bit_slice /* with the value '1' */	1	uimsbf
extra_information_slice	8	uimsbf
}		
}		
extra_bit_slice /* with the value '0' */	1	uimsbf
do {		
macroblock()		
} while (nextbits() != '000 0000 0000 0000 0000 0000')		
next_start_code()		
}		

6.2.5 Macroblock

macroblock() {	No. of bits	Mnemonic
while (nextbits() == '0000 0001 000')		
macroblock_escape	11	bslbf
macroblock_address_increment	1-11	vlclbf
macroblock_modes()		
if (macroblock_quant)		
quantiser_scale_code	5	uimsbf
if (macroblock_motion_forward ||		
(macroblock_intra && concealment_motion_vectors))		
motion_vectors(0)		
if (macroblock_motion_backward)		
motion_vectors(1)		
if (macroblock_intra && concealment_motion_vectors)		
marker_bit	1	bslbf
if (macroblock_pattern)		
coded_block_pattern()		
for (i = 0; i < block_count; i + +) {		
block(i)		
}		
}		

6.2.5.1 Macroblock modes

macroblock_modes() {	No. of bits	Mnemonic
macroblock_type	1-9	vlclbf
if ((spatial_temporal_weight_code_flag == 1) &&		
(spatial_temporal_weight_code_table_index != '00')) {		
spatial_temporal_weight_code	2	uimsbf
}		
if (macroblock_motion_forward ||		
macroblock_motion_backward) {		
if (picture_structure == 'frame') {		
if (frame_pred_frame_dct == 0)		
frame_motion_type	2	uimsbf
} else {		
field_motion_type	2	uimsbf
}		
}		
if ((picture_structure == "Frame picture") &&		
(frame_pred_frame_dct == 0) &&		
(macroblock_intra || macoblock_pattern)){		
dct_type	1	uimsbf
}		
}		

6.2.5.2 Motion vectors

motion_vectors (s) {	No. of bits	Mnemonic
if (motion_vector_count == 1) {		
if ((mv_format == field) && (dmv != 1))		
motion_vertical_field_select[0][s]	1	uimsbf
motion_vector(0, s)		
} else {		
motion_vertical_field_select[0][s]	1	uimsbf
motion_vector(0, s)		
motion_vertical_field_select[1][s]	1	uimsbf
motion_vector(1, s)		
}		
}		

6.2.5.2.1 Motion vector

motion_vector (r, s) {	No. of bits	Mnemonic
motion_code[r][s][0]	1-11	vlclbf
if ((f_code[s][0] != 1) && (motion_code[r][s][0] != 0))		
motion_residual[r][s][0]	1-8	uimsbf
if (dmv == 1)		
dmvector[0]	1-2	vlclbf
motion_code[r][s][1]	1-11	vlclbf
if ((f_code[s][1] != 1) && (motion_code[r][s][1] != 0))		
motion_residual[r][s][1]	1-8	uimsbf
if (dmv == 1)		
dmvector[1]	1-2	vlclbf
}		

6.2.5.3 Coded block pattern

coded_block_pattern () {	No. of bits	Mnemonic
coded_block_pattern_420	3-9	vlclbf
if (chroma_format == 4:2:2)		
coded_block_pattern_1	2	uimsbf
if (chroma_format == 4:4:4)		
coded_block_pattern_2	6	uimsbf
}		

6.2.6 Block

The detailed syntax for the terms "First DCT coefficient", "Subsequent DCT coefficient" and "End of Block" is fully described in 7.2.

This subclause does not adequately document the block layer syntax when data partitioning is used. See 7.10.

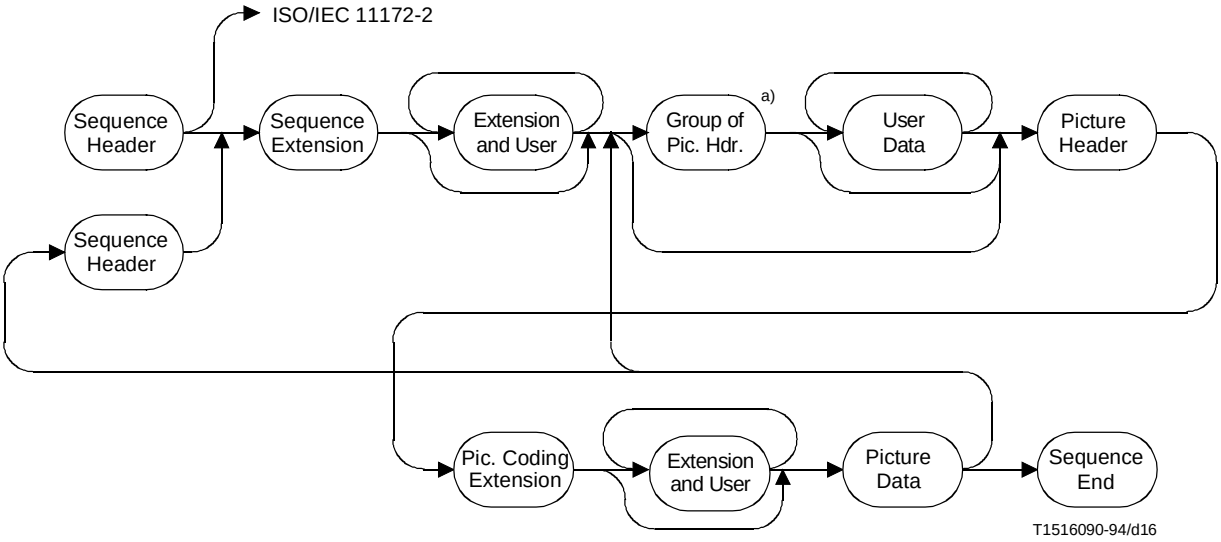
block(i) {	No. of bits	Mnemonic
if (pattern_code[i]) {		
if (macroblock_intra) {		
if (i < 4) {		
dct_dc_size_luminance	2-9	vlclbf
if(dct_dc_size_luminance != 0)		
dct_dc_differential	1-11	uimsbf
} else {		
dct_dc_size_chrominance	2-10	vlclbf
if(dct_dc_size_chrominance != 0)		
dct_dc_differential	1-11	uimsbf
}		
} else {		
First DCT coefficient	2-24	vlclbf
}		
while (nextbits() != End of block)		
Subsequent DCT coefficients	3-24	vlclbf
End of block	2 or 4	vlclbf
}		
}		

6.3 Video bitstream semantics

6.3.1 Semantic rules for higher syntactic structures

This subclause details the rules that govern the way in which the higher level syntactic elements may be combined together to produce a legal bitstream. Subsequent clauses detail the semantic meaning of all fields in the video bitstream.

Figure 6-15 illustrates the high level structure of the video bitstream.



a) After a GOP, the first picture shall be an I-picture.

Figure 6-15 – High level bitstream organisation

The following semantic rules apply:

- If the first sequence_header() of the sequence is not followed by sequence_extension(), then the stream shall conform to ISO/IEC 11172-2 and is not documented within this Specification.
- If the first sequence_header() of a sequence is followed by a sequence_extension(), then all subsequent occurrences of sequence_header() shall also be immediately followed by a sequence_extension().
- sequence_extension() shall only occur immediately following a sequence_header().
- Following a sequence_header() there shall be at least one coded picture before a repeat sequence_header() or a sequence_end_code. This implies that sequence_extension() shall not immediately precede a sequence_end_code.
- If sequence_extension() occurs in the bitstream, then each picture_header() shall be followed immediately by a picture_coding_extension().
- sequence_end_code shall be positioned at the end of the bitstream such that, after decoding and frame re-ordering, there shall be no missing frames.
- picture_coding_extension() shall only occur immediately following a picture_header().
- The first coded frame following a group_of_pictures_header() shall be a coded I-frame.

A number of different extensions are defined in addition to sequence_extension() and picture_coding_extension(). The set of allowed extensions is different at each different point in the syntax where extensions are allowed. Table 6-2 defines a four bit extension_start_code_identifier for each extension.

Table 6-2 – extension_start_code_identifier codes

extension_start_code_identifier	Name
0000	Reserved
0001	Sequence Extension ID
0010	Sequence Display Extension ID
0011	Quant Matrix Extension ID
0100	Copyright Extension ID
0101	Sequence Scalable Extension ID
0110	Reserved
0111	Picture Display Extension ID
1000	Picture Coding Extension ID
1001	Picture Spatial Scalable Extension ID
1010	Picture Temporal Scalable Extension ID
1011	Camera Parameters Extension ID
1100	ITU-T extension ID
1101	Reserved
...	...
1111	Reserved

At each point where extensions are allowed in the bitstream any number of the extensions from the defined allowable set may be included. However, each type of extension shall not occur more than once.

In the case that a decoder encounters an extension with an extension identification that is described as "reserved" in this Specification, the decoder shall discard all subsequent data until the next start code. This requirement allows future definition of compatible extensions to this Specification.

6.3.2 Video sequence

sequence_end_code – The sequence_end_code is the bit string '000001B7' in hexadecimal. It terminates a video sequence.

6.3.3 Sequence header

sequence_header_code – The sequence_header_code is the bit string '000001B3' in hexadecimal. It identifies the beginning of a sequence header.

horizontal_size_value – This word forms the 12 least significant bits of horizontal_size.

vertical_size_value – This word forms the 12 least significant bits of vertical_size.

horizontal_size – The horizontal_size is a 14-bit unsigned integer, the 12 least significant bits are defined in horizontal_size_value, the 2 most significant bits are defined in horizontal_size_extension. The horizontal_size is the width of the displayable part of the luminance component of pictures in samples. The width of the encoded luminance component of pictures in macroblocks, mb_width, is (horizontal_size + 15)/16. The displayable part is left-aligned in the encoded pictures.

In order to avoid start code emulation horizontal_size_value shall not be zero. This precludes values of horizontal_size that are multiples of 4096.

vertical_size – The vertical_size is a 14-bit unsigned integer, the 12 least significant bits are defined in vertical_size_value, the 2 most significant bits are defined in vertical_size_extension. The vertical_size is the height of the displayable part of the luminance component of the frame in lines.

In the case that progressive_sequence is '1' the height of the encoded luminance component of frames in macroblocks, mb_height, is (vertical_size + 15)/16.

In the case that progressive_sequence is '0' the height of the encoded luminance component of frame pictures in macroblocks, mb_height, is 2*((vertical_size + 31)/32). The height of the encoded luminance component of field pictures in macroblocks, mb_height, is ((vertical_size + 31)/32).

The displayable part is top-aligned in the encoded pictures.

In order to avoid start code emulation vertical_size_value shall not be zero. This precludes values of vertical_size that are multiples of 4096.

aspect_ratio_information – This is a four-bit integer defined in Table 6-3.

Table 6-3 – aspect_ratio_information

aspect_ratio_information	Sample Aspect Ratio	DAR
0000	Forbidden	Forbidden
0001	1.0 (Square Sample)	–
0010	–	3 ÷ 4
0011	–	9 ÷ 16
0100	–	1 ÷ 2.21
0101	–	Reserved
…		…
1111	–	Reserved

aspect_ratio_information either specifies that the "Sample Aspect Ratio" (SAR) of the reconstructed frame is 1,0 (square samples) or alternatively it gives the "Display Aspect Ratio" (DAR).

- If sequence_display_extension() is not present, then it is intended that the entire reconstructed frame is intended to be mapped to the entire active region of the display. The sample aspect ratio may be calculated as follows:

$$SAR = DAR \times \frac{horizontal\_size}{vertical\_size}$$

  NOTE 1 – In this case horizontal_size and vertical_size are constrained by the SAR of the source and the DAR selected.

- If sequence_display_extension() is present then the sample aspect ratio may be calculated as follows:

$$SAR = DAR \times \frac{display\_horizontal\_size}{display\_vertical\_size}$$

frame_rate_code – This is a four-bit integer used to define frame_rate_value as shown in Table 6-4. frame_rate may be derived from frame_rate_value, frame_rate_extension_n and frame_rate_extension_d as follows:

frame_rate = frame_rate_value * (frame_rate_extension_n + 1) ÷ (frame_rate_extension_d + 1)

When an entry for the frame rate exists directly in Table 6-4, frame_rate_extension_n and frame_rate_extension_d shall be zero. (frame_rate_extension_n + 1) and (frame_rate_extension_d + 1) shall not have a common divisor greater than one.

Table 6-4 – frame_rate_value

frame_rate_code	frame_rate_value
0000	Forbidden
0001	24 000 ÷ 1001 (23.976…)
0010	24
0011	25
0100	30 000 ÷ 1001 (29.97…)
0101	30
0110	50
0111	60 000 ÷ 1001 (59.94…)
1000	60
1001	Reserved
…	…
1111	Reserved

If progressive_sequence is '1' the period between two successive frames at the output of the decoding process is the reciprocal of the frame_rate. See Figure 7-18.

If progressive_sequence is '0' the period between two successive fields at the output of the decoding process is half of the reciprocal of the frame_rate. See Figure 7-20.

The frame_rate signalled in the enhancement layer of temporal scalability is the combined frame rate after the temporal re-multiplex operation if picture_mux_enable in the sequence_scalable_extension() is set to '1'.

bit_rate_value – The lower 18 bits of bit_rate.

bit_rate – This is a 30-bit integer. The lower 18 bits of the integer are in bit_rate_value and the upper 12 bits are in bit_rate_extension. bit_rate is measured in units of 400 bits/second, rounded upwards. The value zero is forbidden.

The bitrate specified bounds the maximum rate of operation of the VBV as defined in C.3.

The VBV operates in one of two modes depending on the coded values in vbv_delay. In all cases (both constant and variable bitrate operation) the bitrate specified shall be the upper bound of the rate at which the coded data is supplied to the input of the VBV.

NOTE 2 – Since constant bitrate operation is simply a special case of variable bitrate operation there is no requirement that the value of bit_rate is the actual bitrate at which the data is supplied. However it is recommended in the case of constant bitrate operation that bit_rate should represent the actual bitrate.

marker_bit – This is one bit that shall be set to '1'. This bit prevents emulation of start codes.

vbv_buffer_size_value – the lower 10 bits of vbv_buffer_size.

vbv_buffer_size – vbv_buffer_size is an 18-bit integer. The lower 10 bits of the integer are in vbv_buffer_size_value and the upper 8 bits are in vbv_buffer_size_extension. The integer defines the size of the VBV (Video Buffering Verifier, see Annex C) buffer needed to decode the sequence. It is defined as:

$$B = 16 * 1024 * vbv\_buffer\_size$$

where B is the minimum VBV buffer size in bits required to decode the sequence (see Annex C).

constrained_parameters_flag – This flag (used in ISO/IEC 11172-2) has no meaning in this Specification and shall have the value '0'.

load_intra_quantiser_matrix – See 6.3.11 "Quant matrix extension".

intra_quantiser_matrix – See 6.3.11 "Quant matrix extension".

load_non_intra_quantiser_matrix – See 6.3.11 "Quant matrix extension".

non_intra_quantiser_matrix – See 6.3.11 "Quant matrix extension".

6.3.4 Extension and user data

extension_start_code – The extension_start_code is the bit string '000001B5' in hexadecimal. It identifies the beginning of extensions beyond ISO/IEC 11172-2.

6.3.4.1 User data

user_data_start_code – The user_data_start_code is the bit string '000001B2' in hexadecimal. It identifies the beginning of user data. The user data continues until receipt of another start code.

user_data – This is an 8 bit integer, an arbitrary number of which may follow one another. User data is defined by users for their specific applications. In the series of consecutive user_data bytes there shall not be a string of 23 or more consecutive zero bits.

6.3.5 Sequence extension

extension_start_code_identifier – This is a 4-bit integer which identifies the extension. See Table 6-2.

profile_and_level_indication – This is an 8-bit integer used to signal the profile and level identification. The meaning of the bits is given in clause 8.

NOTE – In a scalable hierarchy the bitstreams of each layer may set profile_and_level_indication to a different value as specified in clause 8.

progressive_sequence – When set to '1' the coded video sequence contains only progressive frame-pictures. When progressive_sequence is set to '0' the coded video sequence may contain both frame-pictures and field-pictures, and frame-picture may be progressive or interlaced frames.

chroma_format – This is a two-bit integer indicating the chrominance format as defined in Table 6-5.

horizontal_size_extension – This 2-bit integer is the 2 most significant bits from horizontal_size.

vertical_size_extension – This 2-bit integer is the 2 most significant bits from vertical_size.

bit_rate_extension – This 12-bit integer is the 12 most significant bits from bit_rate.

vbv_buffer_size_extension – This 8-bit integer is the 8 most significant bits from vbv_buffer_size.

Table 6-5 – Meaning of chroma_format

chroma_format	Meaning
00	Reserved
01	4:2:0
10	4:2:2
11	4:4:4

low_delay – This flag, when set to '1', indicates that the sequence does not contain any B-pictures, that the frame re-ordering delay is not present in the VBV description and that the bitstream may contain "big pictures", i.e. that C.7 of the VBV may apply.

When set to '0', it indicates that the sequence may contain B-pictures, that the frame re-ordering delay is present in the VBV description and that bitstream shall not contain big pictures, i.e. C.7 of the VBV does not apply.

This flag is not used during the decoding process and therefore can be ignored by decoders, but it is necessary to define and verify the compliance of low-delay bitstreams.

frame_rate_extension_n – This is a 2-bit integer used to determine the frame_rate. See frame_rate_code.

frame_rate_extension_d – This is a 5-bit integer used to determine the frame_rate. See frame_rate_code.

6.3.6 Sequence display extension

This Specification does not define the display process. The information in this extension does not affect the decoding process and may be ignored by decoders that conform to this Specification.

video_format – This is a three bit integer indicating the representation of the pictures before being coded in accordance with this Specification. Its meaning is defined in Table 6-6. If the sequence_display_extension() is not present in the bitstream, then the video format may be assumed to be "Unspecified video format".

Table 6-6 – Meaning of video_format

video_format	Meaning
000	Component
001	PAL
010	NTSC
011	SECAM
100	MAC
101	Unspecified video format
110	Reserved
111	Reserved

colour_description – A flag which if set to '1' indicates the presence of colour_primaries, transfer_characteristics and matrix_coefficients in the bitstream.

colour_primaries – This 8-bit integer describes the chromaticity coordinates of the source primaries, and is defined in Table 6-7.

In the case that sequence_display_extension() is not present in the bitstream or colour_description is zero, the chromaticity is assumed to be implicitly defined by the application.

transfer_characteristics – This 8-bit integer describes the opto-electronic transfer characteristic of the source picture, and is defined in Table 6-8.

Table 6-7 – Colour Primaries

Value	Primaries		
0	(Forbidden)		
1	Recommendation ITU-R BT.709		
	primary	x	y
	green	0.300	0.600
	blue	0.150	0.060
	red	0.640	0.330
	white D65	0.3127	0.3290
2	Unspecified Video		
	Image characteristics are unknown		
3	Reserved		
4	Recommendation ITU-R BT.470-2 System M		
	primary	x	y
	green	0.21	0.71
	blue	0.14	0.08
	red	0.67	0.33
	white C	0.310	0.316
5	Recommendation ITU-R BT.470-2 System B, G		
	primary	x	y
	green	0.29	0.60
	blue	0.15	0.06
	red	0.64	0.33
	white D65	0.313	0.329
6	SMPTE 170M		
	primary	x	y
	green	0.310	0.595
	blue	0.155	0.070
	red	0.630	0.340
	white D65	0.3127	0.3290
7	SMPTE 240M (1987)		
	primary	x	y
	green	0.310	0.595
	blue	0.155	0.070
	red	0.630	0.340
	white D65	0.3127	0.3291
8-255	Reserved		

Table 6-8 – Transfer Characteristics

Value	Transfer Characteristic
0	(Forbidden)
1	Recommendation ITU-R BT.709 $V = 1.099\ L_c^{0.45} - 0.099$ for $1 \geq L_c \geq 0.018$ $V = 4.500\ L_c$ for $0.018 > L_c \geq 0$
2	Unspecified Video Image characteristics are unknown
3	Reserved
4	Recommendation ITU-R BT.470-2 System M Assumed display gamma 2.2
5	Recommendation ITU-R BT.470-2 System B, G Assumed display gamma 2.8
6	SMPTE 170M $V = 1.099\ L_c^{0.45} - 0.099$ for $1 \geq L_c \geq 0.018$ $V = 4.500\ L_c$ for $0.018 > L_c \geq 0$
7	SMPTE 240M (1987) $V = 1.1115\ L_c^{0.45} - 0.1115$ for $L_c \geq 0.0228$ $V = 4.0\ L_c$ for $0.0228 > L_c$
8	Linear transfer characteristics i.e. $V = L_c$
9-255	Reserved

In the case that sequence_display_extension() is not present in the bitstream or colour_description is zero, the transfer characteristics are assumed to be implicitly defined by the application.

matrix_coefficients – This 8-bit integer describes the matrix coefficients used in deriving luminance and chrominance signals from the green, blue, and red primaries, and is defined in Table 6-9.

Table 6-9 – Matrix Coefficients

Value	Matrix
0	(Forbidden)
1	Recommendation ITU-R BT.709 $E'_Y = 0.7154\ E'_G + 0.0721\ E'_B + 0.2125\ E'_R$ $E'_{PB} = -0.386\ E'_G + 0.500\ E'_B - 0.115\ E'_R$ $E'_{PR} = -0.454\ E'_G - 0.046\ E'_B + 0.500\ E'_R$
2	Unspecified Video Image characteristics are unknown
3	Reserved
4	FCC $E'_Y = 0.59\ E'_G + 0.11\ E'_B + 0.30\ E'_R$ $E'_{PB} = -0.331\ E'_G + 0.500\ E'_B - 0.169\ E'_R$ $E'_{PR} = -0.421\ E'_G - 0.079\ E'_B + 0.500\ E'_R$
5	Recommendation ITU-R BT.470-2 System B, G $E'_Y = 0.587\ E'_G + 0.114\ E'_B + 0.299\ E'_R$ $E'_{PB} = -0.331\ E'_G + 0.500\ E'_B - 0.169\ E'_R$ $E'_{PR} = -0.419\ E'_G - 0.081\ E'_B + 0.500\ E'_R$
6	SMPTE 170M $E'_Y = 0.587\ E'_G + 0.114\ E'_B + 0.299\ E'_R$ $E'_{PB} = -0.331\ E'_G + 0.500\ E'_B - 0.169\ E'_R$ $E'_{PR} = -0.419\ E'_G - 0.081\ E'_B + 0.500\ E'_R$
7	SMPTE 240M (1987) $E'_Y = 0.701\ E'_G + 0.087\ E'_B + 0.212\ E'_R$ $E'_{PB} = -0.384\ E'_G + 0.500\ E'_B - 0.116\ E'_R$ $E'_{PR} = -0.445\ E'_G - 0.055\ E'_B + 0.500\ E'_R$
8-255	Reserved

In Table 6-9:

- E'_Y is analogue with values between 0 and 1;
- E'_{PB} and E'_{PR} are analogue between the values -0.5 and 0.5;
- E'_R, E'_G and E'_B are analogue with values between 0 and 1;
- Y, Cb and Cr are related to E'_Y, E'_{PB} and E'_{PR} by the following formulae:

$$Y = (219 * E'_Y) + 16$$
$$Cb = (224 * E'_{PB}) + 128$$
$$Cr = (224 * E'_{PR}) + 128$$

NOTE 1 – The decoding process given by this Specification limits output sample values for Y, Cr and Cb to the range [0:255]. Thus, sample values outside the range implied by the above equations may occasionally occur at the output of the decoding process. In particular the sample values 0 and 255 may occur.

In the case that sequence_display_extension() is not present in the bitstream or colour_description is zero the matrix coefficients are assumed to be implicitly defined by the application.

NOTE 2 – In applications which may have signals with more than one set of colour primaries, transfer characteristics, and/or matrix coefficients, it is recommended to transmit a sequence display extension with colour_description set to one, and to specify the appropriate values for the colorimetry parameters.

display_horizontal_size – See display_vertical_size.

display_vertical_size – display_horizontal_size and display_vertical_size together define a rectangle which may be considered as the "intended display's" active region. If this rectangle is smaller than the encoded frame size, then the display process may be expected to display only a portion of the encoded frame. Conversely if the display rectangle is larger than the encoded frame size, then the display process may be expected to display the reconstructed frames on a portion of the display device rather than on the whole display device.

display_horizontal_size shall be in the same units as horizontal_size (samples of the encoded frames).

display_vertical_size shall be in the same units as vertical_size (lines of the encoded frames).

display_horizontal_size and display_vertical_size do not affect the decoding process but may be used by the display process that is not standardised in this Specification.

6.3.7 Sequence scalable extension

It is a syntactic restriction that if a sequence_scalable_extension() is present in the bitstream following a given sequence_extension(), then sequence_scalable_extension() shall follow every other occurrence of sequence_extension(). Thus a bitstream is either scalable or it is not scalable. It is not possible to mix scalable and non-scalable coding within a sequence.

scalable_mode – The scalable_mode indicates the type of scalability used in the video sequence. If no sequence_scalable_extension() is present in the bitstream, then no scalability is used for that sequence. scalable_mode also indicates the macroblock_type tables to be used. However, in the case of spatial scalability if no picture_spatial_scalable_extension() is present for a given picture, then that picture shall be decoded in a non-scalable manner (i.e. as if sequence_scalable_extension() had not been present).

Table 6-10 – Definition of scalable_mode

scalable_mode	Meaning	**picture_spatial_scalable-_extension()**	**macroblock_type tables**
sequence_scalable_extension() not present			B-2, B-3 and B-4
00	Data partitioning		B-2, B-3 and B-4
01	Spatial scalability	Present	B-5, B-6 and B-7
		Not present	B-2, B-3 and B-4
10	SNR scalability		B-8
11	Temporal scalability		B-2, B-3 and B-4

layer_id – This is an integer which identifies the layers in a scalable hierarchy. The base layer always has layer_id = 0. However, the base layer of a scalable hierarchy does not carry a sequence_scalable_extension() and hence layer_id, except in the case of data partitioning. Each successive layer has a layer_id which is one greater than the layer for which it is an enhancement.

In the case of data partitioning layer_id shall be zero for partition zero and layer_id shall be one for partition one.

lower_layer_prediction_horizontal_size – This is a 14-bit integer indicating the horizontal size of the lower layer frame which is used for prediction. This shall contain the value contained in horizontal_size (horizontal_size_value and horizontal_size_extension) in the lower layer bitstream.

lower_layer_prediction_vertical_size – This is a 14-bit integer indicating the vertical size of the lower layer frame which is used for prediction. This shall contain the value contained in vertical_size (vertical_size_value and vertical_size_extension) in the lower layer bitstream.

horizontal_subsampling_factor_m – This affects the spatial scalable upsampling process, as defined in 7.7.2. The value zero is forbidden.

horizontal_subsampling_factor_n – This affects the spatial scalable upsampling process, as defined in 7.7.2. The value zero is forbidden.

vertical_subsampling_factor_m – This affects the spatial scalable upsampling process, as defined in 7.7.2. The value zero is forbidden.

vertical_subsampling_factor_n – This affects the spatial scalable upsampling process, as defined in 7.7.2. The value zero is forbidden.

picture_mux_enable – If set to 1, picture_mux_order and picture_mux_factor are used for re-multiplexing prior to display.

mux_to_progressive_sequence – This flag when set to '1' indicates that the decoded pictures corresponding to the two layers shall be temporally multiplexed to generate a progressive sequence for display. When the temporal multiplexing is intended to generate an interlaced sequence this flag shall be '0'.

picture_mux_order – It denotes number of enhancement layer pictures prior to the first base layer picture. It thus assists re-multiplexing of pictures prior to display as it contains information for inverting the demultiplexing performed at the encoder.

picture_mux_factor – It denotes number of enhancement layer pictures between consecutive base layer pictures to allow correct re-multiplexing of base and enhancement layers for display. It also assists in re-multiplexing of pictures prior to display as it contains information for inverting the temporal demultiplexing performed at the encoder. The value '000' is reserved.

6.3.8 Group of pictures header

group_start_code – The group_start_code is the bit string '000001B8' in hexadecimal. It identifies the beginning of a group of pictures header.

time_code – This is a 25-bit integer containing the following: drop_frame_flag, time_code_hours, time_code_minutes, marker_bit, time_code_seconds and time_code_pictures as shown in Table 6-11. The parameters correspond to those defined in the IEC standard publication 60461 for "time and control codes for video tape recorders" (see Bibliography, Annex F). The time code refers to the first picture after the group of pictures header that has a temporal_reference of zero. The drop_frame_flag can be set to either '0' or '1'. It may be set to '1' only if the frame rate is 29.97 Hz. If it is '0' then pictures are counted assuming rounding to the nearest integral number of pictures per second, for example 29.97 Hz would be rounded to and counted as 30 Hz. If it is '1' then picture numbers 0 and 1 at the start of each minute, except minutes 0, 10, 20, 30, 40, 50 are omitted from the count.

NOTE – The information carried by time_code plays no part in the decoding process.

Table 6-11 – time_code

time_code	Range of value	No. of bits	Mnemonic
drop_frame_flag		1	uimsbf
time_code_hours	0 - 23	5	uimsbf
time_code_minutes	0 - 59	6	uimsbf
marker_bit	1	1	bslbf
time_code_seconds	0 - 59	6	uimsbf
time_code_pictures	0 - 59	6	uimsbf

closed_gop – This is a one-bit flag which indicates the nature of the predictions used in the first consecutive B-pictures (if any) immediately following the first coded I-frame following the group of picture header.

closed_gop is set to '1' to indicate that these B-pictures have been encoded using only backward prediction or intra coding.

This bit is provided for use during any editing which occurs after encoding. If the previous pictures have been removed by editing, broken_link may be set to '1' so that a decoder may avoid displaying these B-Pictures following the first I-Picture following the group of picture header. However, if the closed_gop bit is set to '1', then the editor may choose not to set the broken_link bit as these B-Pictures can be correctly decoded.

broken_link – This is a one-bit flag which shall be set to '0' during encoding. It is set to '1' to indicate that the first consecutive B-Pictures (if any) immediately following the first coded I-frame following the group of picture header may not be correctly decoded because the reference frame which is used for prediction is not available (because of the action of editing).

A decoder may use this flag to avoid displaying frames that cannot be correctly decoded.

6.3.9 Picture header

picture_start_code – The picture_start_code is a string of 32 bits having the value 00000100 in hexadecimal.

temporal_reference – The temporal_reference is a 10-bit unsigned integer associated with each coded picture.

The following simple specification applies only when low_delay is equal to zero.

When a coded frame is in the form of two field pictures, the temporal_reference associated with each picture shall be the same (it is called the temporal_reference of the coded frame). The temporal_reference of each coded frame shall increment by one modulo 1024 when examined in display order at the output of the decoding process, except when a group of pictures header occurs. Among the frames coded after a group of pictures header, the temporal_reference of the coded frame that is displayed first, shall be set to zero.

The following more general specification applies when low_delay is equal to zero or one.

If picture A is not a big picture, i.e. the VBV buffer is only examined once before the coded picture A is removed from the VBV buffer and if N is the temporal_reference of picture A, then the temporal_reference of picture B immediately following picture A in display order is equal to:

- 0 if there is a group of pictures header present between picture A and picture B (in coded order).
- (N + 1) % 1024 if picture B is a frame picture or is the first field of a pair of field pictures.
- N if picture B is the second field of a pair of field pictures.

When low_delay is equal to one, there may be situations where the VBV buffer shall be re-examined several times before removing a coded picture (referred to as a big picture) from the VBV buffer.

If picture A is a big picture and if K is the number of times that the VBV buffer is re-examined as defined in C.7 (K > 0), if N is the temporal_reference of picture A, then the temporal_reference of picture B immediately following picture A in display order is equal to:

- K % 1024 if there is a group of pictures header present between picture A and picture B (in coded order).
- (N + K + 1) % 1024 if picture B is a frame picture or is the first field of a pair of field pictures.
- (N + K) % 1024 if picture B is the second field of a pair of field pictures.

NOTE 1 – If the big picture is the first field of a frame coded with field pictures, then the temporal_reference of the two field pictures of that coded frame are not identical.

picture_coding_type – The picture_coding_type identifies whether a picture is an intra-coded picture(I), predictive-coded picture(P) or bidirectionally predictive-coded picture(B). The meaning of picture_coding_type is defined in Table 6-12.

NOTE 2 – Intra-coded pictures with only DC coefficients (D-pictures) that may be used in ISO/IEC 11172-2 are not supported by this Specification.

Table 6-12 – picture_coding_type

picture_coding_type	coding method
000	Forbidden
001	intra-coded (I)
010	predictive-coded (P)
011	bidirectionally-predictive-coded (B)
100	Shall not be used (dc intra-coded (D) in ISO/IEC11172-2)
101	Reserved
110	Reserved
111	Reserved

vbv_delay – The vbv_delay is a 16-bit unsigned integer. In all cases other then when vbv_delay has the value hexadecimal FFFF, the value of vbv_delay is the number of periods of a 90 kHz clock derived from the 27 MHz system clock that the VBV shall wait after receiving the final byte of the picture start code before decoding the picture. vbv_delay shall be coded to represent the delay as specified above or it shall be coded with the value hexadecimal FFFF. If any vbv_delay field in a sequence is coded with hexadecimal FFFF, then all of them shall be coded with this value. If vbv_delay takes the value hexadecimal FFFF, input of data to the VBV buffer is defined in C.3.2, otherwise input to the VBV buffer is defined in C.3.1.

If low_delay is equal '1' and if the bitstream contains big pictures, the vbv_delay values encoded in the picture_header() of big pictures may be wrong if not equal to hexadecimal FFFF.

NOTE 3 – There are several ways of calculating vbv_delay in an encoder.

In all cases it may be calculated by noting that the end-to-end delay through the encoder and decoder buffer is constant for all pictures. The encoder is capable of knowing the delay experienced by the relevant picture start code in the encoder buffer and the total end-to-end delay. Therefore, the value encoded in vbv_delay (the decoder buffer delay of the picture start code) is calculated as the total delay less the delay of the corresponding picture start code in the encoder buffer measured in periods of a 90 kHz clock derived from the 27 MHz system clock.

Alternatively, for constant bitrate operation only, vbv_delay may be calculated from the state of the VBV as follows:

$$vbv\_delay_n = 90\,000 * B_n^* / R$$

where:

$n > 0$

B_n^* = VBV occupancy, measured in bits, immediately before removing picture n from the buffer but after removing any header(s), user data and stuffing that immediately precedes the data elements of picture n.

R = the actual bitrate (i.e. to full accuracy rather than the quantised value given by bit_rate in the sequence header).

An equivalent method of calculating vbv_delay for variable bitrate streams can be derived from the equation in C.3.1. This will be in the form of a recurrence relation for the vbv_delay given the previous vbv_delay, the decoding times of the current and previous pictures, and the number of bytes in the previous picture. This method can be applied if, at the time vbv_delay is encoded, the average bitrate of the transfer of the picture data of the previous picture is known.

full_pel_forward_vector – This flag that is used in ISO/IEC 11172-2 is not used by this Specification. It shall have the value '0'.

forward_f_code – This 3 bit string (which is used in ISO/IEC 11172-2) is not used by this Specification. It shall have the value '111'.

full_pel_backward_vector – This flag that is used in ISO/IEC 11172-2 is not used by this Specification. It shall have the value '0'.

backward_f_code – This 3 bit string (which is used in ISO/IEC 11172-2) is not used by this Specification. It shall have the value '111'.

extra_bit_picture – A bit indicates the presence of the following extra information. If extra_bit_picture is set to '1', extra_information_picture will follow it. If it is set to '0', there are no data following it. extra_bit_picture shall be set to '0', the value '1' is reserved for possible future extensions defined by ITU-T | ISO/IEC.

extra_information_picture – Reserved. A decoder conforming to this Specification that encounters extra_information_picture in a bitstream shall ignore it (i.e. remove from the bitstream and discard). A bitstream conforming to this Specification shall not contain this syntax element.

6.3.10 Picture coding extension

f_code[s][t] – A 4 bit unsigned integer taking values 1 through 9, or 15. The value zero is forbidden and the values 10 through 14 are reserved. It is used in the decoding of motion vectors, see 7.6.3.1.

In an I-picture in which concealment_motion_vectors is zero f_code[s][t] is not used (since motion vectors are not used) and shall take the value 15 (all ones).

Similarly, in an I-picture or a P-picture f_code[1][t] is not used in the decoding process (since it refers to backwards motion vectors) and shall take the value 15 (all ones).

See Table 7-7 for the meaning of the indices; s and t.

intra_dc_precision – This is a 2-bit integer defined in the Table 6-13.

Table 6-13 – Intra DC precision

intra_dc_precision	Precision (bits)
00	8
01	9
10	10
11	11

The inverse quantisation process for the Intra DC coefficients is modified by this parameter as explained in 7.4.1.

picture_structure – This is a 2-bit integer defined in the Table 6-14.

Table 6-14 – Meaning of picture_structure

picture_structure	Meaning
00	Reserved
01	Top Field
10	Bottom Field
11	Frame picture

When a frame is encoded in the form of two field pictures both fields must be of the same picture_coding_type, except where the first encoded field is an I-picture in which case the second may be either an I-picture or a P-picture.

The first encoded field of a frame may be a top-field or a bottom field, and the next field must be of opposite parity.

When a frame is encoded in the form of two field pictures, the following syntax elements may be set independently in each field picture:

- f_code[0][0], f_code[0][1];
- f_code[1][0], f_code[1][1];
- intra_dc_precision, concealment_motion_vectors, q_scale_type;
- intra_vlc_format, alternate_scan;
- vbv_delay;
- temporal_reference.

top_field_first – The meaning of this element depends upon picture_structure, progressive_sequence and repeat_first_field.

If progressive_sequence is equal to '0', this flag indicates what field of a reconstructed frame is output first by the decoding process.

In a field picture top_field_first shall have the value '0', and the only field output by the decoding process is the decoded field picture.

In a frame picture top_field_first being set to '1' indicates that the top field of the reconstructed frame is the first field output by the decoding process. top_field_first being set to '0' indicates that the bottom field of the reconstructed frame is the first field output by decoding process.

If progressive_sequence is equal to '1', this flag, combined with repeat_first_field, indicates how many times (one, two or three) the reconstructed frame is output by the decoding process.

If repeat_first_field is set to 0, top_field_first shall be set to '0'. In this case the output of the decoding process corresponding to this reconstructed frame consists of one progressive frame.

If top_field_first is set to 0 and repeat_first_field is set to '1', the output of the decoding process corresponding to this reconstructed frame consists of two identical progressive frames.

If top_field_first is set to 1 and repeat_first_field is set to '1', the output of the decoding process corresponding to this reconstructed frame consists of three identical progressive frames.

frame_pred_frame_dct – If this flag is set to '1', then only frame-DCT and frame prediction are used. In a field picture it shall be '0'. frame_pred_frame_dct shall be '1' if progressive_sequence is '1'. This flag affects the syntax of the bitstream.

concealment_motion_vectors – This flag has the value '1' to indicate that motion vectors are coded in intra macroblocks. This flag has the value '0' to indicate that no motion vectors are coded in intra macroblocks.

q_scale_type – This flag affects the inverse quantisation process as described in 7.4.2.2.

intra_vlc_format – This flag affects the decoding of transform coefficient data as described in 7.2.2.1.

alternate_scan – This flag affects the decoding of transform coefficient data as described in 7.3.

repeat_first_field – This flag is applicable only in a frame picture; in a field picture it shall be set to zero and does not affect the decoding process.

If progressive_sequence is equal to 0 and progressive_frame is equal to 0, repeat_first_field shall be zero, and the output of the decoding process corresponding to this reconstructed frame consists of two fields.

If progressive_sequence is equal to 0 and progressive_frame is equal to 1:

If this flag is set to 0, the output of the decoding process corresponding to this reconstructed frame consists of two fields. The first field (top or bottom field as identified by top_field_first) is followed by the other field.

If it is set to 1, the output of the decoding process corresponding to this reconstructed frame consists of three fields. The first field (top or bottom field as identified by top_field_first) is followed by the other field, then the first field is repeated.

If progressive_sequence is equal to 1:

If this flag is set to 0, the output of the decoding process corresponding to this reconstructed frame consists of one frame.

If it is set to 1, the output of the decoding process corresponding to this reconstructed frame consists of two or three frames, depending on the value of top_field_first.

chroma_420_type – If chroma_format is "4:2:0", the value of chroma_420_type shall be the same as progressive_frame; else chroma_420_type has no meaning and shall be equal to zero. This flag exists for historical reasons.

progressive_frame – If progressive_frame is set to 0 it indicates that the two fields of the frame are interlaced fields in which an interval of time of the field period exists between (corresponding spatial samples) of the two fields. In this case the following restriction applies:

- repeat_first_field shall be zero (two field duration).

If progressive_frame is set to 1 it indicates that the two fields (of the frame) are actually from the same time instant as one another. In this case a number of restrictions to other parameters and flags in the bitstream apply:

- picture_structure shall be "Frame";
- if progressive_sequence is equal to one, then frame_pred_frame_dct shall be 1.

progressive_frame is used when the video sequence is used as the lower layer of a spatial scalable sequence. Here it affects the up-sampling process used in forming a prediction in the enhancement layer from the lower layer.

composite_display_flag – This flag is set to 1 to indicate that the following fields that are of use when the input pictures have been coded as (analogue) composite video prior to encoding into a bitstream that complies with this Specification. If it is set to 0, then these parameters do not occur in the bitstream.

The information relates to the picture that immediately follows the extension. In the case that this picture is a frame picture, the information relates to the first field of that frame. The equivalent information for the second field may be derived (there is no way to represent it in the bitstream).

NOTE 1 – The various syntactic elements that are included in the bitstream if composite_display_flag is '1' are not used in the decoding process.

NOTE 2 – repeat_first_field will cause a composite video field to be repeated out of the 4-field or 8-field sequence. It is recommended that repeat_first_field and composite_display_flag are not both set simultaneously.

v_axis – A 1-bit integer used only when the bitstream represents a signal that had previously been encoded according to PAL systems. v_axis is set to 1 on a positive sign, v_axis is set to 0 otherwise.

field_sequence – A 3-bit integer which defines the number of the field in the eight field sequence used in PAL systems or the four field sequence used in NTSC systems as defined in the Table 6-15.

Table 6-15 – Definition of field_sequence

Field sequence	Frame	Field
000	1	1
001	1	2
010	2	3
011	2	4
100	3	5
101	3	6
110	4	7
111	4	8

sub_carrier – This is a 1-bit integer. Set to 0 means the sub-carrier/line frequency relationship is correct. When set to 1 the relationship is not correct.

burst_amplitude – This is a 7-bit integer defining the burst amplitude (for PAL and NTSC only). The amplitude of the sub-carrier burst is quantised as a Recommendation ITU-R BT.601 luminance signal, with the MSB omitted.

sub_carrier_phase – This is an 8-bit integer defining the phase of the reference sub-carrier at the field-synchronisation datum with respect, to field start as defined in Recommendation ITU-R BT.470 (see Table 6-16).

Table 6-16 – Definition of sub_carrier_phase

sub_carrier_phase	Phase
0	([360° ÷ 256] * 0)
1	([360° ÷ 256] * 1)
…	…
255	([360° ÷ 256] * 255)

6.3.11 Quant matrix extension

Each quantisation matrix has a default set of values. When a sequence_header_code is decoded all matrices shall be reset to their default values. User defined matrices may be downloaded and this can occur in a sequence_header() or in a quant_matrix_extension().

With 4:2:0 data only two matrices are used, one for intra blocks the other for non-intra blocks.

With 4:2:2 or 4:4:4 data four matrices are used. Both an intra and a non-intra matrix are provided for both luminance blocks and for chrominance blocks. Note, however, that it is possible to download the same user defined matrix into both the luminance and chrominance matrix at the same time.

The default matrix for intra blocks (both luminance and chrominance) is:

		u							
		0	1	2	3	4	5	6	7
	0	8	16	19	22	26	27	29	34
	1	16	16	22	24	27	29	34	37
	2	19	22	26	27	29	34	34	38
	3	22	22	26	27	29	34	37	40
	4	22	26	27	29	32	35	40	48
	5	26	27	29	32	35	40	48	58
	6	26	27	29	34	38	46	56	69
v	7	27	29	35	38	46	56	69	83

The default matrix for non-intra blocks (both luminance and chrominance) is:

		u							
		0	1	2	3	4	5	6	7
v	0	16	16	16	16	16	16	16	16
	1	16	16	16	16	16	16	16	16
	2	16	16	16	16	16	16	16	16
	3	16	16	16	16	16	16	16	16
	4	16	16	16	16	16	16	16	16
	5	16	16	16	16	16	16	16	16
	6	16	16	16	16	16	16	16	16
	7	16	16	16	16	16	16	16	16

load_intra_quantiser_matrix – This is a one-bit flag which is set to '1' if intra_quantiser_matrix follows. If it is set to '0' then there is no change in the values that shall be used.

intra_quantiser_matrix – This is a list of sixty-four 8-bit unsigned integers. The new values, encoded in the default zigzag scanning order as described in 7.3.1, replace the previous values. The first value shall always be 8 (values 1 to 7 and 9 to 255 are reserved). For all of the 8-bit unsigned integers, the value zero is forbidden. With 4:2:2 and 4:4:4 data the new values shall be used for both the luminance intra matrix and the chrominance intra matrix. However, the chrominance intra matrix may subsequently be loaded with a different matrix.

load_non_intra_quantiser_matrix – This is a one-bit flag which is set to '1' if non_intra_quantiser_matrix follows. If it is set to '0' then there is no change in the values that shall be used.

non_intra_quantiser_matrix – This is a list of sixty-four 8-bit unsigned integers. The new values, encoded in the default zigzag scanning order as described in 7.3.1, replace the previous values. For all the 8-bit unsigned integers, the value zero is forbidden. With 4:2:2 and 4:4:4 data, the new values shall be used for both the luminance non-intra matrix and the chrominance non-intra matrix. However, the chrominance non-intra matrix may subsequently be loaded with a different matrix.

load_chroma_intra_quantiser_matrix – This is a one-bit flag which is set to '1' if chroma_intra_quantiser_matrix follows. If it is set to '0' then there is no change in the values that shall be used. If chroma_format is "4:2:0", this flag shall take the value '0'.

chroma_intra_quantiser_matrix – This is a list of sixty-four 8-bit unsigned integers. The new values, encoded in the default zigzag scanning order as described in 7.3.1, replace the previous values. The first value shall always be 8 (values 1 to 7 and 9 to 255 are reserved). For all of the 8-bit unsigned integers, the value zero is forbidden.

load_chroma_non_intra_quantiser_matrix – This is a one-bit flag which is set to '1' if chroma_non_intra_quantiser_matrix follows. If it is set to '0' then there is no change in the values that shall be used. If chroma_format is "4:2:0", this flag shall take the value '0'.

chroma_non_intra_quantiser_matrix – This is a list of sixty-four 8-bit unsigned integers. The new values, encoded in the default zigzag scanning order as described in 7.3.1, replace the previous values. For all the 8-bit unsigned integers, the value zero is forbidden.

6.3.12 Picture display extension

This Specification does not define the display process. The information in this extension does not affect the decoding process and may be ignored by decoders that conform to this Specification.

The picture display extension allows the position of the display rectangle whose size is specified in sequence_display_extension() to be moved on a picture-by-picture basis. One application for this is the implementation of pan-scan.

frame_centre_horizontal_offset – This is a 16-bit signed integer giving the horizontal offset in units of 1/16th sample. A positive value shall indicate that the centre of the reconstructed frame lies to the right of the centre of the display rectangle.

frame_centre_vertical_offset – This is a 16-bit signed integer giving the vertical offset in units of 1/16th sample. A positive value shall indicate that the centre of the reconstructed frame lies below the centre of the display rectangle.

The dimensions of the display rectangular region are defined in the sequence_display_extension(). The coordinates of the region within the coded picture are defined in the picture_display_extension().

The centre of the reconstructed frame is the centre of the rectangle defined by horizontal_size and vertical_size.

Since (in the case of an interlaced sequence) a coded picture may relate to one, two or three decoded fields, the picture_display_extension() may contain up to three offsets.

The number of frame centre offsets in the picture_display_extension() shall be defined as follows:

```
if ( progressive_sequence == 1) {
    if ( repeat_first_field == '1' ) {
        if ( top_field_first == '1' )
            number_of_frame_centre_offsets = 3
        else
            number_of_frame_centre_offsets = 2
    } else {
        number_of_frame_centre_offsets = 1
    }
} else {
    if (picture_structure == "field") {
        number_of_frame_centre_offsets = 1
    } else {
        if (repeat_first_field == '1' )
            number_of_frame_centre_offsets = 3
        else
            number_of_frame_centre_offsets = 2
    }
}
```

A picture_display_extension() shall not occur unless a sequence_display_extension() followed the previous sequence_header().

In the case that a given picture does not have a picture_display_extension(), then the most recently decoded frame centre offset shall be used. Note that each of the missing frame centre offsets have the same value (even if two or three frame centre offsets would have been contained in the picture_display_extension() had been present). Following a sequence_header() the value zero shall be used for all frame centre offsets until a picture_display_extension() defines non-zero values.

Figure 6-16 illustrates the picture display parameters. As shown, the frame centre offsets contained in the picture_display_extension() shall specify the position of the centre of the reconstructed frame from the centre of the display rectangle.

NOTE 1 – The display rectangle may also be larger than the reconstructed frame.

NOTE 2 – Even in a field picture the frame_centre_vertical_offset still represents the offset of the centre of the frame in $1/16^{th}$ of a **frame** line (not a line in the field).

NOTE 3 – In the example of Figure 6-16 both frame_centre_horizontal_offset and frame_centre_vertical_offset have negative values.

6.3.12.1 Pan-scan

The frame centre offsets may be used to implement pan-scan in which a rectangular region is defined which may be panned around the entire reconstructed frame.

By way of example only; this facility may be used to identify a 3/4 aspect ratio window in a 9/16 coded picture format. This would allow a decoder to produce usable pictures for a conventional definition television set from an encoded format intended for enhanced definition. The 3/4 aspect ratio region is intended to contain the "most interesting" region of the picture.

The 3/4 region is defined by display_horizontal_size and display_vertical_size. The 9/16 frame size is defined by horizontal_size and vertical_size.

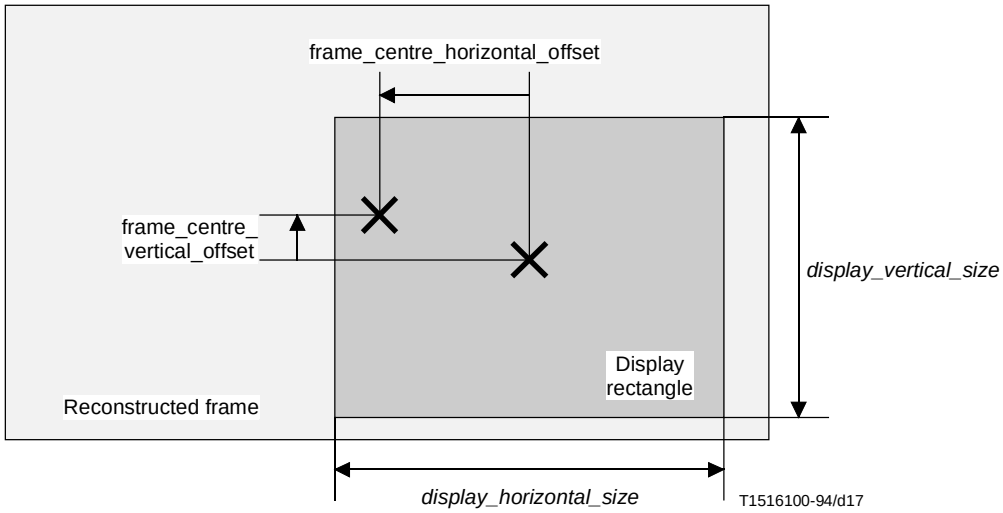


Figure 6-16 – Frame centre offset parameters

6.3.13 Picture temporal scalable extension

NOTE – See also 7.9.

reference_select_code – This is a 2-bit code that identifies reference frames or reference fields for prediction depending on the picture type.

forward_temporal_reference – A 10 bit unsigned integer value which indicates temporal reference of the lower layer frame to be used to provide the forward prediction. If the lower layer indicates temporal reference with more than 10 bits, the least significant bits are encoded here. If the lower layer indicates temporal reference with fewer than 10 bits, all bits are encoded here and the more significant bits shall be set to zero.

backward_temporal_reference – A 10 bit unsigned integer value which indicates temporal reference of the lower layer frame to be used to provide the backward prediction. If the lower layer indicates temporal reference with more than 10 bits, the least significant bits are encoded here. If the lower layer indicates temporal reference with fewer than 10 bits, all bits are encoded here and the more significant bits shall be set to zero.

6.3.14 Picture spatial scalable extension

lower_layer_temporal_reference – A 10 bit unsigned integer value which indicates temporal reference of the lower layer frame to be used to provide the prediction. If the lower layer indicates temporal reference with more than 10 bits, the least significant bits are encoded here. If the lower layer indicates temporal reference with fewer than 10 bits, all bits are encoded here and the more significant bits shall be set to zero.

lower_layer_horizontal_offset – This 15 bit signed (twos complement) integer specifies the horizontal offset (of the top left hand corner) of the upsampled lower layer frame relative to the enhancement layer picture. It is expressed in units of the enhancement layer picture sample width. If the chrominance format is 4:2:0 or 4:2:2, then this parameter shall be an even number.

lower_layer_vertical_offset – This 15 bit signed (twos complement) integer specifies the vertical offset (of the top left hand corner) of the upsampled lower layer picture relative to the enhancement layer picture. It is expressed in units of the enhancement layer picture sample height. If the chrominance format is 4:2:0, then this parameter shall be an even number.

spatial_temporal_weight_code_table_index – This 2-bit integer indicates which table of spatial temporal weight codes is to be used as defined in 7.7. Permissible values of spatial_temporal_weight_code_table_index are defined in Table 7-21.

lower_layer_progressive_frame – This flag shall be set to 0 if the lower layer frame is interlaced and shall be set to '1' if the lower layer frame is progressive. The use of this flag in the spatial scalable upsampling process is defined in 7.7.

lower_layer_deinterlaced_field_select – This flag affects the spatial scalable upsampling process, as defined in 7.7.

6.3.15 Copyright extension

extension_start_code_identifier – This is a 4-bit integer which identifies the extension (see Table 6-2).

copyright_flag – This is a one bit flag. When copyright_flag is set to '1', it indicates that the source video material encoded in all the coded pictures following the copyright extension, in coding order, up to the next copyright extension or end of sequence code, is copyrighted. The copyright_identifier and copyright_number identify the copyrighted work. When copyright_flag is set to '0', it does not indicate whether the source video material encoded in all the coded pictures following the copyright extension, in coding order, is copyrighted or not.

copyright_identifier – This is an 8-bit integer given by a Registration Authority as designated by ISO/IEC JTC1/SC29. Value zero indicates that this information is not available. The value of copyright_number shall be zero when copyright_identifier is equal to zero.

When copyright_flag is set to '0', copyright_identifier has no meaning and shall have the value 0.

original_or_copy – This is a one bit flag. It is set to '1' to indicate that the material is an original, and set to '0' to indicate that it is a copy.

reserved – This is a 7-bit integer, reserved for future extension. It shall have the value zero.

copyright_number_1 – This is a 20-bit integer, representing bits 44 to 63 of copyright_number.

copyright_number_2 – This is a 22-bit integer, representing bits 22 to 43 of copyright_number.

copyright_number_3 – This is a 22-bit integer. representing bits 0 to 21 of copyright_number.

copyright_number – This is a 64-bit integer, derived from copyright_number_1, copyright_number_2, and copyright_number_3 as follows:

copyright_number **= (**copyright_number_1 << 44) + (copyright_number_2 << 22) + copyright_number_3.

The meaning of copyright_number is defined only when copyright_flag is set to '1'. In this case, the value of copyright_number identifies uniquely the copyrighted work marked by the copyrighted extension. The value 0 for copyright_number indicates that the identification number of the copyrighted work is not available.

When copyright_flag is set to '0', copyright_number has no meaning and shall have the value 0.

6.3.16 Slice

slice_start_code – The slice_start_code is a string of 32-bits. The first 24-bits have the value 000001 in hexadecimal and the last 8-bits are the slice_vertical_position having a value in the range 01 through AF hexadecimal inclusive.

slice_vertical_position – This is given by the last eight bits of the slice_start_code. It is an unsigned integer giving the vertical position in macroblock units of the first macroblock in the slice.

In large pictures (when the vertical size of the frame is greater than 2800 lines) the slice vertical position is extended by the **slice_vertical_position_extension**.

The macroblock row may be calculated as follows:

```
if ( vertical_size > 2800 )
        mb_row = (slice_vertical_position_extension << 7) + slice_vertical_position –1;
    else
        mb_row = slice_vertical_position –1;
```

The slice_vertical_position of the first row of macroblocks is one. Some slices may have the same slice_vertical_position, since slices may start and finish anywhere. The maximum value of slice_vertical_position is 175 unless slice_vertical_position_extension is present in which case slice_vertical_position shall be in the range [1:128].

priority_breakpoint – This is a 7-bit integer that indicates the point in the syntax where the bitstream shall be partitioned. The allowed values and their semantic interpretation is given in Table 7-30 priority_breakpoint shall take the value zero in partition 1.

quantiser_scale_code – A 5 bit unsigned integer in the range 1 to 31 . The decoder shall use this value until another quantiser_scale_code is encountered either in slice() or macroblock(). The value zero is forbidden.

slice_extension_flag – This flag shall be set to '1' to indicate the presence of intra_slice, slice_picture_id_enable, slice_picture_id in the bitstream.

intra_slice – This flag shall be set to '0' if any of the macroblocks in the slice are non-intra macroblocks. If all of the macroblocks, are intra macroblocks, then intra_slice may be set to '1'.

intra_slice may be omitted from the bitstream (by setting intra_slice_flag to '0') in which case it shall be assumed to have the value zero.

intra_slice is not used by the decoding process. intra_slice is intended to aid a DSM application in performing FF/FR (see D.12).

slice_picture_id_enable – This flag controls the semantics of slice_picture_id. If slice_picture_id_enable is set to '0', slice_picture_id is not used by this Specification and shall have the value zero. If slice_picture_id_enable is set to '1', slice_picture_id may have a value different from zero.

slice_picture_id_enable must have the same value in all the slices of a picture. slice_picture_id_enable may be omitted from the bitstream (by setting slice_extension_flag to '0') in which case it shall be assumed to have the value zero.

slice_picture_id_enable is not used by the decoding process.

slice_picture_id – This is a 6-bit integer. If slice_picture_id_enable is set to '0', slice_picture_id is not used by this Specification and shall have the value zero. If slice_picture_id_enable is set to '1', slice_picture_id is application defined and may have any value, with the constraint that slice_picture_id shall have the same value in all the slices of a picture.

slice_picture_id is not used by the decoding process. slice_picture_id is intended to aid recovery on severe bursts of errors for certain types of applications. For example, the application may increment slice_picture_id with each transmitted picture, so that in case of severe burst error, when several slices are lost, the decoder can know if the slice following the burst error belongs to the current picture or to another picture, which may be the case if at least a picture header has been lost.

extra_bit_slice – This flag indicates the presence of the following extra information. If extra_bit_slice is set to '1', extra_information_slice will follow it. If it is set to '0', there are no data following it. extra_bit_slice shall be set to '0', the value '1' is reserved for possible future extensions defined by ITU-T | ISO/IEC.

extra_information_slice – Reserved. A decoder conforming to this Specification that encounters extra_information_slice in a bitstream shall ignore it (i.e. remove from the bitstream and discard). A bitstream conforming to this Specification shall not contain this syntax element.

6.3.17 Macroblock

NOTE – "macroblock_stuffing" which is supported in ISO/IEC 11172-2 shall not be used in a bitstream defined by this Specification.

macroblock_escape – The macroblock_escape is a fixed bit-string '0000 0001 000' which is used when the difference between macroblock_address and previous_macroblock_address is greater than 33. It causes the value of macroblock_address_increment to be 33 greater than the value that will be decoded by subsequent macroblock_escape and the macroblock_address_increment codewords.

For example, if there are two macroblock_escape codewords preceding the macroblock_address_increment, then 66 is added to the value indicated by macroblock_address_increment.

macroblock_address_increment – This is a variable length coded integer coded as per Table B.1 which indicates the difference between macroblock_address and previous_macroblock_address. The maximum value of macroblock_address_increment is 33. Values greater than this can be encoded using the macroblock_escape codeword.

The macroblock_address is a variable defining the absolute position of the current macroblock. The macroblock_address of the top-left macroblock is zero.

The previous_macroblock_address is a variable defining the absolute position of the last non-skipped macroblock (see 7.6.6 for the definition of skipped macroblocks) except at the start of a slice. At the start of a slice previous_macroblock_address is reset as follows:

$$\text{previous\_macroblock\_address} = (\text{mb\_row} * \text{mb\_width}) - 1$$

The horizontal spatial position in macroblock units of a macroblock in the picture (mb_column) can be computed from the macroblock_address as follows:

$$\text{mb\_column} = \text{macroblock\_address} \ \% \ \text{mb\_width}$$

where mb_width is the number of macroblocks in one row of the picture.

Except at the start of a slice, if the value of macroblock_address recovered from macroblock_address_increment and the macroblock_escape codes (if any) differs from the previous_macroblock_address by more than one then some macroblocks have been skipped. It is a requirement that:

- There shall be no skipped macroblocks in I-pictures except when either
  - picture_spatial_scalable_extension() follows the picture_header() of the current picture; or
  - sequence_scalable_extension() is present in the bitstream and scalable_mode = "SNR scalability".
- In a B-picture there shall be no skipped macroblocks immediately following a macroblock in which macroblock_intra is one.

It should be noted that the syntax does not allow the first and last macroblock of a slice to be skipped.

6.3.17.1 Macroblock modes

macroblock_type – Variable length coded indicator which indicates the method of coding and content of the macroblock according to the Tables B.2 through B.8, selected by picture_coding_type and scalable_mode.

macroblock_quant – Derived from macroblock_type according to the Tables B.2 through B.8. This is set to 1 to indicate that quantiser_scale_code is present in the bitstream.

macroblock_motion_forward – Derived from macroblock_type according to the Tables B.2 through B.8. This flag affects the bitstream syntax and is used by the decoding process.

macroblock_motion_backward – Derived from macroblock_type according to the Tables B.2 through B.8. This flag affects the bitstream syntax and is used by the decoding process.

macroblock_pattern – Derived from macroblock_type according to the Tables B.2 through B.8. This is set to 1 to indicate that coded_block_pattern() is present in the bitstream.

macroblock_intra – Derived from macroblock_type according to the Tables B.2 through B.8. This flag affects the bitstream syntax and is used by the decoding process.

spatial_temporal_weight_code_flag – Derived from the macroblock_type. This indicates whether the spatial_temporal_weight_code is present in the bitstream.

When spatial_temporal_weight_code_flag is '0' (indicating that spatial_temporal_weight_code is not present in the bitstream) the spatial_temporal_weight_class is derived from Tables B.5 to B.7. When spatial_temporal_weight_code_flag is '1' spatial_temporal_weight_class is derived from Table 7-20.

spatial_temporal_weight_code – This is a two bit code which indicates, in the case of spatial scalability, how the spatial and temporal predictions shall be combined to form the prediction for the macroblock. A full description of how to form the spatial scalable prediction is given in 7.7.

frame_motion_type – This is a two bit code indicating the macroblock prediction type, defined in Table 6-17.

Table 6-17 – Meaning of frame_motion_type

Code	**spatial_temporal _weight_class**	Prediction type	**motion_vector _count**	**mv_format**	dmv
00		Reserved			
01	0, 1	Field-based	2	Field	0
01	2, 3	Field-based	1	Field	0
10	0, 1, 2, 3	Frame-based	1	Frame	0
11	0, 2, 3	Dual-Prime	1	Field	1

If frame_pred_frame_dct is equal to 1 then frame_motion_type is omitted from the bitstream. In this case motion vector decoding and prediction formation shall be performed as if frame_motion_type had indicated "Frame-based prediction".

In the case of intra macroblocks (in a frame picture) when concealment_motion_vectors is equal to 1 frame_motion_type is not present in the bitstream. In this case motion vector decoding and update of the motion vector predictors shall be performed as if frame_motion_type had indicated "Frame-based" (see 7.6.3.9).

field_motion_type – This is a two bit code indicating the macroblock prediction type, defined in Table 6-18.

Table 6-18 – Meaning of field_motion_type

Code	**spatial_temporal _weight_class**	Prediction type	**motion_vector _count**	**mv_format**	dmv
00		Reserved			
01	0, 1	Field-based	1	Field	0
10	0, 1	16 × 8 MC	2	Field	0
11	0	Dual-Prime	1	Field	1

In the case of intra macroblocks (in a field picture) when concealment_motion_vectors is equal to 1 field_motion_type is not present in the bitstream. In this case, motion vector decoding and update of the motion vector predictors shall be performed as if field_motion_type had indicated "Field-based" (see 7.6.3.9).

dct_type – This is a flag indicating whether the macroblock is frame DCT coded or field DCT coded. If this is set to '1', the macroblock is field DCT coded.

In the case that **dct_type** is not present in the bitstream, then the value of dct_type (used in the remainder of the decoding process) shall be derived as shown in Table 6-19.

Table 6-19 – Value of dct_type if dct_type is not in the bitstream

Condition	**dct_type**
picture_structure == "field"	Unused because there is no frame/field distinction in a field picture.
frame_pred_frame_dct == 1	0 (“frame")
!(macroblock_intra ‖ macroblock_pattern)	Unused – Macroblock is not coded
macroblock is skipped	Unused – Macroblock is not coded

6.3.17.2 Motion vectors

motion_vector_count is derived from field_motion_type or frame_motion_type as indicated in Tables 6-17 and 6-18.

mv_format is derived from field_motion_type or frame_motion_type as indicated in the Tables 6-17 and 6-18. mv_format indicates if the motion vector is a field-motion vector or a frame-motion vector. mv_format is used in the syntax of the motion vectors and in the process of motion vector prediction.

dmv is derived from field_motion_type or frame_motion_type as indicated in Tables 6-17 and 6-18.

motion_vertical_field_select[r][s] – This flag indicates which reference field shall be used to form the prediction. If motion_vertical_field_select[r][s] is zero, then the top reference field shall be used, if it is one then the bottom reference field shall be used. (See Table 7-7 for the meaning of the indices r and s.)

6.3.17.3 Motion vector

motion_code[r][s][t] – This is a variable length code, as defined in Table B.10, which is used in motion vector decoding as described in 7.6.3.1. (See Table 7-7 for the meaning of the indices r, s and t.)

motion_residual[r][s][t] – This is an integer which is used in motion vector decoding as described in 7.6.3.1. (See Table 7-7 for the meaning of the indices r, s and t.) The number of bits in the bitstream for motion_residual[r][s][t], r_size, is derived from f_code[s][t] as follows:

$$r\_size = f\_code[s][t] - 1$$

NOTE – The number of bits for both motion_residual[0][s][t] and motion_residual[1][s][t] is denoted by f_code[s][t].

dmvector[t] – This is a variable length code, as defined in Table B.11, which is used in motion vector decoding as described in 7.6.3.6. (See Table 7-7 for the meaning of the index t.)

6.3.17.4 Coded block pattern

coded_block_pattern_420 – A variable length code that is used to derive the variable cbp according to Table B.9.

coded_block_pattern_1

coded_block_pattern_2 – For 4:2:2 and 4:4:4 data the coded block pattern is extended by the addition of either a two bit or six bit fixed length code, coded_block_pattern_1 or coded_block_pattern_2. Then the pattern_code[i] is derived using the following:

```
for (i = 0; i < 12; i++) {
    if (macroblock_intra)
        pattern_code[i] = 1;
    else
        pattern_code[i] = 0;
}
if (macroblock_pattern) {
    for (i = 0; i < 6; i++)
        if ( cbp & (1<<(5 – i)) ) pattern_code[i] = 1;
    if (chroma_format == "4:2:2")
        for (i = 6; i < 8; i++)
            if ( coded_block_pattern_1 & (1<<(7 – i)) ) pattern_code[i] = 1;
    if (chroma_format == "4:4:4")
        for (i = 6; i < 12; i++)
            if ( coded_block_pattern_2 & (1<<(11 – i)) ) pattern_code[i] = 1;
}
```

If pattern_code[i] equals to 1, i = 0 to (block_count-1), then the block number i defined in Figures 6-10, 6-11 and 6-12 is contained in this macroblock.

The number "block_count" which determines the number of blocks in the macroblock is derived from the chrominance format as shown in Table 6-20.

Table 6-20 – block_count as a function of chroma_format

chroma_format	block_count
4:2:0	6
4:2:2	8
4:4:4	12

6.3.18 Block

The semantics of block() are described in clause 7.

6.3.19 Camera parameters extension

camera_id – The number in camera_id identifies a camera.

height_of_image_device – This is a 22-bit unsigned integer which specifies the height of image device. Its value shall be measured to a resolution of 0,001 millimeter and having a range of zero to 4 194,303 mm.

focal_length – This is a 22-bit unsigned integer which specifies the focal length. Its value shall be measured to a resolution of 0,001 millimeter and having a range of zero to 4 194,303 mm.

f_number – This is a 22-bit unsigned integer which specifies the F-number. F-number is defined by (focal_length)/(effective aperture of lens). Its value shall be measured to a resolution of 0,001 and having a range of zero to 4 194,303.

vertical_angle_of_view – This is a 22-bit unsigned integer which specifies the vertical angle of the field of view as determined between the top and bottom edges of the image device. Its value shall be measured to a resolution of 0,0001 degree and having a range of zero to 180 degrees.

camera_position_x_upper, camera_position_y_upper, camera_position_z_upper – These words constitute the 16 most significant bits of camera_position_x, camera_position_y and camera_position_z respectively.

camera_position_x_lower, camera_position_y_lower, camera_position_z_lower – These words constitute the 16 least significant bits of camera_position_x, camera_position_y and camera_position_z respectively.

camera_position_x, camera_position_y, camera_position_z – A set of these values specifies the position of the optical principal point of the camera in a user-specified world coordinate system. Each of these values shall be measured to a resolution of 0,001 millimeter and having a range of +2 147 483,647 mm to –2 147 483,648 mm. The camera_position_x is a 32-bit signed (two's complement) integer, the 16 least significant bits are defined in camera_position_x_lower, the 16 most significant bits are defined in camera_position_x_upper. The camera_position_y is a 32-bit signed (two's complement) integer, the 16 least significant bits are defined in camera_position_y_lower, the 16 most significant bits are defined in camera_position_y_upper. The camera_position_z is a 32-bit signed (two's complement) integer, the 16 least significant bits are defined in camera_position_z_lower, the 16 most significant bits are defined in camera_position_z_upper.

camera_direction_x, camera_direction_y, camera_direction_z – A set of these values specifies the direction of the camera. The direction of the camera is defined by using the vector from optical principal point to a point which is in front of the camera and is on the optical axis of the camera. Each of these values is a 22-bit signed (two's complement) integer and having a range of +2 097 151 to –2 097 152.

image_plane_vertical_x, image_plane_vertical_y, image_plane_vertical_z – A set of these values specifies the upper direction of the camera. The upper direction of the camera is defined by using the vector which is parallel to the side edge of the image device and is from bottom edge to top edge. Each of these values is a 22-bit signed (two's complement) integer and is having a range of +2 097 151 to –2 097 152.

Figure 6-17 explains these terms pictorially.

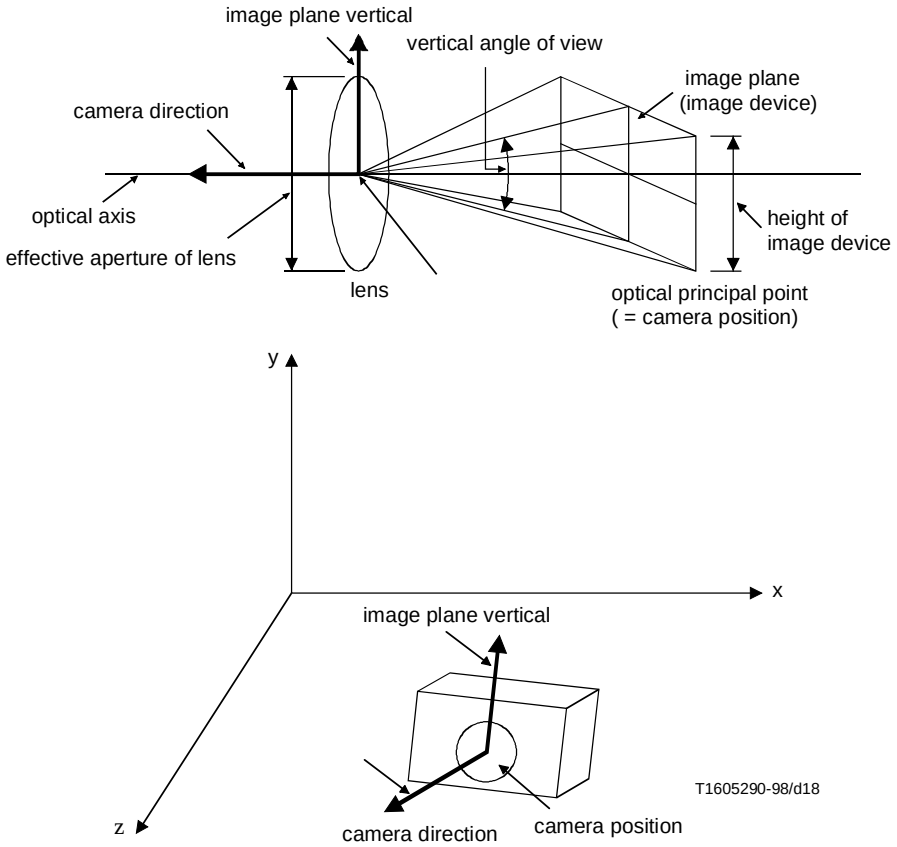


Figure 6-17 -- Camera parameters

6.3.20 ITU-T extension

The use of this extension is defined in Annex A/H.320.

7 The video decoding process

This clause specifies the decoding process that a decoder shall perform to reconstruct frames from the coded bitstream.

The IDCT function f[y][x] used in the decoding process may be any of several approximations of the saturated mathematical integer-number IDCT defined in Annex A. Requirements on the accuracy of the IDCT function used in the decoding process are specified in Annex A.

In 7.1 through 7.6 the simplest decoding process is specified in which no scalability features are used. Subclauses 7.7 to 7.11 specify the decoding process when scalable extensions are used. Subclause 7.12 defines the output of the decoding process.

Figure 7-1 is a diagram of the Video Decoding Process without any scalability. The diagram is simplified for clarity.

NOTE – Throughout this Specification two dimensional arrays are represented as *name*[*q*][*p*] where '*q*' is the index in the vertical dimension and '*p*' the index in the horizontal dimension.

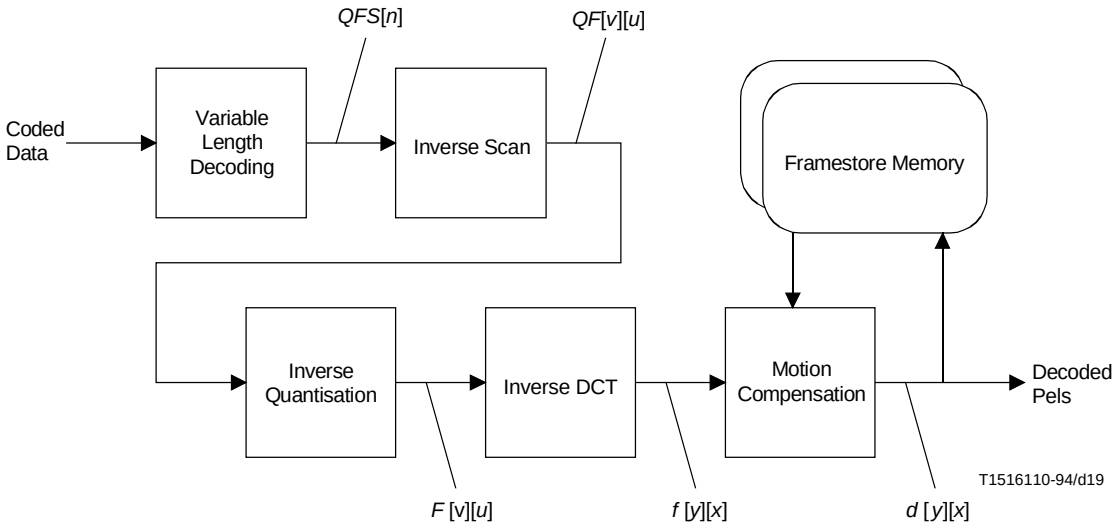


Figure 7-1 – Simplified Video Decoding Process

7.1 Higher syntactic structures

The various parameters and flags in the bitstream for macroblock() and all syntactic structures above macroblock() shall be interpreted as indicated in clause 6. Many of these parameters and flags affect the decoding process described in the following subclauses. Once all of the macroblocks in a given picture have been processed, the entire picture will have been reconstructed.

Reconstructed fields shall be associated together in pairs to form reconstructed frames. (See "picture_structure" in 6.3.10.)

The sequence of reconstructed frames shall be re-ordered as described in 6.1.1.11.

If progressive_sequence == 1 the reconstructed frames shall be output from the decoding process at regular intervals of the frame period as shown in Figure 7-19.

If progressive_sequence == 0 the reconstructed frames shall be broken into a sequence of fields which shall be output from the decoding process at regular intervals of the field period as shown in Figure 7-20. In the case that a frame picture has repeat_first_field == 1 the first field of the frame shall be repeated after the second field. (See "repeat_first_field" in 6.3.10.)

7.2 Variable length decoding

Subclause 7.2.1 specifies the decoding process used for the DC coefficient ($n = 0$) in an intra coded block. (n is the index of the coefficient in the appropriate zigzag scanning order.) Subclause 7.2.2 specifies the decoding process for all other coefficients, AC coefficients ($n > 0$) and DC coefficients in non-intra coded blocks.

Let *cc* denote the colour component. It is related to the block number as specified in Table 7-1. Thus, *cc* is zero for the Y component, one for the Cb component and two for the Cr component.

Table 7-1 – Definition of *cc*, colour component index

Block Number	*cc*		
	4:2:0	4:2:2	4:4:4
0	0	0	0
1	0	0	0
2	0	0	0
3	0	0	0
4	1	1	1
5	2	2	2
6		1	1
7		2	2
8			1
9			2
10			1
11			2

7.2.1 DC coefficients in intra blocks

DC coefficients in blocks in intra macroblocks are encoded as a variable length code denoting dct_dc_size as defined in Tables B.12 and B.13. If dct_dc_size is not equal to zero, then this shall be followed by a fixed length code, dct_dc_differential, of dct_dc_size bits. A differential value is first recovered from the coded data which is added to a predictor in order to recover the final decoded coefficient.

If *cc* is zero then Table B.12 shall be used for dct_dc_size. If *cc* is non-zero, then Table B.13 shall be used for dct_dc_size.

Three predictors are maintained, one for each of the colour components, *cc*. Each time a DC coefficient in a block in an intra macroblock is decoded the predictor is added to the differential to recover the actual coefficient. Then the predictor shall be set to the value of the coefficient just decoded. At various times, as described below, the predictors shall be reset. The reset value is derived from the parameter intra_dc_precision as specified in Table 7-2.

Table 7-2 – Relation between intra_dc_precision and the predictor reset value

intra_dc_precision	Bits of precision	reset value
0	8	128
1	9	256
2	10	512
3	11	1024

The predictors shall be reset to the reset value at the following times:

- At the start of a slice.
- Whenever a non-intra macroblock is decoded.
- Whenever a macroblock is skipped. i.e. when macroblock_address_increment > 1.

The predictors are denoted *dct_dc_pred*[*cc*].

QFS[0] shall be calculated from dct_dc_size and dct_dc_differential by any process equivalent to:

```
if ( dct_dc_size == 0 ) {
    dct_diff = 0;
} else {
    half_range = 2 ^ ( dct_dc_size - 1 );
    if ( dct_dc_differential > = half_range )
        dct_diff = dct_dc_differential;
    else
        dct_diff = (dct_dc_differential + 1) - (2 * half_range);
}
QFS[0] = dct_dc_pred[cc] + dct_diff;
dct_dc_pred[cc] = QFS[0]
```

NOTE 1 – The symbol ^ *denotes power (not XOR).*

NOTE 2 – *dct_diff* and *half_range* are temporary variables which are not used elsewhere in this Specification.

It is a requirement of the bitstream that QFS[0] shall lie in the range:

0 to ((2^(8 + intra_dc_precision)) - 1)

7.2.2 Other coefficients

All coefficients with the exception of the DC intra coefficients shall be encoded using Tables B.14, B.15 and B.16.

In all cases a variable length code shall first be decoded using either Table B.14 or Table B.15. The decoded value of this code denotes one of three courses of action:

1) *End of Block* – In this case there are no more coefficients in the block in which case the remainder of the coefficients in the block (those for which no value has yet been decoded) shall be set to zero. This is denoted by "End of block" in the syntax specification of 6.2.6.

2) A "normal" coefficient in which a value of *run* and *level* is decoded followed by a single bit, *s*, giving the sign of the coefficient *signed_level* is computed from *level* and *s* as shown below. *run* coefficients shall be set to zero and the subsequent coefficient shall have the value *signed_level.*

```
if (s ==0)
        signed_level = level;
    else
        signed_level = (-level);
```

3) An "Escape" coded coefficient. In which the values of *run* and *signed_level* are fixed length coded as described in 7.2.2.3.

7.2.2.1 Table selection

Table 7-3 indicates which Table shall be used for decoding the DCT coefficients.

Table 7-3 – Selection of DCT coefficient VLC tables

intra_vlc_format	0	1
intra blocks (macroblock_intra = 1)	B.14	B.15
non-intra blocks (macroblock_intra = 0)	B.14	B.14

7.2.2.2 First coefficient of a non-intra block

In the case of the first coefficient of a non-intra block (a block in a non-intra macroblock) Table B.14 is modified as indicated by Notes 2 and 3 at the foot of that Table.

This modification only affects the entry that represents run = 0, level = ± 1. Since it is not possible to encode an End of block as the first coefficient of a block (the block would be "not coded" in this case) no possibility for ambiguity exists.

The positions in the syntax that use this modified Table are denoted by "First DCT coefficient" in the syntax specification of 6.2.6. The remainder of the coefficients are denoted by "Subsequent DCT coefficients".

NOTE – In the case that Table B.14 is used for an intra block, the first coefficient shall be coded as specified in 7.2.1. Table B.14 shall therefore not be modified as the first coefficient that uses Table B.14 is the second coefficient in the block.

7.2.2.3 Escape coding

Many possible combinations of run and level have no variable length code to represent them. In order to encode these statistically rare combinations an Escape coding method is used.

Table B.16 defines the escape coding method. The Escape VLC is followed by a 6-bit fixed length code giving "*run*". This is followed by a 12-bit fixed length code giving the values of "*signed_level*".

NOTE – Attention is drawn to the fact that the escape coding method used in this Specification is different to that used in ISO/IEC 11172-2.

7.2.2.4 Summary

To summarise 7.2.2. The variable length decoding process shall be equivalent to the following. At the start of this process *n* shall take the value zero for non-intra blocks and one for intra blocks.

```
eob_not_read = 1;
while ( eob_not_read )
{
    <decode VLC, decode Escape coded coefficient if required>
    if ( <decoded VLC indicates End of block> ) {
        eob_not_read = 0;
        while ( n < 64) {
            QFS[n] = 0;
            n = n + 1;
        }
    } else {
        for ( m = 0; m < run; m++ ) {
            QFS[n] = 0;
            n = n + 1;
        }
        QFS[n] = signed_level
        n = n + 1;
    }
}
```

NOTE – *eob_not_read* and *m* are temporary variables that are not used elsewhere in this Specification.

7.3 Inverse scan

Let the data at the output of the variable length decoder be denoted by *QFS*[*n*]. *n* is in the range 0 to 63.

This subclause specifies the way in which the one-dimensional data, *QFS*[*n*], is converted into a two-dimensional array of coefficients denoted by *QF*[*v*][*u*]. *u* and *v* both lie in the range 0 to 7.

Two scan patterns are defined. The scan that shall be used shall be determined by alternate_scan which is encoded in the picture coding extension.

Figure 7-2 defines *scan*[alternate_scan][*v*][*u*] for the case that alternate_scan is zero. Figure 7-3 defines *scan*[alternate_scan][*v*][*u*] for the case that alternate_scan is one.

The inverse scan shall be any process equivalent to the following:

```
for (v = 0; v < 8; v++)
    for (u = 0; u < 8; u++)
        QF[v][u] = QFS[scan[alternate_scan][v][u]]
```

NOTE – The scan patterns defined here are often referred to as "zigzag scanning order".

		u							
		0	1	2	3	4	5	6	7
	0	0	1	5	6	14	15	27	28
	1	2	4	7	13	16	26	29	42
	2	3	8	12	17	25	30	41	43
	3	9	11	18	24	31	40	44	53
	4	10	19	23	32	39	45	52	54
	5	20	22	33	38	46	51	55	60
	6	21	34	37	47	50	56	59	61
v	7	35	36	48	49	57	58	62	63

Figure 7-2 – Definition of *scan*[0][*v*][*u*]

		u							
		0	1	2	3	4	5	6	7
	0	0	4	6	20	22	36	38	52
	1	1	5	7	21	23	37	39	53
	2	2	8	19	24	34	40	50	54
	3	3	9	18	25	35	41	51	55
	4	10	17	26	30	42	46	56	60
	5	11	16	27	31	43	47	57	61
	6	12	15	28	32	44	48	58	62
v	7	13	14	29	33	45	49	59	63

Figure 7-3 – Definition of *scan*[1][*v*][*u*]

7.3.1 Inverse scan for matrix download

When the quantisation matrices are downloaded they are encoded in the bitstream in a scan order that is converted into the two-dimensional matrix used in the inverse quantiser in an identical manner to that used for coefficients.

For matrix download the scan defined by Figure 7-2 (i.e. *scan*[0][*v*][*u*]) shall always be used.

Let *W*[*w*][*v*][*u*] denote the weighting matrix in the inverse quantiser (see 7.4.2.1), and *W'*[*w*][*n*] denote the matrix as it is encoded in the bitstream. The matrix download shall then be equivalent to the following:

```
for (v = 0; v < 8; v++)
    for (u = 0; u < 8; u++)
        W[w][v][u] = W'[w][scan[0][v][u]]
```

7.4 Inverse quantisation

The two-dimensional array of coefficients, $QF[v][u]$, is inverse quantised to produce the reconstructed DCT coefficients. This process is essentially a multiplication by the quantiser step size. The quantiser step size is modified by two mechanisms; a weighting matrix is used to modify the step size within a block and a scale factor is used in order that the step size can be modified at the cost of only a few bits (as compared to encoding an entire new weighting matrix).

Figure 7-4 illustrates the overall inverse quantisation process. After the appropriate inverse quantisation arithmetic the resulting coefficients, $F''[v][u]$, are saturated to yield $F'[v][u]$ and then a mismatch control operation is performed to give the final reconstructed DCT coefficients, $F[v][u]$.

NOTE – Attention is drawn to the fact that the method of achieving mismatch control in this Specification is different to that employed by ISO/IEC 11172-2.

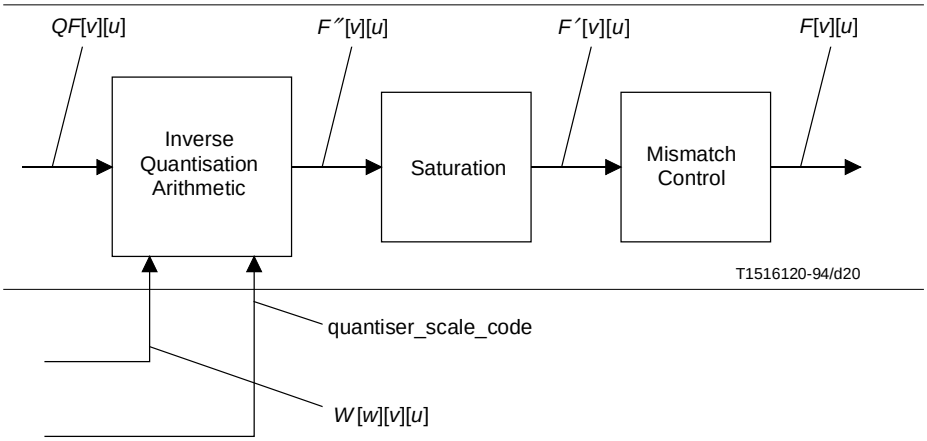


Figure 7-4 – Inverse quantisation process

7.4.1 Intra DC coefficient

The DC coefficients of intra coded blocks shall be inverse quantised in a different manner to all other coefficients.

In intra blocks $F''[0][0]$ shall be obtained by multiplying $QF[0][0]$ by a constant multiplier, *intra_dc_mult*, (constant in the sense that it is not modified by either the weighting matrix or the scale factor). The multiplier is related to the parameter intra_dc_precision that is encoded in the picture coding extension. Table 7-4 specifies the relation between intra_dc_precision and *intra_dc_mult*.

Thus; $F''[0][0] = \text{intra\_dc\_mult} \times QF[0][0]$

Table 7-4 – Relation between intra_dc_precision and *intra_dc_mult*

intra_dc_precision	Bits of precision	***intra_dc_mult***
0	8	8
1	9	4
2	10	2
3	11	1

7.4.2 Other coefficients

All coefficients other than the DC coefficient of an intra block shall be inverse quantised as specified in this subclause.

7.4.2.1 Weighting matrices

When 4:2:0 data is used two weighting matrices are used. One shall be used for intra macroblocks and the other for non-intra macroblocks. When 4:2:2 or 4:4:4 data is used, four matrices are used allowing different matrices to be used for luminance and chrominance data. Each matrix has a default set of values which may be overwritten by down-loading a user defined matrix as explained in 6.2.3.2.

Let the weighting matrices be denoted by *W*[*w*][*v*][*u*] where *w* takes the values 0 to 3 indicating which of the matrices is being used. Table 7-5 summarises the rules governing the selection of *w*.

Table 7-5 – Selection of *w*

	4:2:0		4:2:2 and 4:4:4	
	Luminance (cc = 0)	Chrominance (cc ≠ 0)	Luminance (cc = 0)	Chrominance (cc ≠ 0)
intra blocks (macroblock_intra = 1)	0	0	0	2
non-intra blocks (macroblock_intra = 0)	1	1	1	3

7.4.2.2 Quantiser scale factor

The quantisation scale factor is encoded as a 5-bit fixed length code, quantiser_scale_code. This indicates the appropriate *quantiser_scale* to apply in the inverse quantisation arithmetic.

q_scale_type (encoded in the picture coding extension) indicates which of two mappings between quantiser_scale_code and *quantiser_scale* shall apply. Table 7-6 shows the two mappings between quantiser_scale_code and *quantiser_scale*.

7.4.2.3 Reconstruction formulae

The following equation specifies the arithmetic to reconstruct *F''*[*v*][*u*] from *QF*[*v*][*u*] (for all coefficients except intra DC coefficients).

$$F''[v][u] = ((2 \times QF[v][u] + k) \times W[w][v][u] \times quantizer\_scale / 32$$

where:

$$k = \begin{cases} 0 & \text{intra blocks} \\ Sign(QF[v][u]) & \text{non - intra blocks} \end{cases}$$

NOTE – The above equation uses the "/" operator as defined in 4.1.

7.4.3 Saturation

The coefficients resulting from the Inverse Quantisation Arithmetic are saturated to lie in the range [–2048:+2047]. Thus:

$$F'[v][u] = \begin{cases} 2047 & F''[v][u] > 2047 \\ F''[v][u] & -2048 \le F''[v][u] \le 2047 \\ -2048 & F''[v][u] < -2048 \end{cases}$$

7.4.4 Mismatch control

Mismatch control shall be performed by any process equivalent to the following. Firstly all of the reconstructed, saturated coefficients, *F'[v*][*u*] in the block shall be summed. This value is then tested to determine whether it is odd or even. If the sum is even then a correction shall be made to just one coefficient; *F*[7][7]. Thus:

$$sum = \sum_{v=0}^{v<8} \sum_{u=0}^{u<8} F'[v][u]$$

$$F[v][u] = F'[v][u] \text{ for all u, v except u = v = 7}$$

$$F[7][7] = \begin{cases} F'[7][7] & \text{if sum is odd} \\ \begin{cases} F'[7][7] - 1 & \text{if } F'[7][7] \text{ is odd} \\ F'[7][7] + 1 & \text{if } F'[7][7] \text{ is even} \end{cases} & \text{if sum is even} \end{cases}$$

NOTE 1 – It may be useful to note that the above correction for *F*[7][7] may simply be implemented by toggling the least significant bit of the twos complement representation of the coefficient. Also since only the "oddness" or "evenness" of the *sum* is of interest an exclusive OR (of just the least significant bit) may be used to calculate "*sum*".

NOTE 2 – Warning – Small non-zero inputs to the IDCT may result in zero output for compliant IDCTs. If this occurs in an encoder, mismatch may occur in some pictures in a decoder that uses a different compliant IDCT. An encoder should avoid this problem and may do so by checking the output of its own IDCT. It should ensure that it never inserts any non-zero coefficients into the bitstream when the block in question reconstructs to zero through its own IDCT function. If this action is not taken by the encoder, situations can arise where large and very visible mismatches between the state of the encoder and decoder occur.

Table 7-6 – Relation between *quantiser_scale* and quantiser_scale_code

quantiser_scale_code	quantiser_scale[q_scale_type]	
	q_scale_type = 0	q_scale_type = 1
0	(Forbidden)	
1	2	1
2	4	2
3	6	3
4	8	4
5	10	5
6	12	6
7	14	7
8	16	8
9	18	10
10	20	12
11	22	14
12	24	16
13	26	18
14	28	20
15	30	22
16	32	24
17	34	28
18	36	32
19	38	36
20	40	40
21	42	44
22	44	48
23	46	52
24	48	56
25	50	64
26	52	72
27	54	80
28	56	88
29	58	96
30	60	104
31	62	112

7.4.5 Summary

In summary the inverse quantisation process is any process numerically equivalent to:

```
for (v = 0; v < 8;v++) {
    for (u = 0; u < 8;u++) {
        if ( (u==0) && (v==0) && (macroblock_intra) ) {
            F''[v][u] = intra_dc_mult * QF[v][u];
        } else {
            if ( macroblock_intra ) {
                F''[v][u] = ( QF[v][u] * W[w][v][u] * quantiser_scale * 2 ) / 32;
            } else {
                F''[v][u] = ( ( ( QF[v][u] *  2 ) + Sign(QF[v][u]) ) * W[w][v][u]
                                                                    * quantiser_scale ) / 32;
            }
        }
    }
}


sum = 0;
    for (v = 0; v < 8;v++) {
        for (u = 0; u < 8;u++) {
            if ( F''[v][u] > 2047 ) {
                F'[v][u] = 2047;
            } else {
                if ( F''[v][u] < –2048 ) {
                    F'[v][u] = –2048;
                } else {
                    F'[v][u] = F''[v][u];
                }
            }
        sum = sum + F'[v][u];
        F[v][u] = F'[v][u];
        }
}


if ((sum & 1) == 0) {
    if ((F[7][7] & 1) ! = 0) {
        F[7][7] = F'[7][7] – 1;
    } else {
        F[7][7] = F'[7][7] + 1;
    }
}
```

7.5 Inverse DCT

Once the DCT coefficients, F[v][u] are reconstructed, an IDCT transform that conforms to the specifications of Annex A shall be applied to obtain the inverse transformed values f[y][x].

7.5.1 Non-coded blocks and skipped macroblocks

In a macroblock that is not skipped, if pattern_code[i] is one for a given block in the macroblock, then coefficient data is included in the bitstream for that block. This is decoded using as specified in the preceding clauses.

However, if pattern_code[i] is zero, or if the macroblock is skipped, then that block contains no coefficient data. The sample domain coefficients *f*[*y*][*x*] for such a block shall all take the value zero.

7.6 Motion compensation

The motion compensation process forms predictions from previously decoded pictures which are combined with the coefficient data (from the output of the IDCT) in order to recover the final decoded samples. Figure 7-5 shows a simplified diagram of this process.

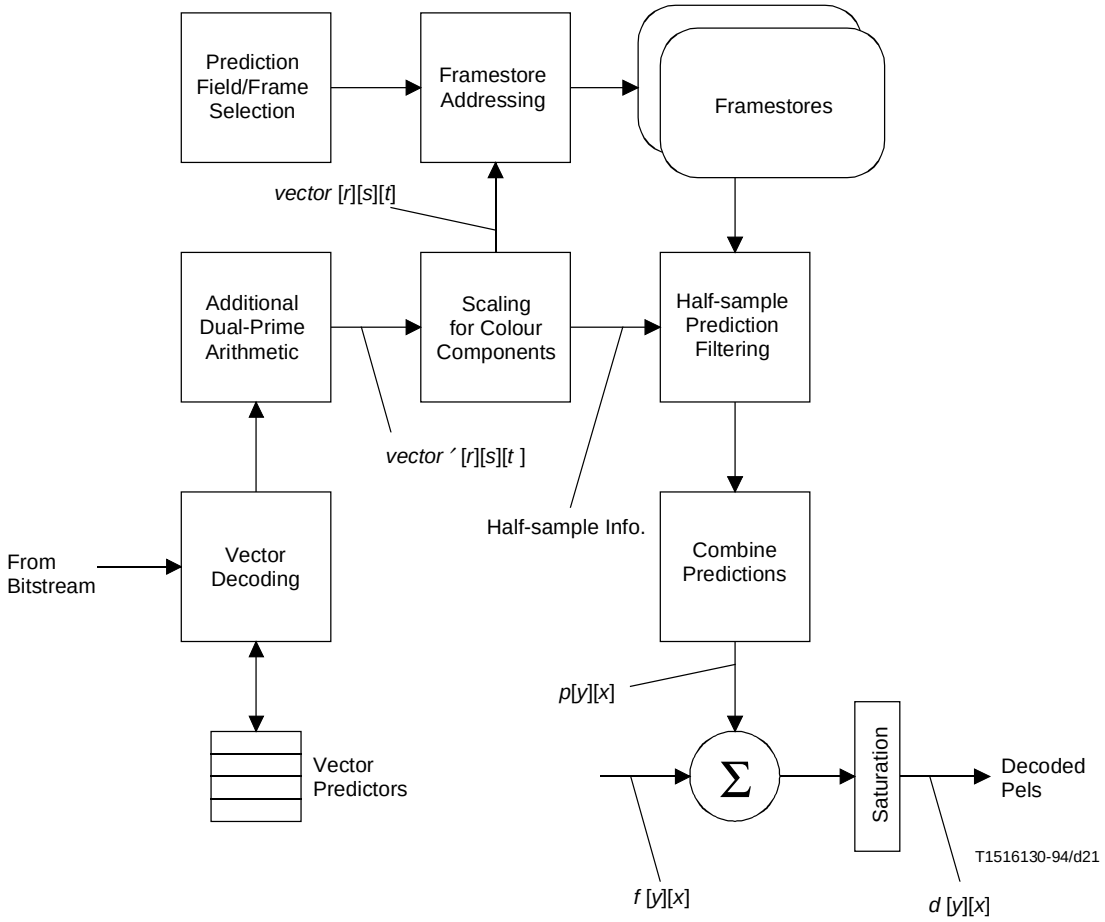


Figure 7-5 – Simplified motion compensation process

In general up to four separate predictions are formed for each block which are combined together to form the final prediction block p[y][x].

In the case of intra coded macroblocks no prediction is formed so that p[y][x] will be zero. The saturation shown in Figure 7-5 is still required in order to remove negative values from f[y][x]. Intra coded macroblocks may carry motion vectors known as "concealment motion vectors". Despite this no prediction is formed in the normal course of events. This motion vector information is intended for use in the case that bitstream errors preclude the decoding of coefficient information. The way in which a decoder shall use this information is not specified. The only requirement for these motion vectors is that they shall have the correct syntax for motion vectors. A description of the way in which these motion vectors may be used can be found in 7.6.3.9.

In the case where a block is not coded, either because the entire macroblock is skipped or the specific block is not coded there is no coefficient data. In this case f[y][x] is zero and the decoded samples are simply the prediction, p[y][x].

7.6.1 Prediction modes

There are two major classifications of the prediction mode:

– field prediction; and

– frame prediction.

In field prediction, predictions are made independently for each field by using data from one or more previously decoded fields. Frame prediction forms a prediction for the frame from one or more previously decoded frames. It must be understood that the fields and frames from which predictions are made may themselves have been decoded as either field pictures or frame pictures.

Within a field picture all predictions are field predictions. However, in a frame picture either field predictions or frame predictions may be used (selected on a macroblock-by macroblock basis).

In addition to the major classification of field or frame prediction two special prediction modes are used:

- *16 × 8 motion compensation* – In which two motion vectors are used for each macroblock. The first motion vector is used for the upper 16 × 8 region, the second for the lower 16 × 8 region. In the case of a bidirectionally predicted macroblock a total of four motion vectors will be used since there will be two for the forward prediction and two for the backward prediction. In this Specification 16 × 8 motion compensation shall only be used with field pictures.

- *Dual-prime* – In which only one motion vector is encoded (in its full format) in the bitstream together with a small differential motion vector. In the case of field pictures two motion vectors are then derived from this information. These are used to form predictions from two reference fields (one top, one bottom) which are averaged to form the final prediction. In the case of frame pictures this process is repeated for the two fields so that a total of four field predictions are made. This mode shall only be used in P-pictures where there are no B-pictures between the predicted and reference fields or frames.

7.6.2 Prediction field and frame selection

The selection of which fields and frames shall be used to form predictions shall be made as detailed in this clause.

7.6.2.1 Field prediction

In P-pictures, the two reference fields from which predictions shall made are the most recently decoded reference top field and the most recently decoded reference bottom field. The simplest case illustrated in Figure 7-6 shall be used when predicting the first picture of a coded frame or when using field prediction within a frame-picture. In these cases the two reference fields are part of the same reconstructed frame.

NOTE 1 – The reference fields may themselves have been reconstructed from two field-pictures or a single frame-picture.

NOTE 2 –In the case of predicting a field picture, the field being predicted may be either the top field or the bottom field.

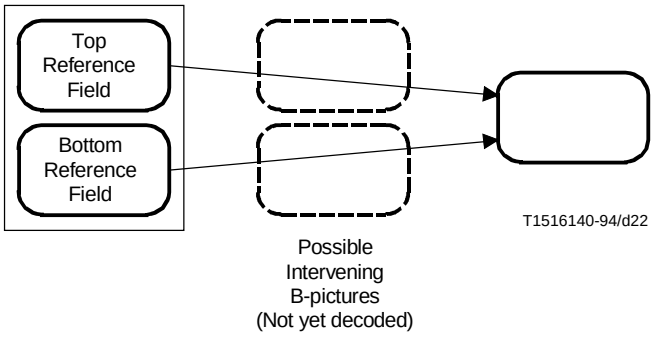


Figure 7-6 – Prediction of the first field or field prediction in a frame-picture

The case when predicting the second field picture of a coded frame is more complicated because the two most recently decoded reference fields shall be used, and in this case, the most recent reference field was obtained from decoding the first field picture of the coded frame. Figure 7-7 illustrates the situation when this second picture is the bottom field. Figure 7-8 illustrates the situation when this second picture is the top field.

NOTE 3 – The earlier reference field may itself have been reconstructed by decoding a field picture or a frame picture.

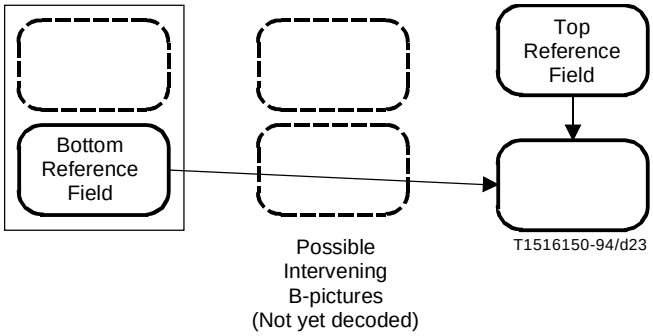


Figure 7-7 – Prediction of the second field-picture when it is the bottom field

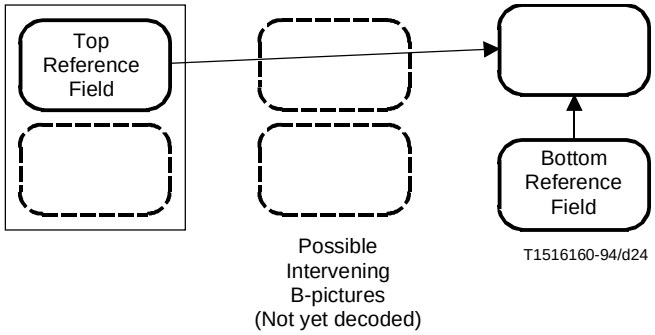


Figure 7-8 – Prediction of the second field-picture when it is the top field

Field prediction in B-pictures shall be made from the two fields of the two most recently reconstructed reference frames. Figure 7-9 illustrates this situation.

NOTE 4 – The reference frames may themselves have been reconstructed from two coded field-pictures or a single coded frame-picture.

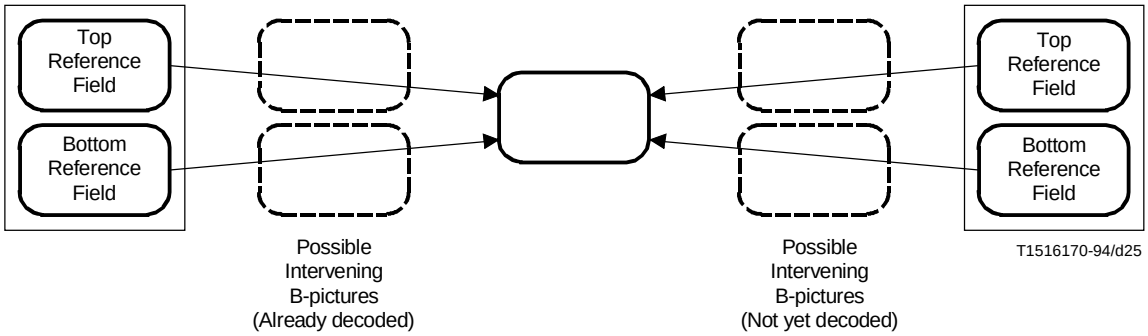


Figure 7-9 – Field-prediction of B-field pictures or B-frame pictures

7.6.2.2 Frame prediction

In P-pictures prediction shall be made from the most recently reconstructed reference frame. This is illustrated in Figure 7-10.

NOTE 1 – The reference frame may itself have been coded as two field pictures or a single frame picture.

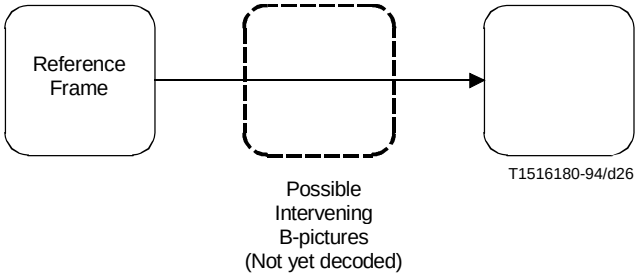


Figure 7-10 – Frame-prediction for l-pictures and P-pictures

Similarly frame prediction in B-pictures shall be made from the two most recently reconstructed reference frames as illustrated in Figure 7-11.

NOTE 2 – The reference frames themselves may each have been coded as either two field pictures or a single frame picture.

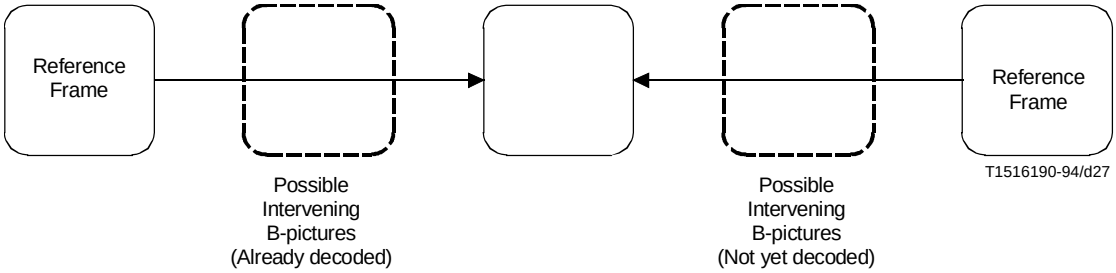


Figure 7-11 – Frame-prediction for B-pictures

7.6.3 Motion vectors

Motion vectors are coded differentially with respect to previously decoded motion vectors in order to reduce the number of bits required to represent them. In order to decode the motion vectors the decoder shall maintain four motion vector predictors (each with a horizontal and vertical component) denoted *PMV*[*r*][*s*][*t*]. For each prediction, a motion vector, *vector'*[*r*][*s*][*t*] is first derived. This is then scaled depending on the sampling structure (4:2:0, 4:2:2 or 4:4:4) to give a motion vector, *vector*[*r*][*s*][*t*], for each colour component. The meanings associated with the dimensions in this array are defined in Table 7-7.

Table 7-7 – Meaning of indices in *PMV*[*r*][*s*][*t*], *vector*[*r*][*s*][*t*] and *vector'*[*r*][*s*][*t*]

	0	1
r	First motion vector in Macroblock	Second motion vector in Macroblock
s	Forward motion Vector	Backwards motion Vector
t	Horizontal Component	Vertical Component
NOTE – *r* also takes the values 2 and 3 for derived motion vectors used with dual-prime prediction. Since these motion vectors are derived they do not themselves have motion vector predictors.		

7.6.3.1 Decoding the motion vectors

Each motion vector component, *vector'*[*r*][*s*][*t*], shall be calculated by any process that is equivalent to the following one. Note that the motion vector predictors shall also be updated by this process.

```
r_size = f_code[s][t] – 1
f = 1 << r_size
high = ( 16 * f ) – 1;
low = ( (–16) * f );
range = ( 32 * f );

if ( (f == 1) || (motion_code[r][s][t] == 0) )
      delta = motion_code[r][s][t] ;
else {
      delta = ( ( Abs(motion_code[r][s][t]) – 1 ) * f ) + motion_residual[r][s][t] + 1;
      if (motion_code[r][s][t] < 0)
            delta = – delta;
}

prediction = PMV[r][s][t];
if ( (mv_format == "field") && (t==1) && (picture_structure == "Frame picture") )
      prediction = PMV[r][s][t] DIV 2;

vector'[r][s][t] = prediction + delta;
if (vector'[r][s][t] < low )
      vector'[r][s][t] = vector'[r][s][t] + range;
if (vector'[r][s][t] > high)
      vector'[r][s][t] = vector'[r][s][t] – range;


if ( (mv_format == "field") && (t == 1) && (picture_structure == "Frame picture") )
      PMV[r][s][t] = vector'[r][s][t] * 2;
else
      PMV[r][s][t] = vector'[r][s][t];
```

The parameters in the bitstream shall be such that the reconstructed differential motion vector, *delta*, shall lie in the range [*low*:*high*]. In addition the reconstructed motion vector, *vector'*[*r*][*s*][*t*], and the updated value of the motion vector predictor *PMV*[*r*][*s*][*t*], shall also lie in the range [*low* : *high*].

r_size, *f*, *delta*, *high*, *low* and *range* are temporary variables that are not used in the remainder of this Specification.

motion_code[r][s][t] and motion_residual[r][s][t] are fields recovered from the bitstream. mv_format is recovered from the bitstream using Tables 6-17 and 6-18.

r, *s* and *t* specify the particular motion vector component being processed as identified in Table 7-7.

vector'[*r*][*s*][*t*] is the final reconstructed motion vector for the luminance component of the macroblock.

The vector'[r][s][t] value considered in this subclause is the one obtained from the pseudo code above. In case of dual-prime, this restriction that vector'[r][s][t] shall be in the range [low:high] does not apply to the scaled motion vectors vector'[2:3][0][0:1] defined in 7.6.3.6. Other restrictions on motion vectors, including scaled dual-prime motion vectors are specified in 7.6.3.8 and 8.3.

7.6.3.2 Motion vector restrictions

In frame pictures, the vertical component of field motion vectors shall be restricted so that they only cover half the range that is supported by the f_code that relates to those motion vectors. This restriction ensures that the motion vector predictors will always have values that are appropriate for decoding subsequent frame motion vectors. Table 7-8 summarises the size of motion vectors that may be coded as a function of f_code.

7.6.3.3 Updating motion vector predictors

Once all of the motion vectors present in the macroblock have been decoded using the process defined in the previous clause it is sometimes necessary to update other motion vector predictors. This is because in some prediction modes fewer than the maximum possible number of motion vectors are used. The remainder of the predictors that might be used in the picture must retain "sensible" values in case they are subsequently used.

Table 7-8 – Allowable motion vector range as a function of *f_code*[*s*][*t*]

f_code[*s*][*t*]	Vertical components (*t* == 1) of field vectors in frame pictures	All other cases
0	(Forbidden)	
1	[–4: +3.5]	[–8: +7.5]
2	[–8: +7.5]	[–16: +15.5]
3	[–16: +15.5]	[–32: +31.5]
4	[–32: +31.5]	[–64: +63.5]
5	[–64: +63.5]	[–128: +127.5]
6	[–128: +127.5]	[–256: +255.5]
7	[–256: +255.5]	[–512: +511.5]
8	[–512: +511.5]	[–1024: +1023.5]
9	[–1024: +1023.5]	[–2048: +2047.5]
10-14	(Reserved)	
15	(Used when a particular *f_code*[*s*][*t*] will not be used)	

The motion vector predictors shall be updated as specified in Table 7-9 and 7-10. The rules for updating motion vector predictors in the case of skipped macroblocks are specified in 7.6.6.

NOTE – It is possible for an implementation to optimise the updating (and resetting) of motion vector predictors depending on the picture type. For example in a P-picture the predictors for backwards motion vectors are unused and need not be maintained.

Table 7-9 – Updating of motion vector predictors in frame pictures

frame_motion_-type	**macroblock_motion_-**		**macroblock_-intra**	Predictors to Update
	forward	**backward**		
Frame-based[a)]	–	–	1	*PMV*[1][0][1:0] = *PMV*[0][0][1:0][b)]
Frame-based	1	1	0	*PMV*[1][0][1:0] = *PMV*[0][0][1:0] *PMV*[1][1][1:0] = *PMV*[0][1][1:0]
Frame-based	1	0	0	*PMV*[1][0][1:0] = *PMV*[0][0][1:0]
Frame-based	0	1	0	*PMV*[1][1][1:0] = *PMV*[0][1][1:0]
Frame-based[a)]	0	0	0	*PMV*[*r*][*s*][*t*] = 0[c)]
Field-based	1	1	0	(None)
Field-based	1	0	0	(None)
Field-based	0	1	0	(None)
Dual prime	1	0	0	*PMV*[1][0][1:0] = *PMV*[0][0][1:0]

a) **frame_motion_type** is not present in the bitstream but is assumed to be Frame-based.

b) If **concealment_motion_vectors** is zero then *PMV*[*r*][*s*][*t*] is set to zero (for all *r*, *s* and *t*).

c) (Only occurs in P-picture) *PMV*[*r*][*s*][*t*] is set to zero (for all *r*, *s* and *t*). See 7.6.3.4.

NOTE – *PMV*[*r*][*s*][1:0] = *PMV*[*u*][*v*][1:0] means that:

PMV[*r*][*s*][1] = *PMV*[*u*][*v*][1] and *PMV*[*r*][*s*][0] = *PMV*[*u*][*v*][0]

Table 7-10 – Updating of motion vector predictors in field pictures

frame_motion_-type	macroblock_motion_-		macroblock_-intra	Predictors to Update
	forward	backward		
Field-based[a)]	–	–	1	*PMV*[1][0][1:0] = *PMV*[0][0][1:0][b)]
Field-based	1	1	0	*PMV*[1][0][1:0] = *PMV*[0][0][1:0] *PMV*[1][1][1:0] = *PMV*[0][1][1:0]
Field-based	1	0	0	*PMV*[1][0][1:0] = *PMV*[0][0][1:0]
Field-based	0	1	0	*PMV*[1][1][1:0] = *PMV*[0][1][1:0]
Field-based[a)]	0	0	0	*PMV*[*r*][*s*][*t*] = 0[c)]
16 × 8 MC	1	1	0	(None)
16 × 8 MC	1	0	0	(None)
16 × 8 MC	0	1	0	(None)
Dual prime	1	0	0	*PMV*[1][0][1:0] = *PMV*[0][0][1:0]

a) **frame_motion_type** is not present in the bitstream but is assumed to be Field-based.

b) If **concealment_motion_vectors** is zero then *PMV*[*r*][*s*][*t*] is set to zero (for all *r*, *s* and *t*).

c) (Only occurs in P-picture) *PMV*[*r*][*s*][*t*] is set to zero (for all *r*, *s* and *t*). See 7.6.3.4.

NOTE – *PMV*[*r*][*s*][1:0] = *PMV*[*u*][*v*][1:0] means that:

PMV[*r*][*s*][1] = *PMV*[*u*][*v*][1] and *PMV*[*r*][*s*][0] = *PMV*[*u*][*v*][0]

7.6.3.4 Resetting motion vector predictors

All motion vector predictors shall be reset to zero in the following cases:

- At the start of each slice.
- Whenever an intra macroblock is decoded which has no concealment motion vectors.
- In a P-picture when a non-intra macroblock is decoded in which macroblock_motion_forward is zero.
- In a P-picture when a macroblock is skipped.

7.6.3.5 Prediction in P-pictures

In P-pictures, in the case that *macroblock_motion_forward* is zero and *macroblock_intra* is also zero no motion vectors are encoded for the macroblock yet a prediction must be formed. If this occurs in a P-field picture the following apply;

- the prediction type shall be "Field-based";
- the (field) motion vector shall be zero (0;0);
- the motion vector predictors shall be reset to zero;
- predictions shall be made from the field of the same parity as the field being predicted.

If this occurs in a P-frame picture the following apply:

- the prediction type shall be "Frame-based";
- the (frame) motion vector shall be zero (0;0);
- the motion vector predictors shall be reset to zero.

In the case that a P-field picture is used as the second field of a frame in which the first field is an I-field picture a series of semantic restrictions apply. These ensure that prediction is only made from the I field picture. These restrictions are:

- There shall be no macroblocks that are coded with *macroblock_motion_forward* zero and *macroblock_intra* zero.
- Dual prime prediction shall not be used.
- Field prediction in which **motion_vertical_field_select** indicates the same parity as the field being predicted shall not be used.
- There shall be no skipped macroblocks.

7.6.3.6 Dual prime additional arithmetic

In dual prime prediction one field motion vector (*vector'*[0][0][1:0]) will have been decoded by the process already described. This represents the motion vector used to form predictions from the reference field (or reference fields in a frame picture) of the same parity as the prediction being formed. Here the word "parity" is used to differentiate the two fields. The top field has parity zero, the bottom field has parity one.

In order to form a motion vector for the opposite parity (*vector'*[*r*][0][1:0]) the existing motion vector is scaled to reflect the different temporal distance between the fields. A correction is made to the vertical component (to reflect the vertical shift between the lines of top field and bottom field) and then a small differential motion vector is added. This process is illustrated in Figure 7-12 which shows the situation for a frame picture.

dmvector[0] is the horizontal component of the differential motion vector and *dmvector*[1] the vertical component. The two components of the differential motion vector shall be decoded directly using Table B.11 and shall take only one of the values –1, 0, + 1.

m[*parity_ref*][*parity_pred*] is the field distance between the predicted field and the reference field as defined in Table 7-11. "*parity_ref*" is the parity of the reference field for which the new motion vector is being computed. "*parity_pred*" is the parity of the field that shall be predicted.

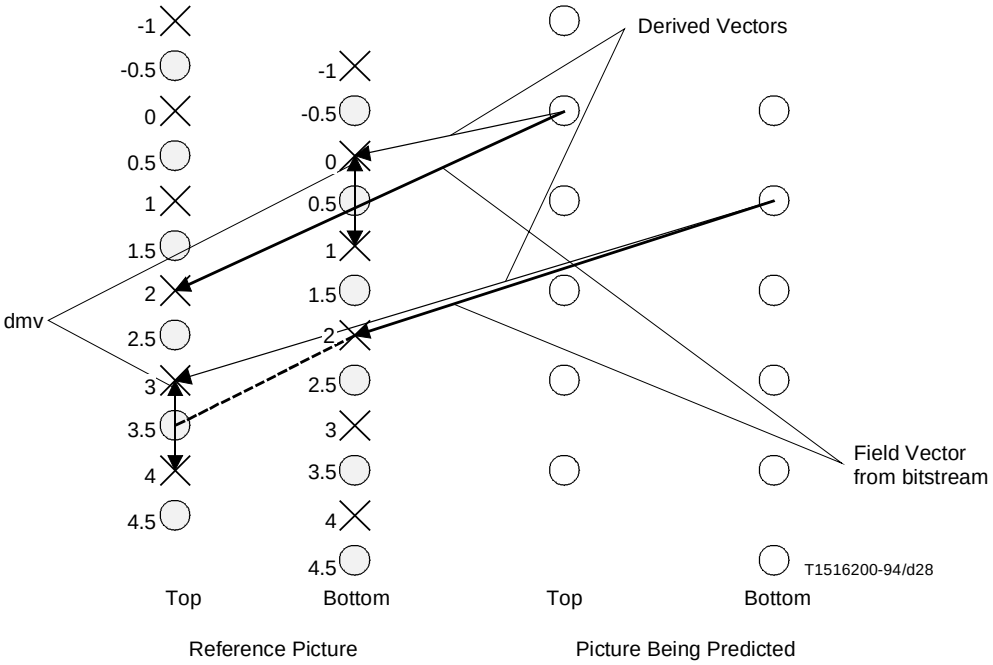


Figure 7-12 – Scaling of motion vectors for dual prime prediction

Table 7-11 – Definition of *m*[*parity_ref*][*parity_pred*]

picture_structure	top_field_first	m[*parity_ref*][*parity_pred*]	
		m[1][0]	m[0][1]
11 (Frame)	1	1	3
11 (Frame)	0	3	1
01 (Top Field)	–	1	–
10 (Bottom Field)	–	–	1

e[*parity_ref*][*parity_pred*] is the adjustment necessary to reflect the vertical shift between the lines of top field and bottom field as defined in Table 7-12.

Table 7-12 – Definition of *e*[*parity_ref*][*parity_pred*]

parity_ref	*parity_pred*	*e[parity_ref][parity_pred]*
0	1	+1
1	0	–1

The motion vector (or motion vectors) used for predictions of opposite parity shall be computed as follows:

vector'[*r*][0][0] = ((*vector'*[0][0][0] * *m*[*parity_ref*][*parity_pred*])//2) + *dmvector*[0];

vector'[*r*][0][1] = ((*vector'*[0][0][1] * *m*[*parity_ref*][*parity_pred*])//2)
+ *e*[*parity_ref*][*parity_pred*] + *dmvector*[1];

In the case of field pictures only one such motion vector is required and here r = 2. Thus, the (encoded) motion vector used for the same parity prediction is *vector'*[0][0][1:0] and the motion vector used for the opposite parity prediction is *vector'*[2][0][1:0].

In the case of frame pictures two such motion vectors are required. Both fields use the encoded motion vector (*vector'*[0][0][1:0]) for predictions of the same parity. The top field shall use *vector'*[2][0][1:0] for opposite parity prediction and the bottom field shall use *vector'*[3][0][1:0] for opposite parity prediction.

7.6.3.7 Motion vectors for chrominance components

The motion vectors calculated in the previous clauses refer to the luminance component where:

vector[*r*][*s*][*t*] = *vector'*[*r*][*s*][*t*] (for all r, s and t)

For each of the two chrominance components the motion vectors shall be scaled as follows:

4:2:0 Both the horizontal and vertical components of the motion vector are scaled by dividing by two:

vector[*r*][*s*][0] = *vector'*[*r*][*s*][0] / 2;

vector[*r*][*s*][1] = *vector'*[*r*][*s*][1] / 2;

4:2:2 The horizontal component of the motion vector is scaled by dividing by two, the vertical component is not altered:

vector[*r*][*s*][0] = *vector'*[*r*][*s*][0] / 2;

vector[*r*][*s*][1] = *vector'*[r][s][1];

4:4:4 The motion vector is unmodified:

vector[*r*][*s*][0] = *vector'*[*r*][*s*][0];

vector[*r*][*s*][1] = *vector'*[*r*][*s*][1];

7.6.3.8 Semantic restrictions concerning predictions

It is a requirement on the bitstream that it shall only demand of a decoder that predictions shall be made from slices actually encoded in a reference frame or reference field. This rule applies even for skipped macroblocks and macroblocks in P-pictures in which a zero motion vector is assumed (as explained in 7.6.3.5).

NOTE – As explained in 6.1.2 it is, in general, not necessary for the slices to cover the entire picture. However, in many defined levels of defined profiles the "restricted slice structure" is used in which case the slices do cover the entire picture. In this case the semantic rule may be more simply stated: "it is a restriction on the bitstream that reconstructed motion vectors shall not refer to samples outside the boundary of the coded picture."

7.6.3.9 Concealment motion vectors

Concealment motion vectors are motion vectors that may be carried by intra macroblocks for the purpose of concealing errors if data errors preclude decoding the coefficient data. A concealment motion vector shall be present for all intra macroblocks if (and only if) concealment_motion_vectors (in the picture_coding_extension()) has the value one.

In the normal course of events no prediction shall be formed for such macroblocks (as would be expected since macroblock_intra = 1). This Specification does not specify how error recovery shall be performed. However it is a recommendation that concealment motion vectors are suitable for use by a decoder that performs concealment by forming predictions as if field_motion_type and frame_motion_type (from which the prediction type is derived) have the following values:

- In a field picture: field_motion_type = "Field-based";
- In a frame picture: frame_motion_type = "Frame-based".

NOTE – If concealment is used in an I-picture then the decoder should perform prediction in a similar way to a P-picture.

Concealment motion vectors are intended for use in the case that a data error results in information being lost. There is therefore little point in encoding the concealment motion vector in the macroblock for which it is intended to be used since if the data error results in the need for error recovery it is very likely that the concealment motion vector itself would be lost or corrupted. As a result the following semantic rules are appropriate:

- For all macroblocks except those in the bottom row of macroblocks concealment motion vectors should be appropriate for use in the macroblock that lies vertically below the macroblock in which the motion vector occurs.
- When the motion vector is used with respect to the macroblock identified in the previous rule a decoder must assume that the motion vector may refer to samples outside of the slices encoded in the reference frame or reference field.
- For all macroblocks in the bottom row of macroblocks the reconstructed concealment motion vectors will not be used. Therefore the motion vector (0;0) may be used to reduce unnecessary overhead.

7.6.4 Forming predictions

Predictions are formed by reading prediction samples from the reference fields or frames. A given sample is predicted by reading the corresponding sample in the reference field or frame offset by the motion vector.

A positive value of the horizontal component of a motion vector indicates that the prediction is made from samples (in the reference field/frame) that lie to the right of the samples being predicted.

A positive value of the vertical component of a motion vector indicates that the prediction is made from samples (in the reference field/frame) that lie below the samples being predicted.

All motion vectors are specified to an accuracy of one half sample. Thus, if a component of the motion vector is odd, the samples will be read from mid-way between the actual samples in the reference field/frame. These half-samples are calculated by simple linear interpolation from the actual samples.

In the case of field-based predictions it is necessary to determine which of the two available fields to use to form the prediction. In the case of dual-prime this is specified in that a motion vector is derived for both of the fields and a prediction is formed from each. In the case of field-based prediction and 16 × 8 MC an additional bit, motion_vertical_field_select, is encoded to indicate which field to use.

If motion_vertical_field_select is zero, then the prediction is taken from the top reference field.

If motion_vertical_field_select is one, then the prediction is taken from the bottom reference field.

For each prediction block the integer sample motion vectors int_vec[t] and the half sample flags half_flag[t] shall be formed as follows;

```
for (t = 0; t< 2; t++) {
    int_vec[t] = vector[r][s][t] DIV 2;
    if ((vector[r][s][t] - (2 * int_vec[t]) != 0)
        half_flag[t] = 1;
    else
        half_flag[t] = 0;
}
```

Then for each sample in the prediction block the samples are read and the half sample prediction applied as follows;

```
if ( (! half_flag[0] )&& (! half_flag[1]) )
    pel_pred[y][x] = pel_ref[y + int_vec[1]][x + int_vec[0]];


if ( (! half_flag[0] )&& half_flag[1] )
    pel_pred[y][x] = ( pel_ref[y + int_vec[1]][x + int_vec[0]] +
                       pel_ref[y + int_vec[1]+1][x + int_vec[0]] ) // 2;
```

```
if ( half_flag[0]&& (! half_flag[1]) )
    pel_pred[y][x] = ( pel_ref[y + int_vec[1]][x + int_vec[0]] +
                       pel_ref[y + int_vec[1]][x + int_vec[0]+1] ) // 2;
if ( half_flag[0]&& half_flag[1] )
    pel_pred[y][x] = ( pel_ref[y + int_vec[1]][x + int_vec[0]] +
                       pel_ref[y + int_vec[1]][x + int_vec[0]+1] +
                           pel_ref[y + int_vec[1]+1][x + int_vec[0]] +
                               pel_ref[y + int_vec[1]+1][x + int_vec[0]+1] ) // 4;
```

where *pel_pred*[*y*][*x*] is the prediction sample being formed and *pel_ref*[*y*][*x*] are samples in the reference field or frame.

7.6.5 Motion vector selection

Table 7-13 shows the prediction modes used in field pictures and Table 7-14 shows the predictions used in frame pictures. In each table the motion vectors that are present in the bitstream are listed in the order in which they appear in the bitstream.

Table 7-13 – Predictions and motion vectors in field pictures

field_ motion_ type	**macroblock_motion_-**		**macro-block_-**	Motion vector	Prediction formed for
	forward	**backward**	**intra**		
Field-based[a)]	–	–	1	*vector'*[0][0][1:0][b)]	None (motion vector is for concealment)
Field-based	1	1	0	*vector'*[0][0][1:0] *vector'*[0][1][1:0]	Whole field, forward Whole field, backward
Field-based	1	0	0	*vector'*[0][0][1:0]	Whole field, forward
Field-based	0	1	0	*vector'*[0][1][1:0]	Whole field, backward
Field-based[a)]	0	0	0	*vector'*[0][0][1:0][c) d)]	Whole field, forward
16 × 8 MC	1	1	0	*vector'*[0][0][1:0] *vector'*[1][0][1:0] *vector'*[0][1][1:0] *vector'*[1][1][1:0]	Upper 16 × 8 field, forward Lower 16 × 8 field, forward Upper 16 × 8 field, backward Lower 16 × 8 field, backward
16 × 8 MC	1	0	0	*vector'*[0][0][1:0] *vector'*[1][0][1:0]	Upper 16 × 8 field, forward Lower 16 × 8 field, forward
16 × 8 MC	0	1	0	*vector'*[0][1][1:0] *vector'*[1][1][1:0]	Upper 16 × 8 field, backward Lower 16 × 8 field, backward
Dual prime	1	0	0	*vector'*[0][0][1:0] *vector'*[2][0][1:0][c) e)]	Whole field, from same parity, forward Whole field, from opposite parity, forward

a) **field_motion_type** is not present in the bitstream but is assumed to be Field-based.

b) The motion vector is only present if **concealment_motion_vectors** is one.

c) These motion vectors are not present in the bitstream.

d) The motion vector is taken to be (0; 0) as explained in 7.6.3.5.

e) These motion vectors are derived from *vector'*[0][0][1:0] as described in 7.6.3.6.

NOTE – Motion vectors are listed in the order they appear in the bitstream.

Table 7-14 – Predictions and motion vectors in frame pictures

frame_-motion_-type	**macroblock_motion_-**		**macro-block_-intra**	Motion vector	Prediction formed for
	forward	**backward**			
Frame-based[a)]	–	–	1	*vector'*[0][0][1:0][b)]	None (motion vector is for concealment)
Frame-based	1	1	0	*vector'*[0][0][1:0]	Frame, forward
				vector'[0][1][1:0]	Frame, backward
Frame-based	1	0	0	*vector'*[0][0][1:0]	Frame, forward
Frame-based	0	1	0	*vector'*[0][1][1:0]	Frame, backward
Frame-based[a)]	0	0	0	*vector'*[0][0][1:0][c) d)]	Frame, forward
Field-based	1	1	0	*vector'*[0][0][1:0]	Top field, forward
				vector'[1][0][1:0]	Bottom field, forward
				vector'[0][1][1:0]	Top field, backward
				vector'[1][1][1:0]	Bottom field, backward
Field-based	1	0	0	*vector'*[0][0][1:0]	Top field, forward
				vector'[1][0][1:0]	Bottom field, forward
Field-based	0	1	0	*vector'*[0][1][1:0]	Top field, backward
				vector'[1][1][1:0]	Bottom field, backward
Dual prime	1	0	0	*vector'*[0][0][1:0]	Top field, from same parity, forward
				vector'[0][0][1:0]	Bottom field, from same parity, forward
				vector'[2][0][1:0][c) e)]	Top field, from opposite parity, forward
				vector'[3][0][1:0][c) e)]	Bottom field, from opposite parity, forward

a) **frame_motion_type** is not present in the bitstream but is assumed to be Frame-based.

b) The motion vector is only present if **concealment_motion_vectors** is one.

c) These motion vectors are not present in the bitstream.

d) The motion vector is taken to be (0; 0) as explained in 7.6.3.5.

e) These motion vectors are derived from *vector'*[0][0][1:0] as described in 7.6.3.6.

NOTE – Motion vectors are listed in the order they appear in the bitstream.

7.6.6 Skipped macroblocks

A skipped macroblock is a macroblock for which no data is encoded, that is part of a coded slice. Except at the start of a slice, if the number (macroblock_address - previous_macroblock_address - 1) is larger than zero, then this number indicates the number of macroblocks that have been skipped. The decoder shall form a prediction for skipped macroblocks which shall then be used as the final decoded sample values.

The handling of skipped macroblocks is different between P-pictures and B-pictures. In addition, the process differs between field pictures and frame pictures.

There shall be no skipped macroblocks in I-pictures except when either:

– picture_spatial_scalable_extension() follows the picture_header() of the current picture; or

– sequence_scalable_extension() is present in the bitstream and scalable_mode = "SNR scalability".

7.6.6.1 P field picture

- the prediction shall be made as if field_motion_type is "Field-based";
- the prediction shall be made from the field of the same parity as the field being predicted;
- motion vector predictors shall be reset to zero;
- the motion vector shall be zero.

7.6.6.2 P frame picture

- the prediction shall be made as if frame_motion_type is "Frame-based";
- motion vector predictors shall be reset to zero;
- the motion vector shall be zero.

7.6.6.3 B field picture

- the prediction shall be made as if field_motion_type is "Field-based";
- the prediction shall be made from the field of the same parity as the field being predicted;
- the direction of the prediction forward/backward/bi-directional shall be the same as the previous macroblock;
- motion vector predictors are unaffected;
- the motion vectors are taken from the appropriate motion vector predictors. Scaling of the motion vectors for colour components shall be performed as described in 7.6.3.7.

7.6.6.4 B frame picture

- the prediction shall be made as if frame_motion_type is "Frame-based";
- the direction of the prediction forward/backward/bi-directional shall be the same as the previous macroblock;
- motion vector predictors are unaffected;
- the motion vectors are taken directly from the appropriate motion vector predictors. Scaling of the motion vectors for colour components shall be performed as described in 7.6.3.7.

7.6.7 Combining predictions

The final stage is to combine the various predictions together in order to form the final prediction blocks.

It is also necessary to organise the data into blocks that are either field organised or frame organised in order to be added directly to the decoded coefficients.

The transform data is either field organised or frame organised as specified by *dct_type*.

7.6.7.1 Simple frame predictions

In the case of simple frame predictions the only further processing that may be required is to average forward and backward predictions in B-pictures. If *pel_pred_forward*[*y*][*x*] is the forwards prediction sample and *pel_pred_backward*[*y*][*x*] is the corresponding backward prediction, then the final prediction sample shall be formed as:

$$pel\_pred[y][x] = (pel\_pred\_forward[y][x] + pel\_pred\_backward[y][x])//2$$

The predictions for chrominance components of 4:2:0, 4:2:2 and 4:4:4 formats shall be of size 8 samples by 8 lines, 8 samples by 16 lines and 16 samples by 16 lines respectively.

7.6.7.2 Simple field predictions

In the case of simple field predictions (i.e. neither 16 × 8 or dual prime) the only further processing that may be required is to average forward and backward predictions in B-pictures. This shall be performed as specified for "Frame predictions" in the previous subclause.

In the case of simple field prediction in a frame picture the predictions for chrominance components of 4:2:0, 4:2:2 and 4:4:4 formats for each field shall be of size 8 samples by 4 lines, 8 samples by 8 lines and 16 samples by 8 lines respectively.

In the case of simple field prediction in a field picture the predictions for chrominance components of 4:2:0, 4:2:2 and 4:4:4 formats for each field shall be of size 8 samples by 8 lines, 8 samples by 16 lines and 16 samples by 16 lines respectively.

7.6.7.3 16 × 8 Motion compensation

In this prediction mode separate predictions are formed for the upper 16 × 8 region of the macroblock and the lower 16 × 8 region of the macroblock.

The predictions for chrominance components, for each 16 × 8 region, of 4:2:0, 4:2:2 and 4:4:4 formats shall be of size 8 samples by 4 lines, 8 samples by 8 lines and 16 samples by 8 lines respectively.

7.6.7.4 Dual prime

In dual prime mode two predictions are formed for each field in an analogous manner to the backward and forward predictions in B-pictures. If *pel_pred_same_parity*[*y*][*x*] is the prediction sample from the same parity field and *pel_pred_opposite_parity*[*y*][*x*] is the corresponding sample from the opposite parity field then the final prediction sample shall be formed as:

pel_pred[*y*][*x*] = (*pel_pred_same_parity*[*y*][*x*] + *pel_pred_opposite_parity*[*y*][*x*])//2;

In the case of dual prime prediction in a frame picture, the predictions for chrominance components of each field of 4:2:0, 4:2:2 and 4:4:4 formats shall be of size 8 samples by 4 lines, 8 samples by 8 lines and 16 samples by 8 lines respectively.

In the case of dual prime prediction in a field picture, the predictions for chrominance components of 4:2:0, 4:2:2 and 4:4:4 formats shall be of size 8 samples by 8 lines, 8 samples by 16 lines and 16 samples by 16 lines respectively.

7.6.8 Adding prediction and coefficient data

The prediction blocks have been formed and reorganised into blocks of prediction samples *p*[*y*][*x*] which match the field/frame structure used by the transform data blocks.

The transform data *f*[*y*][*x*] shall be added to the prediction data and saturated to form the final decoded samples *d*[*y*][*x*] as follows:

```
for (y = 0; y < 8; y++) {
    for (x = 0; x < 8; x++) {
        d[y][x] = f[y][x] + p[y][x];
        if (d[y][x] <  0) d[y][x] = 0;
        if (d[y][x] > 255) d[y][x] = 255;
    }
}
```

7.7 Spatial scalability

This subclause specifies the additional decoding process required for the spatial scalable extensions.

Both the lower layer and the enhancement layer shall use the "restricted slice structure" (no gaps between slices).

Figure 7-13 is a diagram of the video decoding process with spatial scalability. The diagram is simplified for clarity.

7.7.1 Higher syntactic structures

In general, the base layer of a spatial scalable hierarchy can conform to any coding standard including Recommendation H.261, ISO/IEC 11172-2 and this Specification. Note however, that within this Specification the decodability of a spatial scalable hierarchy is only considered in the case that the base layer conforms to this Specification or ISO/IEC 11172-2.

Due to the "loose coupling" of layers only one syntactic restriction is needed in the enhancement layer if both lower and enhancement layer are interlaced. In that case picture_structure has to take the same value as in the reference frame used for prediction from the lower layer. See 7.7.3.1 for how to identify this reference frame.

7.7.2 Prediction in the enhancement layer

A motion compensated temporal prediction is made from reference frames in the enhancement layer as described in 7.6. In addition, a spatial prediction is formed from the lower layer decoded frame (d_{lower}[y][x]), as described in 7.7.3. These predictions are selected individually or combined to form the actual prediction.

In general, up to four separate predictions are formed for each macroblock which are combined together to form the final prediction macroblock p[y][x].

In the case that a macroblock is not coded, either because the entire macroblock is skipped or the specific macroblock is not coded, there is no coefficient data. In this case f[y][x] is zero and the decoded samples are simply the prediction, p[y][x].

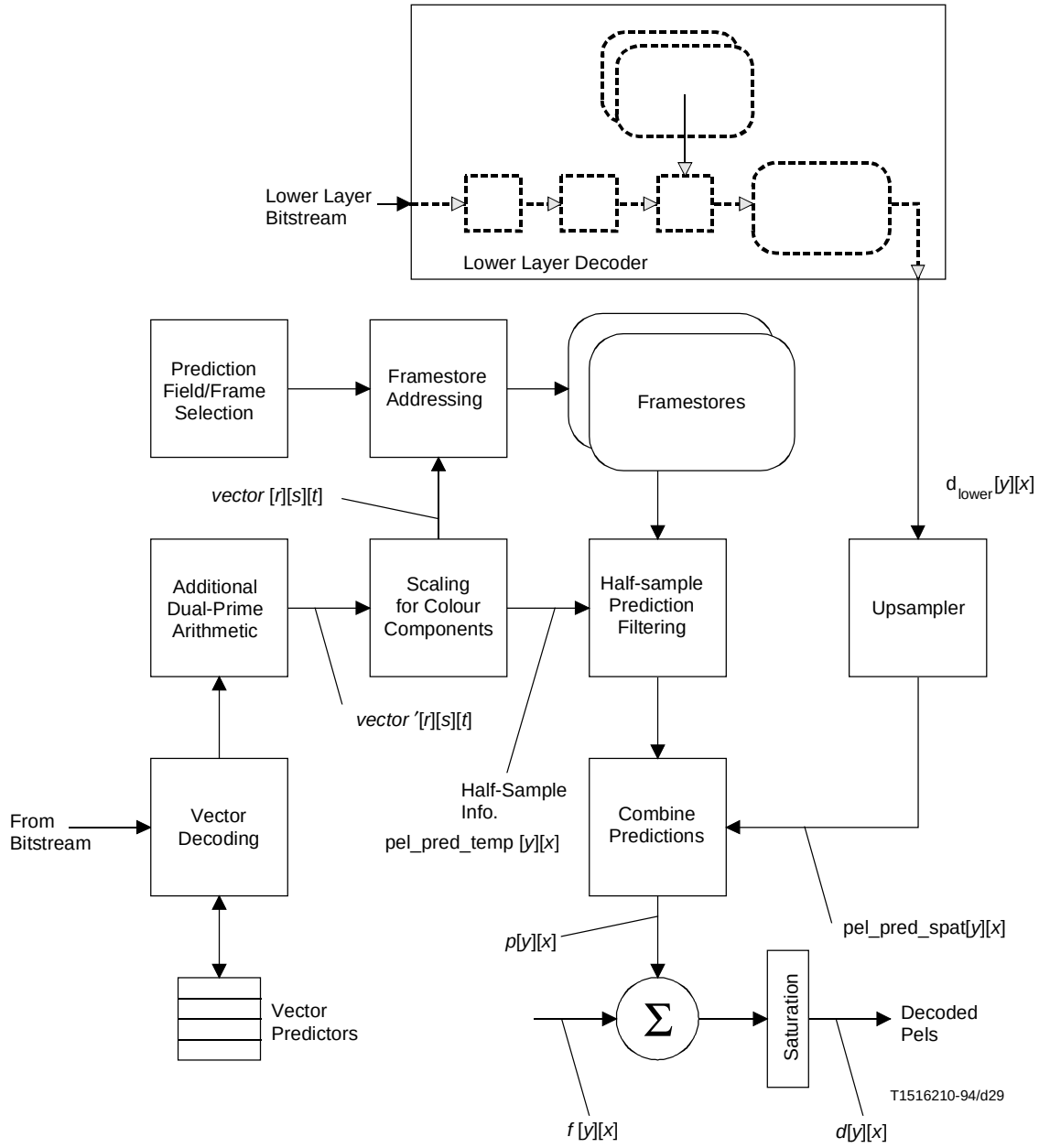


Figure 7-13 – Simplified motion compensation process for spatial scalability

7.7.3 Formation of spatial prediction

Forming the spatial prediction requires identification of the correct reference frame and definition of the spatial resampling process, which is done in the following subclauses.

The resampling process is defined for a whole frame, however, for decoding of a macroblock, only the 16×16 region in the upsampled frame, which corresponds to the position of this macroblock, is needed.

7.7.3.1 Selection of reference frame

The spatial prediction is made from the reconstructed frame of the lower layer referenced by the lower_layer_temporal_reference. However, if lower and enhancement layer bitstreams are embedded in ITU-T Rec. H.220.0 | ISO/IEC 13818-1 (Systems) multiplex, this information is overridden by the timing information given by the decoding time stamps (DTS) in the PES headers.

NOTE – If group_of_pictures_header() occurs often in the lower layer bitstream, then the temporal reference in the lower layer may be ambiguous (because temporal_reference is reset after a group_of_pictures_header()).

The reconstructed picture from which the spatial prediction is made shall be one of the following:

- The coincident or most recently decoded lower layer picture.
- The coincident or most recently decoded lower layer I-picture or P-picture.
- The second most recently decoded lower layer I-picture or P-picture provided that the lower layer does not have low_delay set to '1'. Note furthermore that spatial scalability will only work efficiently when predictions are formed from frames in the lower layer which are also coincident (or very close) in display time with the predicted frame in the enhancement layer.

7.7.3.2 Resampling process

The spatial prediction is made by resampling the lower layer reconstructed frame to the same sample grid as the enhancement layer. This grid is defined in terms of frame coordinates, even if a lower-layer interlaced frame was actually coded with a pair of field pictures.

This resampling process is illustrated in Figure 7-14.

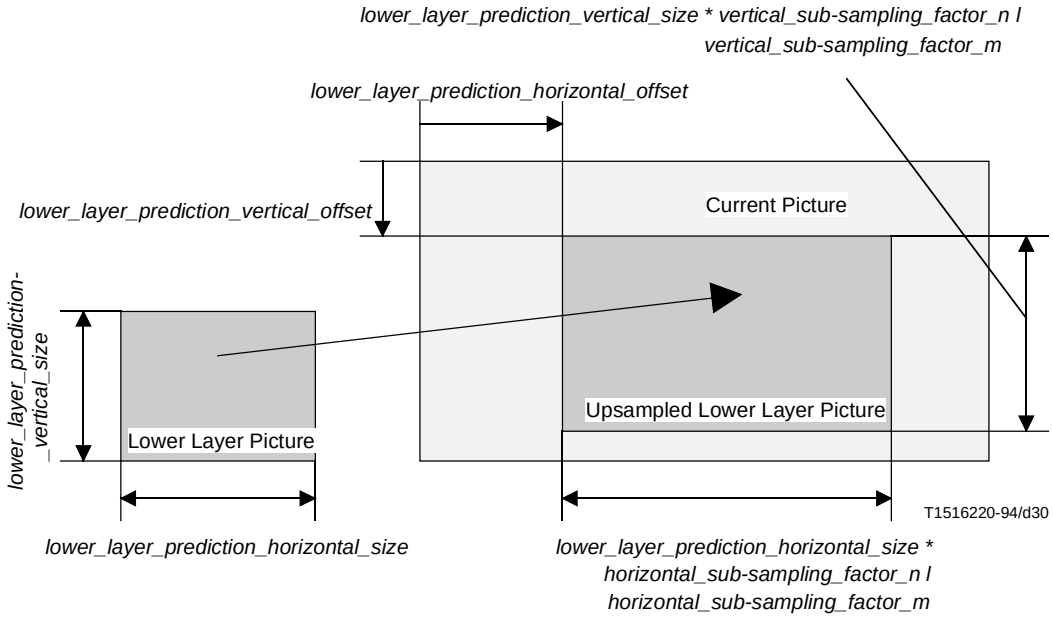


Figure 7-14 – Formation of the "spatial" prediction by interpolation of the lower layer picture

Spatial predictions shall only be made for macroblocks in the enhancement layer that lie wholly within the upsampled lower layer reconstructed frame.

The upsampling process depends on whether the lower layer reconstructed frame is interlaced or progressive, as indicated by lower_layer_progressive_frame and whether the enhancement layer frame is interlaced or progressive, as indicated by progressive_frame.

When lower_layer_progressive_frame is '1', the lower layer reconstructed frame (renamed to prog_pic) is resampled vertically as described in 7.7.3.4. The resulting frame is considered to be progressive if progressive_frame is '1' and interlaced if progressive_frame is '0'. The resulting frame is resampled horizontally as described in 7.7.3.6. lower_layer_deinterlaced_field_select shall have the value '1'.

When lower_layer_progressive_frame is '0' and progressive_frame is '0', each lower layer reconstructed field is deinterlaced as described in 7.7.3.4, to produce a progressive field (prog_pic). This field is resampled vertically as described in 7.7.3.5. The resulting field is resampled horizontally as described in 7.7.3.6. Finally the resulting field is subsampled to produce an interlaced field. lower_layer_deinterlaced_field_select shall have the value '1'.

When lower_layer_progressive_frame is '0' and progressive_frame is '1', each lower layer reconstructed field is deinterlaced as described in 7.7.3.4, to produce a progressive field (prog_pic). Only one of these fields is required. When lower_layer_deinterlaced_field_select is '0' the top field is used, otherwise the bottom field is used. The one that is used is resampled vertically as described in 7.7.3.5. The resulting frame is resampled horizontally as described in 7.7.3.6.

For interlaced frames, if the current (and implicitly the lower-layer) frames are encoded as field pictures, the deinterlacing process described in 7.7.3.5 is done within the field.

lower_layer_vertical_offset and lower_layer_horizontal_offset, defining the position of the lower layer frame within the current frame, shall be taken into account in the resampling definitions in 7.7.3.5 and 7.7.3.6 respectively. The lower layer offsets are limited to even values when the chrominance in the enhancement layer is subsampled in that dimension in order to align the chrominance samples between the two layers.

The upsampling process is summarised Table 7-15.

Table 7-15 – Upsampling process

lower_layer_ deinterlaced_ field_select	**lower_layer_ progressive_frame**	**progressive_ frame**	Apply deinterlace process	Entity used for prediction
0	0	1	Yes	Top field
1	0	1	Yes	Bottom field
1	1	1	No	Frame
1	1	0	No	Frame
1	0	0	Yes	Both fields

7.7.3.3 Colour component processing

Due to the different sampling grids of luminance and chrominance components, some variables used in 7.7.3.4 to 7.7.3.6 take different values for luminance and chrominance resampling. Furthermore it is permissible for the chrominance formats in the lower layer and the enhancement layer to be different from one another.

Table 7-16 defines the values for the variables used in 7.7.3.4 to 7.7.3.6

Table 7-16 – Local variables used in 7.7.3.3 to 7.7.3.6

Variable	Value for luminance processing	Value for chrominance processing
ll_h_size	lower_layer_prediction_horizontal_size	lower_layer_prediction_horizontal_size / chroma_ratio_horizontal[lower]
ll_v_size	lower_layer_prediction_vertical_size	lower_layer_prediction_vertical_size / chroma_ratio_vertical[lower]
ll_h_offset	lower_layer_horizontal_offset	lower_layer_horizontal_offset / chroma_ratio_horizontal[enhance]
ll_v_offset	lower_layer_vertical_offset	lower_layer_vertical_offset / chroma_ratio_vertical[enhance]
h_subs_m	horizontal_subsampling_factor_m	horizontal_subsampling_factor_m
h_subs_n	horizontal_subsampling_factor_n	horizontal_subsampling_factor_n * format_ratio_horizontal
v_subs_m	vertical_subsampling_factor_m	vertical_subsampling_factor_m
v_subs_n	vertical_subsampling_factor_n	vertical_subsampling_factor_n * format_ratio_vertical

Tables 7-17 and 7-18 give additional definitions.

Table 7-17 – chrominance subsampling ratios for layer = {lower, enhance}

Chrominance format lower layer	chroma_ratio_ horizontal[layer]	chroma_ratio_ vertical[layer]
4:2:0	2	2
4:2:2	2	1
4:4:4	1	1

Table 7-18 – Chrominance format ratios

Chrominance format lower layer	Chrominance format enhancement layer	format_ratio_ horizontal	format_ratio_ vertical
4:2:0	4:2:0	1	1
4:2:0	4:2:2	1	2
4:2:0	4:4:4	2	2
4:2:2	4:2:2	1	1
4:2:2	4:4:4	2	1
4:4:4	4:4:4	1	1

7.7.3.4 Deinterlacing

If deinterlacing needs not to be done (according to Table 7-16), the lower layer reconstructed frame ($d_{lower}[y][x]$) is renamed to input_pic.

First, each lower layer field is padded with zeros to form a progressive grid at a frame rate equal to the field rate of the lower layer, and with the same number of lines and samples per line as the lower layer frame. Table 7-19 specifies the filters to be applied next. The luminance component is filtered using the relevant two field aperture filter if picture_structure == "Frame-Picture" or else using the one field aperture filter. The chrominance component is filtered using the one field aperture filter.

Table 7-19 – Deinterlacing Filter

		Two field aperture		One field aperture
Temporal	Vertical	Filter for first field	Filter for second field	Filter (both fields)
–1	–2	0	–1	0
–1	0	0	2	0
–1	2	0	–1	0
0	–1	8	8	8
0	0	16	16	16
0	1	8	8	8
1	–2	–1	0	0
1	0	2	0	0
1	+2	–1	0	0

The temporal and vertical columns of Table 7-19 indicate the relative spatial and temporal coordinates of the samples to which the filter taps defined in the other two columns apply. An intermediate sum is formed by adding the multiplied coefficients together.

The output of the filter (sum) is then scaled according to the following formula:

$$prog\_pic[y][x] = sum \,//\, 16$$

and saturated to lie in the range [0:255].

The filter aperture can extend outside the coded picture size. In this case the samples of the lines outside the active picture shall take the value of the closest neighbouring existing sample (below or above) of the same field as defined below.

For all samples [y][x]:

```
if (y < 0 && (y&1 == 1))
    y = 1
if (y < 0 && (y&1 == 0))
    y = 0
if (y >= ll_v_size &&
            ( (y-ll_v_size)&1 == 1))
    y = ll_v_size – 1
if (y >= ll_v_size &&
            ((y-ll_v_size)&1 == 0))
    y = ll_v_size – 2
```

7.7.3.5 Vertical resampling

The frame subject to vertical resampling, prog_pic, is resampled to the enhancement layer vertical sampling grid using linear interpolation between the sample sites according to the following formula, where vert_pic is the resulting field:

$$vert\_pic[y_h + ll\_v\_offset][x] = (16 - phase) * prog\_pic[y1][x] + phase * prog\_pic[y2][x]$$

where

$y_h + ll\_v\_offset$ = output sample co-ordinate in vert_pic

$y1$ = $(y_h * v\_subs\_m) / v\_subs\_n$

$y2$ = $y1 + 1$ if $y1 < ll\_v\_size - 1$; $y1$ otherwise

$phase$ = $(16 * ((y_h * v\_subs\_m) \,\%\, v\_subs\_n)) \,//\, v\_subs\_n$

Samples which lie outside the lower layer reconstructed frame which are required for upsampling are obtained by border extension of the lower layer reconstructed frame.

NOTE – The calculation of phase assumes that the sample position in the enhancement layer at $y_h = 0$ is spatially coincident with the first sample position of the lower layer. It is recognised that this is an approximation for the chrominance component if the chroma_format == 4:2:0.

7.7.3.6 Horizontal resampling

The frame subject to horizontal resampling, vert_pic, is resampled to the enhancement layer horizontal sampling grid using linear interpolation between the sample sites according to the following formula, where hor_pic is the resulting field:

$$hor\_pic[y][x_h + ll\_h\_offset] = ((16 - phase) * vert\_pic[y][x1] + phase * vert\_pic[y][x2]) \,//\, 256$$

where

x_h+ ll_h_offset = output sample coordinate in hor_pic

x1 = (x_h * h_subs_m) / h_subs_n

x2 = x1 + 1 if x1 < ll_h_size - 1

x1 otherwise

phase = (16 * ((x_h * h_subs_m) % h_subs_n)) // h_subs_n

Samples which lie outside the lower layer reconstructed frame which are required for upsampling are obtained by border extension of the lower layer reconstructed frame.

7.7.3.7 Reinterlacing

If reinterlacing needs not to be done, the result of the resampling process, hor_pic, is renamed to spat_pred_pic.

If hor_pic was derived from the top field of a lower layer interlaced frame, the even lines of hor_pic are copied to the even lines of spat_pred_pic.

If hor_pic was derived from the bottom field of a lower layer interlaced frame the odd lines of hor_pic are copied to the odd lines of spat_pred_pic.

If hor_pic was derived from a lower layer progressive frame, hor_pic is copied to spat_pred_pic.

7.7.4 Selection and combination of spatial and temporal predictions

The spatial and temporal predictions can be selected or combined to form the actual prediction. The macroblock_type (see Tables B.5, B.6 and B.7) and the additional spatial_temporal_weight_code (see Table 7-21) indicate, by use of the spatial_temporal_weight_class, whether the prediction is temporal-only, spatial-only or a weighted combination of temporal and spatial predictions. Classes are defined in the following way:

- Class 0 indicates temporal-only prediction;
- Class 1 indicates that neither field has spatial-only prediction;
- Class 2 indicates that the top field is spatial-only prediction;
- Class 3 indicates that the bottom field is spatial-only prediction;
- Class 4 indicates spatial-only prediction.

In intra pictures, if spatial_temporal_weight_class is 0, normal intra coding is performed, otherwise the prediction is spatial-only. In predicted and interpolated pictures, if the spatial_temporal_weight_class is 0, prediction is temporal-only, if the spatial_temporal_weight_class is 4, prediction is spatial-only, otherwise one or a pair of prediction weights is used to combine the spatial and temporal predictions.

The possible spatial_temporal_weights are given in a weight table which is selected in the picture spatial scalable extension. Up to four different weight tables are available for use depending on whether the current and lower layers are interlaced or progressive, as indicated in Table 7-20 (allowed, yet not recommended values given in brackets).

Table 7-20 – Intended (allowed) spatial_temporal_weight_code_table_index values

Lower layer format	Enhancement layer format	**spatial_temporal_weight_ code_table_index**
Progressive or interlaced	Progressive	00
Progressive coincident with enhancement layer top fields	Interlaced	10 (00; 01; 11)
Progressive coincident with enhancement layer from bottom fields	Interlaced	01 (00; 10; 11)
Interlaced (picture_structure == Frame-Picture)	Interlaced	00 or 11 (01; 10)
Interlaced (picture_structure != Frame-Picture)	Interlaced	00

In macroblock_modes(), a two bit code, spatial_temporal_weight_code, is used to describe the prediction for each field (or frame), as shown in the Table 7-21. In this table spatial_temporal_integer_weight identifies those spatial_temporal_weight_codes that can also be used with dual prime prediction (see Tables 7-22, 7-23).

Table 7-21 – spatial_temporal_weights and spatial_temporal_weight_classes for the spatial_temporal_weight_code_table_index and spatial_temporal_weight_codes

spatial_temporal_ weight_code_table_ index	spatial_ temporal_ weight_code	spatial_ temporal_ weight (s)	spatial_ temporal_ weight class	spatial_ temporal_ integer_weight
00[a)]	–	(0,5)	1	0
01	00	(0; 1)	3	1
	01	(0; 0,5)	1	0
	10	(0,5; 1)	3	0
	11	(0,5; 0,5)	1	0
10	00	(1; 0)	2	1
	01	(0,5; 0)	1	0
	10	(1; 0,5)	2	0
	11	(0,5; 0,5)	1	0
11	00	(1; 0)	2	1
	01	(1; 0,5)	2	0
	10	(0,5; 1)	3	0
	11	(0,5; 0,5)	1	0

a) For spatial_temporal_weight_code_table_index == 00 no spatial_temporal_weight_code is transmitted.

NOTE – Spatial-only prediction (weight_class == 4) is signalled by different values of macroblock_type (see Tables B.5 to B.7).

When the spatial_temporal_weight combination is given in the form (a; b), "a" gives the proportion of the prediction for the top field which is derived from the spatial prediction and "b" gives the proportion of the prediction for the bottom field which is derived from the spatial prediction for that field.

When the spatial_temporal_weight is given in the form (a), "a" gives the proportion of the prediction for the picture which is derived from the spatial prediction for that picture.

The precise method for predictor calculation is as follows:

pel_pred_temp[y][x] is used to denote the temporal prediction (formed within the enhancement layer) as defined for pel_pred[y][x] in 7.6. pel_pred_spat[y][x] is used to denote the prediction formed from the lower layer by extracting the appropriate samples, co-located with the current macroblock position, from spat_pred_pic.

If the spatial_temporal_weight is zero, then no prediction is made from the lower layer. Therefore:

$$\text{pel\_pred}[y][x] = \text{pel\_pred\_temp}[y][x];$$

If the spatial_temporal_weight is one, then no prediction is made from the enhancement layer. Therefore:

$$\text{pel\_pred}[y][x] = \text{pel\_pred\_spat}[y][x];$$

If the weight is one half then the prediction is the average of the temporal and spatial predictions. Therefore:

$$\text{pel\_pred}[y][x] = (\text{pel\_pred\_temp}[y][x] + \text{pel\_pred\_spat}[y][x])//2;$$

When progressive_frame == 0 chrominance is treated as interlaced, that is, the first weight is used for the top field chrominance lines and the second weight is used for the bottom field chrominance lines.

Addition of prediction and coefficient data is then done as in 7.6.8.

7.7.5 Updating motion vector predictors and motion vector selection

In frame pictures where field prediction is used the possibility exists that one of the fields is predicted using spatial-only prediction. In this case no motion vector is present in the bitstream for the field which has spatial-only prediction. For the case where both fields of a frame have spatial-only prediction, the macroblock_type is such that no motion vectors are present in the bitstream for that macroblock.

The spatial_temporal_weight_class also indicates the number of motion vectors which are present in the coded bitstream and how the motion vector predictors are updated as defined in Table 7-22 and Table 7-23.

Table 7-22 – Updating of motion vector predictors in Field Pictures

frame_motion_type	**macroblock_motion_forward**	**macroblock_motion_backward**	**macroblock_intra**	**spatial_temporal_weight_class**	Predictors to update
Field-based[a)]	–	–	1	0	*PMV*[1][0][1:0] = *PMV*[0][0][1:0][b)]
Field-based	1	1	0	0	*PMV*[1][0][1:0] = *PMV*[0][0][1:0] *PMV*[1][1][1:0] = *PMV*[0][1][1:0]
Field-based	1	0	0	0,1	*PMV*[1][0][1:0] = *PMV*[0][0][1:0]
Field-based	0	1	0	0,1	*PMV*[1][1][1:0] = *PMV*[0][1][1:0]
Field-based[a)]	0	0	0	0,1,4	*PMV*[*r*][*s*][*t*] = 0[c)]
16 × 8 MC	1	1	0	0	(None)
16 × 8 MC	1	0	0	0,1	(None)
16 × 8 MC	0	1	0	0,1	(None)
Dual prime	1	0	0	0	*PMV*[1][0][1:0] = *PMV*[0][0][1:0]

a) **field_motion_type** is not present in the bitstream but is assumed to be Field-based.

b) If **concealment_motion_vectors** is zero then *PMV*[*r*][*s*][*t*] is set to zero (for all *r*, *s* and *t*).

c) *PMV*[*r*][*s*][*t*] is set to zero (for all *r*, *s* and *t*). See 7.6.3.4.

NOTE – *PMV*[*r*][*s*][1:0] = *PMV*[*u*][*v*][1:0] means that:

PMV[*r*][*s*][1] = *PMV*[*u*][*v*][1] and *PMV*[*r*][*s*][0] = *PMV*[*u*][*v*][0]

7.7.5.1 Resetting motion vector predictors

In addition to the cases identified in 7.6.3.4, the motion vector predictors shall be reset in the following cases:

- In a P-picture when a macroblock is purely spatially predicted (spatial_temporal_weight_class == 4)
- In a B-picture when a macroblock is purely spatially predicted (spatial_temporal_weight_class == 4)

NOTE – In case of spatial_temporal_weight_class == 2 in a frame picture when field-based prediction is used, the transmitted vector is applied for the *bottom* field (see Table 7-25). However this vector[0][s][1:0] is predicted from PMV[0][s][1:0] . PMV[1][s][1:0] is then updated as shown in Table 7-23.

7.7.6 Skipped macroblocks

In all cases, a skipped macroblock is the result of a prediction only, and all the DCT coefficients are considered to be zero.

If sequence_scalable_extension is present and scalable_mode = "spatial scalability", the following rules apply in addition to those given in 7.6.6.

Table 7-23 – Updating of motion vector predictors in Frame Pictures

frame_motion_type	**macroblock_motion_forward**	**macroblock_motion_backward**	**macroblock_intra**	**spatial_temporal_weight_class**	Predictors to update
Frame-based[a)]	–	–	1	0	*PMV*[1][0][1:0] = *PMV*[0][0][1:0][c)]
Frame-based	1	1	0	0	*PMV*[1][0][1:0] = *PMV*[0][0][1:0] *PMV*[1][1][1:0] = *PMV*[0][1][1:0]
Frame-based	1	0	0	0,1,2,3	*PMV*[1][0][1:0] = *PMV*[0][0][1:0]
Frame-based	0	1	0	0,1,2,3	*PMV*[1][1][1:0] = *PMV*[0][1][1:0]
Frame-based[a)]	0	0	0	0,1,2,3,4	*PMV*[r][s][t] = 0[d)]
Field-based	1	1	0	0	(None)
Field-based	1	0	0	0,1	(None)
Field-based	1	0	0	2	*PMV*[1][0][1:0] = *PMV*[0][0][1:0]
Field-based	1	0	0	3	*PMV*[1][0][1:0] = *PMV*[0][0][1:0]
Field-based	0	1	0	0,1	(None)
Field-based	0	1	0	2	*PMV*[1][1][1:0] = *PMV*[0][1][1:0]
Field-based	0	1	0	3	*PMV*[1][1][1:0] = *PMV*[0][1][1:0]
Dual prime[b)]	1	0	0	0,2,3	*PMV*[1][0][1:0] = *PMV*[0][0][1:0]

a) **frame_motion_type** is not present in the bitstream but is assumed to be Frame-based.

b) Dual prime can not be used when spatial_temporal_integer_weight = '0'.

c) If **concealment_motion_vectors** is zero then *PMV*[*r*][*s*][*t*] is set to zero (for all *r*, *s* and *t*).

d) *PMV*[*r*][*s*][*t*] is set to zero (for all *r*, *s* and *t*). See 7.6.3.4.

NOTE – *PMV*[*r*][*s*][1:0] = *PMV*[*u*][*v*][1:0] means that:

PMV[*r*][*s*][1] = *PMV*[*u*][*v*][1] and *PMV*[*r*][*s*][0] = *PMV*[*u*][*v*][0]

In I-pictures, skipped macroblocks are allowed. These are defined as spatial-only predicted.

In P-pictures and B-pictures, the skipped macroblock is temporal-only predicted.

In B-pictures a skipped macroblock shall not follow a spatial-only predicted macroblock.

7.7.7 VBV buffer underflow in the lower layer

In the case of spatial scalability, VBV buffer underflow in the lower layer may cause problems. This is because of possible uncertainty in precisely which frames will be repeated by a particular decoder.

7.8 SNR scalability

See Figure 7-15.

This clause describes the additional decoding process required for the SNR scalable extensions.

SNR scalability defines a mechanism to refine the DCT coefficients encoded in another (lower) layer of a scalable hierarchy. As illustrated in Figure 7-15 data from two bitstreams is combined after the inverse quantisation processes by adding the DCT coefficients. Until the data is combined, the decoding processes of the two layers are independent of one another.

Table 7-24 – Predictions and motion vectors in field pictures

field_motion_type	**macroblock_motion_forward**	**macroblock_motion_backward**	**macroblock_intra**	**spatial_temporal_weight_class**	Motion vector	Prediction formed for
Field-based[a)]	–	–	1	0	*vector'*[0][0][1:0][b)]	None (motion vector is for concealment)
Field-based	1	1	0	0	*vector'*[0][0][1:0]	Whole field, forward
					vector'[0][1][1:0]	Whole field, backward
Field-based	1	0	0	0,1	*vector'*[0][0][1:0]	Whole field, forward
Field-based	0	1	0	0,1	*vector'*[0][1][1:0]	Whole field, backward
Field-based[a)]	0	0	0	0,1,4	*vector'*[0][0][1:0][c) d)]	Whole field, forward
16 × 8 MC	1	1	0	0	*vector'*[0][0][1:0]	Upper 16 × 8 field, forward
					vector'[1][0][1:0]	Lower 16 × 8 field, forward
					vector'[0][1][1:0]	Upper 16 × 8 field, backward
					vector'[1][1][1:0]	Lower 16 × 8 field, backward
16 × 8 MC	1	0	0	0,1	*vector'*[0][0][1:0]	Upper 16 × 8 field, forward
					vector'[1][0][1:0]	Lower 16 × 8 field, forward
16 × 8 MC	0	1	0	0,1	*vector'*[0][1][1:0]	Upper 16 × 8 field, backward
					vector'[1][1][1:0]	Lower 16 × 8 field, backward
Dual prime	1	0	0	0	*vector'*[0][0][1:0]	Whole field, same parity, forward
					vector'[2][0][1:0][c) e)]	Whole field, opposite parity, forward

a) **field_motion_type** is not present in the bitstream but is assumed to be Field-based.

b) The motion vector is only present if **concealment_motion_vectors** is one.

c) These motion vectors are not present in the bitstream.

d) The motion vector is taken to be (0; 0) as explained in 7.6.3.5.

e) These motion vectors are derived from *vector'*[0][0][1:0] as described in 7.6.3.6.

NOTE – Motion vectors are listed in the order they appear in the bitstream.

Subclause 7.8.1 defines how to identify these bitstreams in a scalable hierarchy, however they can be classified as follows.

The lower layer, derived from the first bitstream, can itself be either non-scalable, or require the spatial or temporal scalability decoding process (and hence the decoding of additional bitstreams) to be applied.

The enhancement layer, derived from the second bitstream, contains mainly coded DCT coefficients and a small overhead. The decoding process for this layer and the combination of the two layers are described in this subclause.

NOTE – All information regarding prediction is contained in the lower layer bitstream only. Therefore it is not possible to reconstruct an enhancement layer without decoding the lower layer bitstream data in parallel.

Furthermore prediction and reconstruction of the pictures as described in 7.6, 7.7 and 7.9 for the combined lower and enhancement layer is identical to the respective steps for decoding of the lower layer bitstream only.

Semantics and decoding process described in this subclause include a mechanism for "chroma simulcast". This may be used (for instance) to enhance 4:2:0 in the lower layer to 4:2:2 after processing the enhancement layer data. While the luminance data is processed as described before, in this case the chrominance information retrieved from the lower layer bitstream (with exception of intra-DC values, see 7.8.3.4) shall be discarded and replaced by the new information with higher chrominance resolution decoded from the enhancement layer.

Table 7-25 – Predictions and motion vectors in frame pictures

frame_motion_type	**macroblock_motion_forward**	**macroblock_motion_backward**	**macroblock_intra**	**spatial_temporal_weight_class**	Motion vector	Prediction formed for
Frame-based[a)]	–	–	1	0	*vector'*[0][0][1:0][c)]	None (motion vector is for concealment)
Frame-based	1	1	0	0	*vector'*[0][0][1:0]	Frame, forward
					vector'[0][1][1:0]	Frame, backward
Frame-based	1	0	0	0,1,2,3	*vector'*[0][0][1:0]	Frame, forward
Frame-based	0	1	0	0,1,2,3	*vector'*[0][1][1:0]	Frame, backward
Frame-based[a)]	0	0	0	0,1,2,3,4	*vector'*[0][0][1:0][d) e)]	Frame, forward
Field-based	1	1	0	0	*vector'*[0][0][1:0]	Top field, forward
					vector'[1][0][1:0]	Bottom field, forward
					vector'[0][1][1:0]	Top field, backward
					vector'[1][1][1:0]	Bottom field, backward
Field-based	1	0	0	0,1	*vector'*[0][0][1:0]	Top field, forward
					vector'[1][0][1:0]	Bottom field, forward
Field-based	1	0	0	2		Top field, spatial
					vector'[0][0][1:0]	Bottom field, forward
Field-based	1	0	0	3	*vector'*[0][0][1:0]	Top field, forward
						Bottom field, spatial
Field-based	0	1	0	0,1	*vector'*[0][1][1:0]	Top field, backward
					vector'[1][1][1:0]	Bottom field, backward
Field-based	0	1	0	2		Top field, spatial
					vector'[0][1][1:0]	Bottom field, backward
Field-based	0	1	0	3	*vector'*[0][1][1:0]	Top field, backward
						Bottom field, spatial
Dual prime[b)]	1	0	0	0,2,3	*vector'*[0][0][1:0]	Top field, same parity, forward
					vector'[0][0][1:0][d)]	Bottom field, same parity, forward
					vector'[2][0][1:0][d) f)]	Top field, opposite parity, forward
					vector'[3][0][1:0][d) f)]	Bottom field, opposite parity, forward

a) **frame_motion_type** is not present in the bitstream but is assumed to be Frame-based.

b) Dual prime cannot be used when spatial_temporal_integer_weight = '0'.

c) The motion vector is only present if **concealment_motion_vectors** is one.

d) These motion vectors are not present in the bitstream.

e) The motion vector is taken to be (0; 0) as explained in 7.6.3.5.

f) These motion vectors are derived from *vector'*[0][0][1:0] as described in 7.6.3.6.

NOTE – Motion vectors are listed in the order they appear in the bitstream.

It is inherent in SNR scalability that the two layers are very tightly coupled to one another. It is a requirement that corresponding pictures in each layer shall be decoded at the same time as one another.

In the case that the lower layer bitstream conforms to ISO/IEC 11172-2 (and not this Specification), then two different IDCT mismatch control schemes are being used in decoding. Care must be taken in the encoder to take account of this.

7.8.1 Higher syntactic structures

The two bitstream layers in this subclause are identified by their layer_id, decoded from the sequence_scalable_extension.

The two bitstreams shall have consecutive layer ids, with enhancement layer bitstream having layer_id = $id_{enhance}$ and the lower layer bitstream having layer_id = $id_{enhance}$–1.

The syntax and semantics of the enhancement layer are as defined in 6.2 and 6.3, respectively.

In the case that the lower layer bitstream conforms to ISO/IEC 11172-2 (and not this Specification), then both this lower and the enhancement layer shall use the "restricted slice structure" defined in this Specification.

Semantic restrictions apply to several values in the headers and extensions of the enhancement layer as follows.

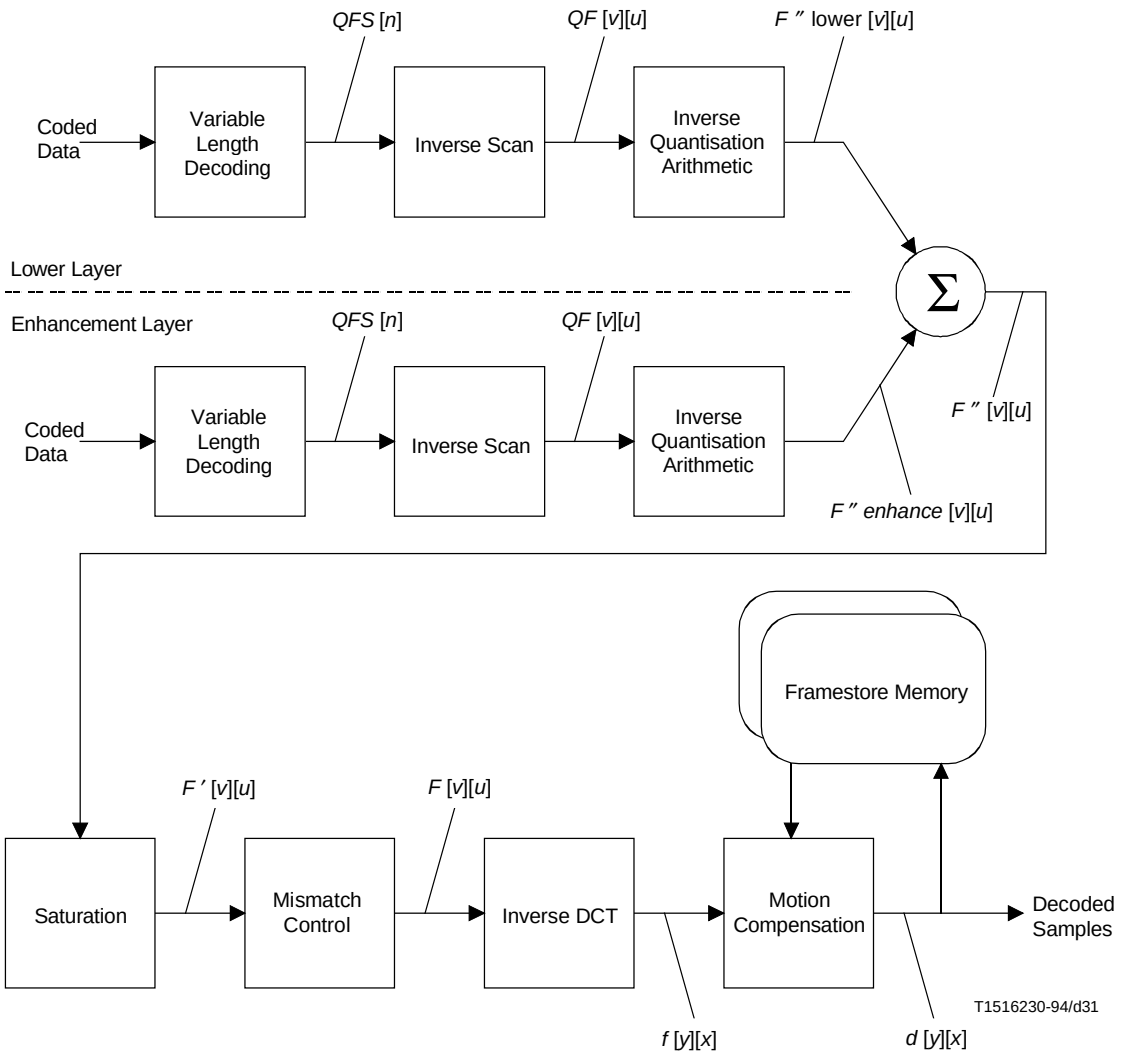


Figure 7-15 – Illustration of decoding process for SNR scalability

Sequence header

This header shall be identical to the one in the lower layer bitstream except for the values of bit_rate, vbv_buffer_size, load_intra_quantiser_matrix, intra_quantiser_matrix, load_non_intra_quantiser_matrix and non_intra_quantiser_matrix. These can be selected independently except for load_intra_quantiser_matrix which shall be zero.

Sequence extension

This extension shall be identical to the one in the lower layer bitstream except for the values of profile_and_level_indication, chroma_format, bit_rate_extension and vbv_buffer_size_extension. Those can be selected independently.

A different value of chroma_format in each layer will cause the chroma_simulcast flag to be set as specified by Table 7-26.

Table 7-26 – chroma_simulcast flag

chroma_format (lower layer)	chroma_format (enhancement layer)	chroma_simulcast
4:2:0	4:2:0	0
4:2:0	4:2:2	1
4:2:0	4:4:4	1
4:2:2	4:2:2	0
4:2:2	4:4:4	1
4:4:4	4:4:4	0

The chroma_format of the enhancement layer shall be higher or equal to the chroma_format of the lower layer bitstream.

In the case that the lower layer bitstream conforms to ISO/IEC 11172-2 (and not This Specification), sequence_extension() is not present in the lower layer bitstream, and the following values shall be assumed for the decoding process.

progressive_sequence = 1
chroma_format = “4:2:0"
horizontal_size_extension = 0
vertical_size_extension = 0
bit_rate_extension = 0
vbv_buffer_size_extension = 0
low_delay = 0
frame_rate_extension_n = 0
frame_rate_extension_d = 0

The sequence_extension() in the enhancement layer shall have the values shown above.

Sequence display extension

This extension shall not be present as there is no separate display process for the enhancement layer.

Sequence scalable extension

This extension shall be present with scalable_mode = "SNR scalability".

GOP header

This header shall be identical to the one in the lower layer bitstream.

NOTE 1 – The GOP header must be present in each layer in order that the temporal_reference in each layer are reset on the same frame.

Picture header

This header shall be identical to the one in the lower layer bitstream except for the value of vbv_delay. This can be selected independently.

Picture coding extension

This extension shall be identical to the one in the lower layer bitstream except for the value of q_scale_type and alternate_scan. These can be selected independently.

chroma_420_type shall be set to '0' if chroma_simulcast is set. Else it shall have the same value as in the lower layer bitstream.

In the case that the lower layer bitstream conforms to ISO/IEC 11172-2 (and not this Specification), then picture_coding_extension() is not present in the lower layer bitstream and the following values shall be assumed for the decoding process:

f_code[0][0]	=	forward_f_code in the lower layer bitstream or 15
f_code[0][1]	=	forward_f_code in the lower layer bitstream or 15
f_code[1][0]	=	backward_f_code in the lower layer bitstream or 15
f_code[1][1]	=	backward_f_code in the lower layer bitstream or 15
intra_dc_precision	=	0
picture_structure	=	“Frame Picture"
top_field_first	=	0
frame_pred_frame_dct	=	1
concealment_motion_vectors	=	0
intra_vlc_format	=	0
repeat_first_field	=	0
chroma_420_type	=	1
progressive_frame	=	1
composite_display_flag	=	0

The picture_coding_extension() in the enhancement layer shall have the values shown above.

For the lower layer q_scale_type and alternate_scan shall be assumed to have the value zero.

NOTE 2 – q_scale_type and alternate_scan can be set independently in the enhancement layer.

Quant matrix extension

This extension is optional. Semantics are described in 6.3.11.

load_intra_quantiser_matrix and load_chroma_intra_quantiser_matrix shall both be zero.

NOTE 3 – Only the non-intra matrices will be used in the subsequent decoding process.

Picture display extension

This extension shall not be present.

NOTE 4 – There is no separate display process for the enhancement layer. If pan-scan functionality is desired, it can be accomplished already by using the information conveyed by the pan-scan extension of the lower layer bitstream.

Slice header

Slices shall be coincident with those in the lower layer. The value of quantiser_scale_code can be set independently from the lower layer bitstream.

7.8.2 Macroblock

Subsequently the "current macroblock" denotes the currently processed macroblock. The current macroblock of the lower layer denotes the macroblock identified by having the same macroblock_address as the current macroblock.

The decoding of the macroblock header information is done according to semantics in 6.3.17.

NOTE – Table B.8 which is used if scalable_mode = = "SNR scalability" will never set the macroblock_intra, macroblock_motion_forward or macroblock_motion_backward flags, since a macroblock in the enhancement layer contains only refinement data for the current macroblock of the lower layer.

However the corresponding syntax elements and flags of the current macroblock in the lower layer bitstream are relevant for the combined decoding process of lower and enhancement layer following the inverse DCT as described in 7.8.3.5.

7.8.2.1 dct_type

The syntax element dct_type may be present in none, one or both of the lower and enhancement layer macroblock_modes(), as indicated by the semantics in 6.3.17.

If dct_type is present in the macroblock_modes() in both layers it shall have identical values.

7.8.2.2 Skipped Macroblocks

Macroblocks can be skipped in the enhancement layer bitstream, meaning that no coefficient enhancement is done ($F''_{enhance}[v][u] = 0$, for all v, u). Regarding this, the decoding process detailed in 7.8.3 shall be applied.

When macroblocks are skipped in both, the lower and the enhancement layer bitstreams, the decoding process is exactly as specified in 7.6.6.

Macroblocks can also be skipped in the lower layer bitstream, while still being coded in the enhancement layer bitstream. In that case the decoding process detailed in the following has to be applied, but $F''_{lower}[v][u] = 0$, for all v, u.

7.8.3 Block

The first part of the decoding process of the enhancement layer block is independent from the lower layer.

The second part of the decoding process of the enhancement layer block has to be done jointly with the decoding process of the coincident lower layer block.

Two sets of inverse quantised coefficients F''_{lower} and $F''_{enhance}$ are added to form F" (see Figure 7-15).

F''_{lower} is derived from the lower layer bitstream exactly as defined in 7.1 to 7.4.2.3.

$F''_{enhance}$ is derived as is defined in the clauses below.

The resulting F" is further processed, starting with saturation, as defined in 7.4.3 to 7.6 (7.7, 7.9).

7.8.3.1 Variable length decoding

In an enhancement layer block the VLC decoding shall be performed according to 7.2, as for a non-intra block (as indicated by macroblock_intra = 0).

7.8.3.2 Inverse scan

Inverse scan shall be done exactly as defined in 7.3.

7.8.3.3 Inverse quantisation

In an enhancement layer block the inverse quantisation shall be performed according to 7.4.2 as for a non-intra block.

In the case that the lower layer bitstream conforms to ISO/IEC 11172-2 (and not this Specification), then the "inverse quantisation arithmetic" used to derive $F''_{lower}[v][u]$ (see Figure 7-14) shall include the IDCT mismatch control (oddification) and saturation specified in ISO/IEC 11172-2.

7.8.3.4 Addition of coefficients from the two layers

Corresponding coefficients from the blocks of each layer shall be added together to form F'' (see Figure 7-15).

$$F''[v][u] = F''_{lower}[v][u] + F''_{enhance}[v][u], \text{ for all } u, v$$

If chroma_simulcast = 1 is set only the luminance blocks are treated as described above.

For chrominance blocks the DC coefficient of the base layer is used as a prediction of the DC coefficient in the coincident block in the enhancement layer, whereas the AC coefficients of the base layer are discarded and AC coefficients of the enhancement layer form F" in Figure 7-14 according to the following formulae:

$$F''[0][0] = F''_{lower}[0][0] + F''_{enhance}[0][0]$$

$$F''[v][u] = F''_{enhance}[v][u], \text{ for all } u, v \text{ except } u = v = 0$$

NOTE – Chroma simulcast blocks are inverse quantised like non-intra blocks and use the chrominance non-intra matrix.

Table 7-27 gives the index of the chrominance block whose DC coefficient ($F''_{lower}[0][0]$) is to be used to predict the DC coefficient in the coincident chrominance block of the enhancement layer ($F''_{enhance}[0][0]$).

Table 7-27 – Block index used to predict DC coefficient

chroma_format	Block index							
	4	5	6	7	8	9	10	11
base: 4:2:0 upper: 4:2:2	4	5	4	5				
base: 4:2:0 upper: 4:4:4	4	5	4	5	4	5	4	5
base: 4:2:2 upper: 4:4:4	4	5	6	7	4	5	6	7

7.8.3.5 Remaining macroblock decoding steps

After addition of coefficients from the two layers, the remainder of the macroblock decoding steps is exactly as described in 7.4.3 to 7.6 (7.7, 7.9, if applicable), since there is now only one data stream F''[v][u] to be processed.

In this process, the spatio/temporal prediction p[y][x] is derived according to the macroblock type syntax elements and flags for the current macroblock known from the lower layer bitstream.

7.9 Temporal scalability

Temporal scalability involves two layers, a lower layer and an enhancement layer. Both the lower and the enhancement layers process the same spatial resolution. The enhancement layer enhances the temporal resolution of the lower layer and if temporally re-multiplexed with the lower layer provides full temporal rate. This is the frame rate indicated in the enhancement layer. The decoding process for enhancement layer pictures is similar to the normal decoding process described in 7.1 to 7.6. The only difference is in the "Prediction field and frame selection" described in 7.6.2.

The reference frames for prediction are selected by reference_select_code as described in Tables 7-28 and 7-29. In P-pictures, the forward reference picture can be one of the following three: most recent enhancement picture, most recent lower layer frame, or next lower layer frame in display order. Note that in the latter case, the reference frame in lower layer used for prediction is backward in time.

Table 7-28 – Prediction references selection in P-pictures

reference_select_code	Forward prediction reference
00	Most recent decoded enhancement picture(s)
01	Most recent lower layer frame in display order
10	Next lower layer frame in display order
11	Forbidden

Table 7-29 – Prediction references selection in B-pictures

reference_select_code	Forward prediction reference	Backward prediction reference
00	Forbidden	Forbidden
01	Most recent decoded enhancement picture(s)	Most recent lower layer picture in display order
10	Most recent decoded enhancement picture(s)	Next lower layer picture in display order
11	Most recent lower layer picture in display order	Next lower layer picture in display order

In B-pictures, the forward reference can be one of the following two: most recent the enhancement pictures or most recent (or temporally coincident) lower layer frame whereas the backward reference can be one of the following two: most recent lower layer picture including temporally coincident picture in display order or next lower layer frame in display order. Note that in this case, the backward reference frame in lower layer used for prediction is forward in time.

Backward prediction cannot be made from a picture in the enhancement layer. This avoids the need for frame reordering in the enhancement layer. Motion compensation process forms predictions using lower layer decoded pictures and/or previous temporal prediction from the enhancement layer.

The enhancement layer can contain I-pictures, P-pictures or B-pictures, but B-pictures in enhancement layer behave more like P-pictures in the sense that a decoded B-picture can be used to predict the following P-pictures or B-pictures in the enhancement layer.

When the most recent frame in the lower layer is used as the reference, this includes the frame that is temporally coincident with the frame or the first field (in case of field pictures) in the enhancement layer. The prediction references used for P-picture and B-pictures are shown in Table 7-28 and Table 7-29 respectively.

The lower and enhancement layers shall use the restricted slice structure.

Figure 7-16 shows a simplified diagram of the motion compensation process for the enhancement layer using temporal scalability.

I-pictures do not use prediction references; to indicate this, the reference_select_code for I-pictures shall be '11'.

Depending on picture_coding_type, when forward_temporal_reference or backward_temporal_reference do not imply references to be used for prediction, they shall take the value 0.

7.9.1 Higher syntactic structures

The two bitstream layers in this subclause are identified by their layer_id, decoded from the sequence_scalable_extension.

The two bitstreams shall have consecutive layer ids, with enhancement layer having layer_id = $id_{enhance}$ and the lower layer having layer_id = $id_{enhance}$−1.

The syntax and semantics of enhancement layers are as defined in 6.2 and 6.3 respectively.

Semantic restrictions apply to several values in the headers and extensions of the enhancement layer as follows.

The lower layer shall conform to this Specification (and not to ISO/IEC 11172-2).

Sequence header

The values in this header can be different from the lower layer except for horizontal_size_value, vertical_size_value and aspect_ratio_information.

Sequence extension

This extension shall be identical to the one in the lower layer except for values of profile_and_level_indication, bit_rate_extension, vbv_buffer_size_extension, low_delay, frame_rate_extension_n and frame_rate_extension_d. These can be selected independently. Note that progressive_sequence indicates the scanning format of the enhancement layer frames only rather than of the output frames after multiplexing. The latter is indicated by mux_to_progressive_sequence (see sequence scalable extension).

Sequence display extension

This extension shall not be present as there is no separate display process for the enhancement layer.

Sequence scalable extension

This extension shall be present with scalable_mode = "Temporal scalability".

When progressive_sequence = 0 and mux_to_progressive_sequence = 0, top_field_first and picture_mux_factor can be selected.

When progressive_sequence = 0 and mux_to_progressive_sequence = 1, top_field_first shall contain a complement of the value of top_field_first of the lower layer but picture_mux_factor shall be 1.

When progressive_sequence = 1 and mux_to_progressive_sequence = 1, top_field_first shall be zero but picture_mux_factor can be selected.

The combination of progressive_sequence = 1 and mux_to_progressive_sequence = 0 shall not occur.

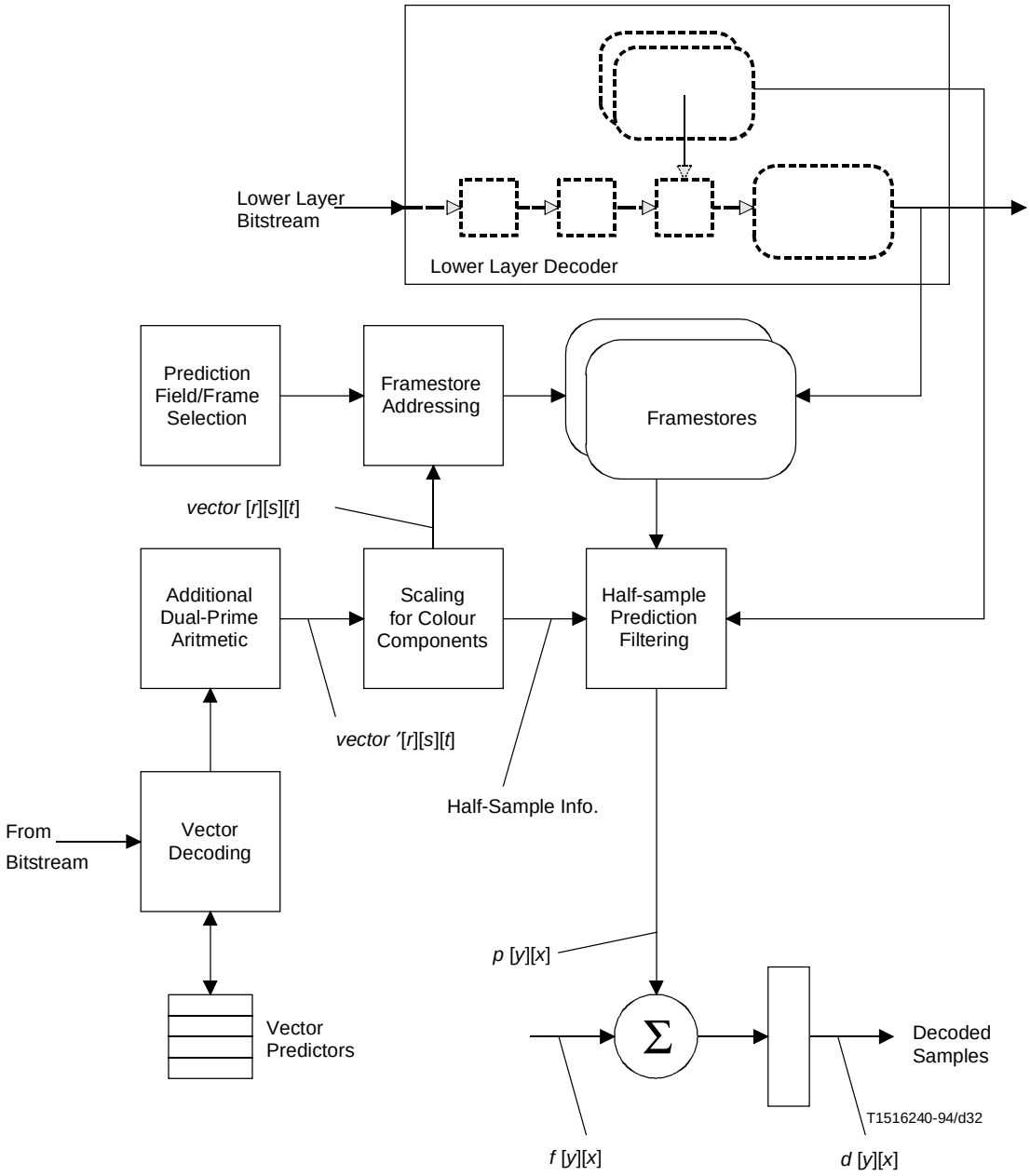


Figure 7-16 – Simplified motion compensation process for the enhancement layer using temporal scalability

GOP header

There is no restriction on GOP header (if present) to be the same as that for lower layer.

Picture header

There is no restriction on picture headers to be the same as in the lower layer.

Picture coding extension

The values in this extension can be different from the lower layer except for top_field_first, concealment_motion_vectors, and chroma_420_type and progressive_frame. The top_field_first shall be based on progressive_sequence and mux_to_progressive_sequence (see sequence_scalable_extension above) and concealment_motion_vectors shall be 0. Chroma_420_type shall be identical to the lower layer. Progressive_frame shall always have the same value as progressive_sequence.

Picture temporal scalable extension

This extension shall be present for each picture.

Quant matrix extension

This extension may be present in the enhancement layer.

7.9.2 Restrictions on temporal prediction

Although temporal predictions can be made from decoded pictures referenced by forward_temporal_reference or both forward_temporal_reference and backward_temporal_references, temporal scalability is efficient if predictions are formed using decoded picture/pictures from lower layer and enhancement layer that are very close in time to the enhancement picture being predicted. It is a requirement on the bitstreams that P-pictures and B-pictures shall form predictions from most recent or next pictures as illustrated by Tables 7-28 and 7-29.

In case group_of_pictures_header occurs very often in lower_layer, ambiguity can occur due to possibility of non-uniqueness of temporal references (which are reset at each group_of_pictures_header). This ambiguity shall be resolved with help of systems layer timing information.

7.10 Data partitioning

Data partitioning is a technique that splits a video bitstream into two layers, called partitions. A priority breakpoint indicates which syntax elements are placed in partition 0, which is the base partition (also called high priority partition). The remainder of the bitstream is placed in partition 1 (which is also called low priority partition). Sequence, GOP, and picture headers are redundantly copied in partition 1 to facilitate error recovery. The sequence_end_code is also redundantly copied into partition 1. All fields in the redundant headers must be identical to the original ones. The only extensions allowed (and required) in partition 1 are sequence_extension(), picture_coding_extension() and sequence_scalable_extension().

NOTE – The slice() syntax given in 6.2.4 is followed in both partitions up to (and including) the syntax element extra_bit_slice.

The interpretation of priority_breakpoint is given in Table 7-30.

Table 7-30 – Priority breakpoint values and associated semantics

priority_breakpoint	Syntax elements included in partition zero
0	This value is reserved for partition 1. All slices in partition 1 shall have a priority_breakpoint equal to 0.
1	All data at the sequence, GOP, picture and slice() down to **extra_bit_slice** in slice().
2	All data included above, plus macroblock syntax elements up to and including **macroblock_address_increment**.
3	All data included above, plus macroblock syntax elements up to but not including coded_block_pattern().
4 … 63	Reserved.
64	All syntax elements up to and including coded_block_pattern() or DC coefficient (**dct_dc_differential**), and the first (run, level) DCT coefficient pair (or EOB). (Note)
65	All syntax elements above, plus up to 2 (run, level) DCT coefficient pairs.
…	
63 + *j*	All syntax elements above, plus up to *j* (run, level) DCT coefficient pairs.
…	
127	All syntax elements above, plus up to 64 (run, level) DCT coefficient pairs.
NOTE – A priority_breakpoint immediately following the DC coefficient is disallowed since it might cause start code emulation.	

Semantics of VBV remains unchanged, i.e. the VBV refers to the sum of two partitions, not any single one.

The bitstream parameters bit_rate (bit_rate_value and bit_rate_extension), vbv_buffer_size (vbv_buffer_size_value and vbv_buffer_size_extension) and vbv_delay shall take the same value in the two partitions. These parameters refer to the characteristics of the entire bitstream formed from the two partitions.

The decoding process is modified in the following manner:

– Set *current_partition* to 0, and start decoding from bitstream that contains the sequence_scalable_extension (partition 0).

– If *current_partition* = 0, check to see if the current point in the bitstream is a priority breakpoint.

  If yes, set *current_partition* to 1. Next item will be decoded from partition 1.

  Otherwise, continue decoding from partition 0. Remove sequence, GOP, and picture headers from both partitions.

– If *current_partition = 1*, check the priority breakpoint to see if the next item to be decoded is expected in partition 0.

  If yes, set *current_partition* to 0. Next item will be decoded from partition 0.

  Otherwise, continue decoding from partition 1.

An example is shown in Figure 7-17 where the priority breakpoint is set at 64 [one (run, level) pair].

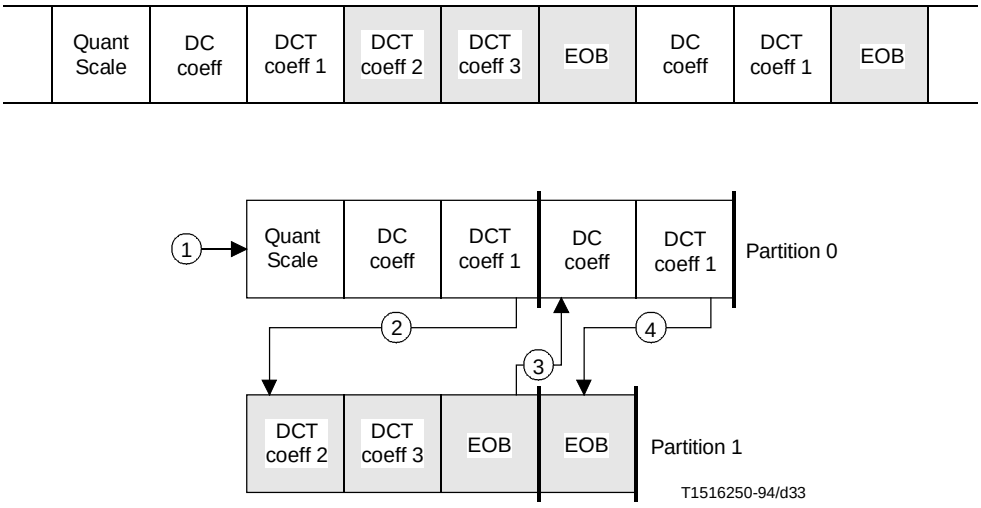


Figure 7-17 – A segment from a bitstream with two partitions, with priority_breakpoint set to 64 (one (run, level) pair). The two partitions are shown, with arrows indicating how the decoder needs to switch between partitions

7.11 Hybrid scalability

Hybrid scalability is the combination of two different types of scalability. The types of scalability that can be combined are SNR scalability, spatial scalability and temporal scalability. When two types of scalability are combined, there are three bitstreams that have to be decoded. The layers to which these bitstreams belong are named in Table 7-31.

Table 7-31 – Names of layers

layer_id	Name
0	Base layer
1	Enhancement layer 1
2	Enhancement layer 2
…	…

For the scalability between the enhancement layers 1 and 2, the enhancement layer 1 is its lower layer, and the enhancement layer 2 is its enhancement layer. No layer can be omitted from the hierarchical ladder. E.g. if there is SNR scalability between enhancement layer 1 and enhancement layer 2, the prediction types in enhancement layer 1 are also valid for the combined decoding process for enhancement layers 1 and 2.

The coupling of layers is more loose with spatial and temporal scalability than with SNR scalability. Therefore, in these kinds of scalability, first the base layer has to be decoded and upconverted before it can be used in the enhancement layer. In SNR scalability, both layers are decoded simultaneously. The decoding order can be summarised as follows:

Case 1

base layer

<spatial or temporal scalability>

enhancement layer 1

<SNR scalability>

enhancement layer 2

First decode the base layer, and then decode both enhancement layers simultaneously.

Case 2

base layer

<SNR scalability>

enhancement layer 1

<spatial or temporal scalability>

enhancement layer 2

First decode the base layer and the enhancement layer 1 simultaneously, and then decode the enhancement layer 2.

Case 3

base layer

<spatial or temporal scalability>

enhancement layer 1

<spatial or temporal scalability>

enhancement layer 2

First decode the base layer, then decode the enhancement layer 1, and finally decode enhancement layer 2.

7.12 Output of the decoding process

This subclause describes the output of the theoretical model of the decoding process that decodes bitstreams conforming to this Specification.

The decoding process input is one or more coded video bitstreams (one for each of the layers). The video layers are generally multiplexed by the means of a system stream that also contains timing information.

The output of the decoding process is a series of fields or frames that are normally the input of a display process. The order in which fields or frames are output by the decoding process is called the display order, and may be different from the coded order (when B-pictures are used). The display process is responsible for the action of displaying the decoded fields or frames on a display device. If the display device cannot display at the frame rate indicated in the bitstream, the display process may perform frame rate conversion. This Specification does not describe a theoretical model of display process nor the operation of the display process.

Since some of the syntax elements, such as progressive_frame, may be needed by the display process, in this theoretical model of the decoding process, all the syntactic elements that are decoded by the decoding process are output by the decoding process and may be accessed by the display process.

When the progressive sequence is decoded (progressive_sequence is equal to 1), the luminance and chrominance samples of the reconstructed frames are output by decoding process in the form of progressive frames and the output rate is the frame rate. Figure 7-18 illustrates this in the case of chroma_format equals to 4:2:0.

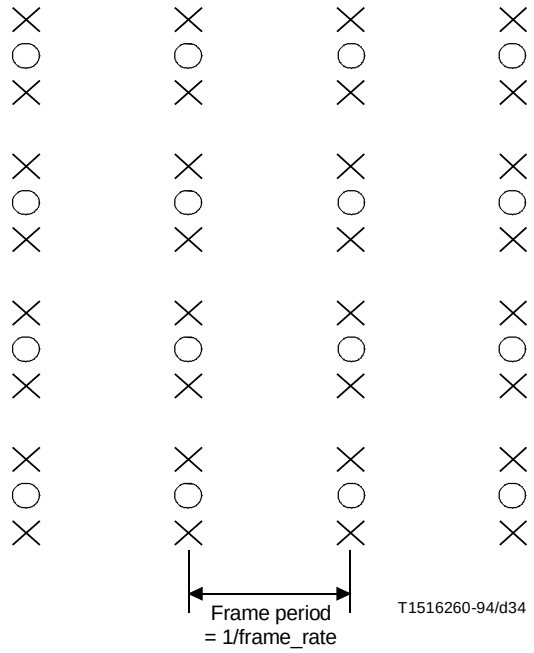


Figure 7-18 – progressive_sequence = = 1

The same reconstructed frame is output one time if repeat_first_field is equal to 0, and two or three consecutive times if repeat_first_field is equal to 1, depending on the value of top_field_first. Figure 7-19 illustrates this in the case of chroma_format equals to 4:2:0 and repeat_first_field equals 1.

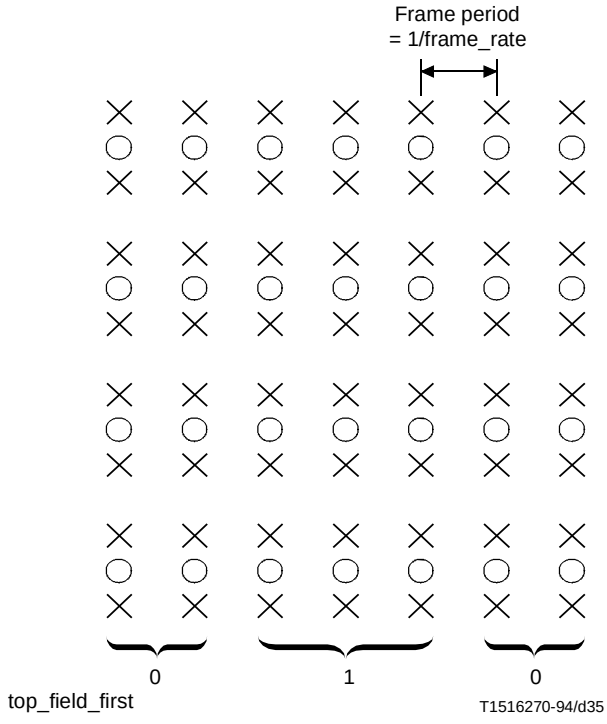


Figure 7-19 – progressive_sequence = = ′1′; repeat_first_field = = ′1′

When decoding an interlaced sequence (progressive_sequence is equal to 0), the luminance samples of the reconstructed frames are output by the decoding process in the form of interlaced fields at a rate that is twice the frame rate. Figure 7-20 illustrates this.

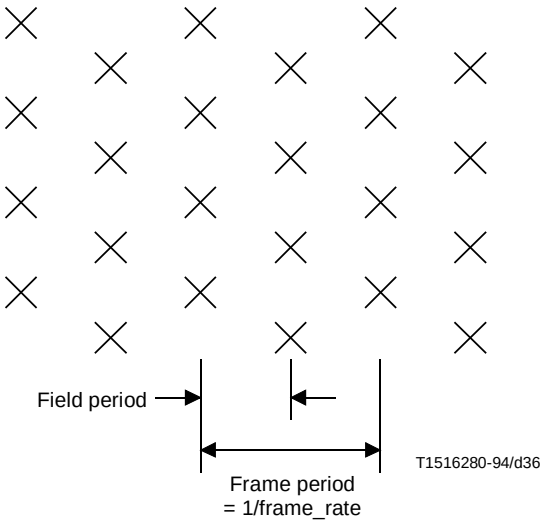


Figure 7-20 – progressive_sequence = = 0

It is a requirement on the bitstream that the fields at the output of the decoding process shall always be alternately top and bottom (note that the very first field of a sequence may be either top or bottom).

If the reconstructed frame is interlaced (progressive_frame is equal to 0), the luminance samples and chrominance samples are output by the decoding process in the form of two consecutive fields. The first field output by the decoding process is the top field or the bottom field of the reconstructed frame, depending on the value of top_field_first.

Although all the samples of progressive frames represent the same instant in time, all the samples are not output at the same time by the decoding process when the sequence is interlaced.

If the reconstructed frame is progressive (progressive_frame is equal to 1), the luminance samples are output by the decoding process in the form of two or three consecutive fields, depending on the value of repeat_first_field.

NOTE – The information that these fields originate from the same progressive frame in the bitstream is conveyed to the display process.

All of the chrominance samples of the reconstructed progressive frame are output by the decoding process at the same time as the first field of luminance samples. This is illustrated in Figures 7-21 and 7-22.

8 Profiles and levels

NOTE – In this Specification the word "profile" is used as defined below. It should not be confused with other definitions of "profile" and in particular it does not have the meaning that is defined by JTC1/SGFS.

Profiles and levels provide a means of defining subsets of the syntax and semantics of this Specification and thereby the decoder capabilities required to decode a particular bitstream. A profile is a defined subset of the entire bitstream syntax that is defined by this Specification. A level is a defined set of constraints imposed on parameters in the bitstream. Conformance tests will be carried out against defined profiles at defined levels.

The purpose of defining conformance points in the form of profiles and levels is to facilitate bitstream interchange among different applications. Implementers of this Specification are encouraged to produce decoders and bitstreams which correspond to those defined conformance regions. The discretely defined profiles and levels are the means of bitstream interchange between applications of this Specification.

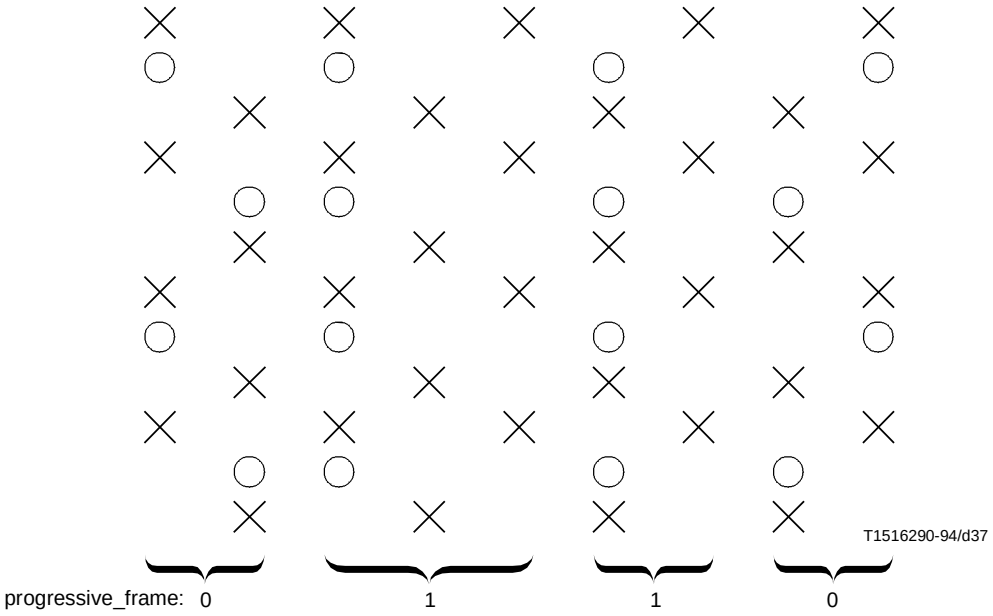


Figure 7-21 – progressive_sequence == 0 with 4:2:0 chrominance

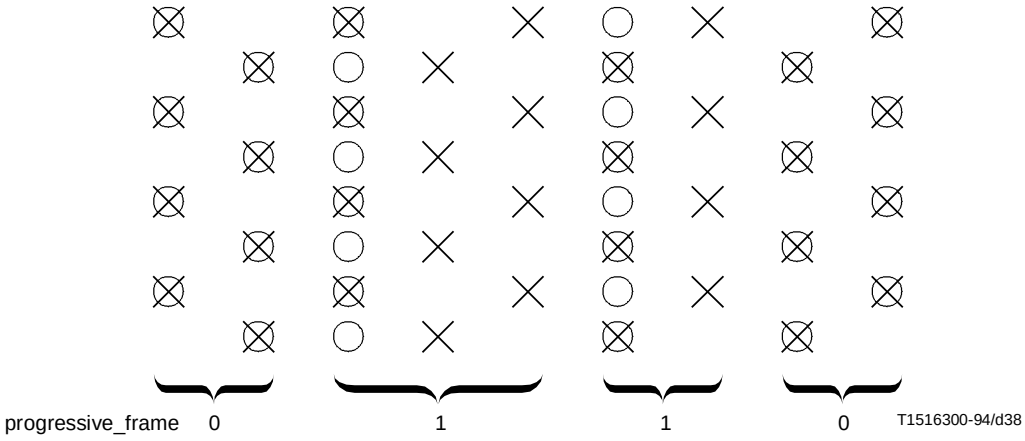


Figure 7-22 – progressive_sequence == 0 with 4:2:2 or 4:4:4 chrominance

In this clause the constrained parts of the defined profiles and levels are described. All syntactic elements and parameter values which are not explicitly constrained may take any of the possible values that are allowed by this Specification. In general, a decoder shall be deemed to be conformant to a given profile at a given level if it is able to properly decode all allowed values of all syntactic elements as specified by that profile at that level. One exception to this rule exists in the case of a Simple profile Main level decoder, which must also be able to decode Main profile, Low level bitstreams. A bitstream shall be deemed to be conformant if it does not exceed the allowed range of allowed values and does not include disallowed syntactic elements.

Attention is drawn to 5.4 which defines the convention for specifying a range of numbers. This is used throughout to specify the range of values and parameters.

The profile_and_level_indication in the sequence_extension indicates the profile and level to which the bitstream complies. The most significant bit of profile_and_level_indication is called 'escape bit'. When the escape bit is set to zero, the profile and level are derived from profile_and_level_indication according to Tables 8-1, 8-2 and 8-3.

Table 8-1 – Meaning of bits in profile_and_level_indication

Bits	Field Size (bits)	Meaning
[7:7]	1	Escape bit
[6:4]	3	Profile identification
[3:0]	4	Level identification

Table 8-2 specifies the profile identification codes and Table 8-3 the level identification codes. When the escape bit equals zero a profile with a numerically larger identification value will be a subset of a profile with a numerically smaller identification value. Similarly, whenever the escape bit equals zero, a level with a numerically larger identification value will be a subset of a level with a numerically smaller identification value.

Table 8-2 – Profile identification

Profile identification	Profile
110 to 111	(Reserved)
101	Simple
100	Main
011	SNR Scalable
010	Spatially Scalable
001	High
000	(Reserved)

Table 8-3 – Level identification

Level identification	Level
1011 to 1111	(Reserved)
1010	Low
1001	(Reserved)
1000	Main
0111	(Reserved)
0110	High 1440
0101	(Reserved)
0100	High
0000 to 0011	(Reserved)

Table 8-4 describes profiles and levels when the escape bit equals 1. For these profiles and levels there is no implied hierarchy from the assignment of profile_and_level_indication and profiles and levels are not necessarily subsets of others.

Attention is drawn to Annex E, which describes in detail those parts of ISO/IEC 13818-2 that are used for a given profile and level.

NOTE 1 – On 4:2:2 Profile: The ITU-T Rec. H.262 | ISO/IEC 13818-2 compression algorithm exploits temporal redundancy, spatial redundancy, and human psycho-visual properties and is not a lossless algorithm. For sequences with substantial spatial and temporal redundancies, or without many sharp lines/edges, the quality of the sequences obtained after decompression will be higher than that obtained for sequences with lower redundancy, or with a large number of sharp lines/edges.

The 4:2:2 profile can provide higher video quality, better chroma resolution and allows a higher bit rate (at Main level, up to 50 Mbit/s) than MP@ML. It also provides the capability to encode all active lines of video.

Although it is not part of the hierarchy of profiles and levels, the 4:2:2 profile @ Main level decoder is required to decode all the bit streams decodable by MP@ML decoders.

The 4:2:2 profile does not support scalability. This allows implementation architectures to be similar to those of MP@ML.

This profile can be used for applications requiring multiple generations of encoding and decoding. In the case of multiple generations without picture manipulation or change in picture coding type between generations, the quality remains nearly constant after the first generation. Use of picture manipulation or change in picture coding type between generations causes some degradation in quality. Nevertheless, the resulting quality is acceptable for a broad range of applications.

The 4:2:2 profile permits all I-picture encoding. This enables fast recovery from transmission errors and can simplify editing applications. This profile allows the high bit rates required to maintain high quality while using only I-picture coding. The 4:2:2 profile also allows the use of P- and B-picture coding types which can further improve quality or reduce bit rate for the same quality.

See Annex J for more information on the picture quality of the 4:2:2 profile.

NOTE 2 – On Multi-view Profile: The Multi-view Profile (MVP) is envisioned to be a profile appropriate for applications that require multiple viewpoints within the context of ITU-T Rec. H.262 | ISO/IEC 13818-2. MVP supports stereoscopic pictures as its source images for a wide range of picture resolution and quality as requested by the applications to be used. A base layer of MVP is assigned to a left view and an enhancement layer is assigned to a right view.

Table 8-4 – Escape profile_and_level_indication identification

profile_and_level_indication	Name
10001111 to 11111111	(Reserved)
10001110	Multi-view profile @ Low level
10001101	Multi-view profile @ Main level
10001100	(Reserved)
10001011	Multi-view profile @ High1440 level
10001010	Multi-view profile @ High level
10000110 to 10001001	(Reserved)
10000101	4:2:2 profile @ Main level
10000011 to 10000100	(Reserved)
10000010	4:2:2 profile @ High level
10000000 to 10000001	(Reserved)

A monoscopic coding with the same tools as Main Profile (MP), including ISO/IEC 11172-2, is applied to the base layer. An enhancement layer is coded using Temporal Scalability tools and a hybrid prediction of motions and disparity can be utilized in the enhanced layer.

MVP, viewed as one of the scalable profiles in terms of multiple viewpoint layers, is expected to have the same type of compatibility features other scalable profiles have, such as compatibility with MP. For example:

1) decoders compliant to MVP at a certain Level are capable of decoding the bitstreams compliant to MP at the corresponding Level (i.e. forward compatibility);
2) decoders compliant to MP at a certain Level are capable of decoding the bitstream in the base layer of MVP (i.e. backward compatibility).

8.1 ISO/IEC 11172-2 compatibility

ISO/IEC 11172-2 "constrained parameter" bitstreams shall be decodable by Simple, Main, SNR Scalable, Spatially Scalable and High profile decoders at all levels. Additionally Simple, Main, SNR Scalable, Spatially Scalable and High profile decoders shall be able to decode D-pictures-only bitstreams of ISO/IEC 11172-2 which are within the level constraints of the decoder.

8.2 Relationship between defined profiles

The Simple, Main, SNR Scalable, Spatially Scalable and High profiles have a hierarchical relationship. Therefore the syntax supported by a 'higher' profile includes all the syntactic elements of 'lower' profiles (e.g. for a given level, a Main profile decoder shall be able to decode a bitstream conforming to Simple profile restrictions). For a given profile, the same syntax set is supported regardless of level. The order of hierarchy is given in Table 8-2.

The syntactic differences between constraints of profiles are given in Table 8-5. This table describes the limits which apply to a bitstream. Note that a Simple Profile conformant decoder must be able to fully decode both Simple profile, Main level and Main profile, Low level bitstreams.

Table 8-5 – Syntactic constraints of profiles

Syntactic Element	Profile						
	Simple	Main	SNR	Spatial	High	4:2:2	Multi-view
chroma_format	4:2:0	4:2:0	4:2:0	4:2:0	4:2:2 or 4:2:0	4:2:2 or 4:2:0	4:2:0
frame_rate_extension_n	0	0	0	0	0	0	0
frame_rate_extension_d	0	0	0	0	0	0	0
aspect_ratio_information	0001, 0010, 0011	0001, 0010, 0011	0001, 0010, 0011	0001, 0010, 0011	0001, 0010, 0011	0001, 0010, 0011	0001, 0010, 0011
picture_coding_type	I, P	I, P, B	I, P, B	I, P, B	I, P, B	I, P, B	I, P, B
repeat_first_field	Constrained		Unconstrained			Constrained	Unconstrained
sequence_scalable_ extension()	No	No	Yes	Yes	Yes	No	Yes
scalable_mode	–	–	SNR	SNR or Spatial	SNR or Spatial	–	Temporal
picture_spatial_scalable_ extension()	No	No	No	Yes	Yes	No	No
picture_temporal_scalable_ extension()	No	No	No	No	No	No	Yes
intra_dc_precision	8, 9, 10	8, 9, 10	8, 9, 10	8, 9, 10	8, 9, 10, 11	8, 9, 10, 11	8, 9, 10
Slice structure	Restricted 6.1.2.2						

For all defined profiles, there is a semantic restriction on the bitstream that all of the data for a macroblock shall be represented with not more than the number of bits indicated by Table 8-6. However, a maximum of two macroblocks in each horizontal row of macroblocks may exceed this limitation.

Table 8-6 – Maximum number of bits in a macroblock

chroma_format	Maximum number of bits
4:2:0	4608
4:2:2	6144
4:2:2 (in 4:2:2 Profile)	Unconstrained
4:4:4	9216

In this context, a macroblock is deemed to start with the first bit of the macroblock_address_increment (or macroblock_escape, if any) and continues until the last bit of the macroblock() syntactic structure. The bits required to represent any slice() that precedes (or follows) the macroblock are not counted as part of the macroblock.

The High profile is also distinguished by having different constraints on luminance sample rate, maximum bit rate, and VBV buffer size. Refer to Tables 8-12, 8-13 and 8-14.

Decoders that are Simple profile @ Main level compliant shall be capable of decoding Main profile @ Low level bitstreams.

8.2.1 Use of repeat_first_field

The use of repeat_first_field in Simple and Main profile bitstreams is constrained as specified in Table 8-7.

Table 8-7 – Constraints on use of repeat_first_field for Simple and Main Profiles

frame_rate_code	frame_rate_value	**Repeat_first_field**	
		progressive_ sequence==0	**progressive_ sequence**==1
0000	Forbidden		
0001	24 000 ÷ 1001 (23,976…)	0	0
0010	24	0	0
0011	25	0 or 1	0
0100	30 000 ÷ 1001 (29,97…)	0 or 1	0
0101	30	0 or 1	0
0110	50	0 or 1	0
0111	60 000 ÷ 1001 (59,94…)	0 or 1	0 or 1
1000	60	0 or 1	0 or 1
…	Reserved		
1111	Reserved		

Additional constraints exist for Main profile @ Main level and Simple profile @ Main level only:

- if (vertical_size > 480 lines) or (frame_rate is "25Hz") then if picture_coding_type == 011 (i.e. B-picture), repeat_first_field shall be 0.
- if vertical_size > 480 lines frame_rate shall be "25Hz"

Additionally, the following constraints exist for 4:2:2 profile @ Main level only:

- if vertical_size > 512 lines,

  then if picture_coding_type=011 (i.e. B-picture), repeat_first_field shall be 0;
- if vertical_size > 512 lines frame_rate shall be "25Hz".

8.3 Relationship between defined levels

The Low, Main, High-1440 and High levels have a hierarchical relationship. Therefore the parameter constraints of a 'higher' level equal or exceed the constraints of 'lower' levels (e.g. for a given profile, a Main level decoder shall be able to decode a bitstream conforming to Low level restrictions). The order of hierarchy is given in Table 8-3.

The different parameter constraints for levels are given in Table 8-8.

8.4 Scalable layers

The SNR Scalable, Spatial Scalable, High and Multi-view profiles may use more than one bitstream to code the image. These different bitstreams represent layers of coding, which when combined create a higher quality image than that obtainable from one layer alone (see Annex D). The maximum number of layers for a given profile is specified in Table 8-9. The scalable layers are named according to Table 7-31. The syntactic and parameter constraints for these profile/level combinations when coded using the maximum permitted number of layers are given in Tables 8-11, 8-12, 8-13 and 8-14. When the number of layers is less than the maximum permitted, reference should also be made to Tables E-21 to E-46 as appropriate.

It should be noted that a bitstream of the base layer of SNR Scalable and Multi-view profiles can always be decoded by a Main profile decoder of equivalent level. Conversely, a Main profile bitstream shall be decodable by either SNR Scalable or Multi-view profile decoder of equivalent level.

Table 8-8 – Parameter constraints for levels

Syntactic Element	Level			
	Low	Main	High-1440	High
f_code[0][0] (forward horizontal)	[1:7]	[1:8]	[1:9]	[1:9]
f_code[1][0][a)] (backward horizontal)	[1:7]	[1:8]	[1:9]	[1:9]
Frame picture				
f_code[0][1] (forward vertical)	[1:4]	[1:5]	[1:5]	[1:5]
f_code[1][1][a)] (backward vertical)	[1:4]	[1:5]	[1:5]	[1:5]
Vertical vector range[b)]	[–64:63,5]	[–128:127,5]	[–128:127,5]	[–128:127,5]
Field picture				
f_code[0][1] (forward vertical)	[1:3]	[1:4]	[1:4]	[1:4]
f_code[1][1][a)] (backward vertical)	[1:3]	[1:4]	[1:4]	[1:4]
Vertical vector range[b)]	[–32:31,5]	[–64:63,5]	[–64:63,5]	[–64:63,5]
frame_rate_code	[1:5]	[1:5]	[1:8]	[1:8]
Sample Density	Table 8-11			
Luminance Sample Rate	Table 8-12			
Maximum Bit Rate	Table 8-13			
Buffer Size	Table 8-14			

a) For Simple profile bitstreams which do not include B-pictures, f_code[1][0] and f_code[1][1] shall be set to 15 (not used).

b) This restriction applies to the final reconstructed motion vector. In the case of dual prime motion vectors, this restriction applies to all the following values:

vector'[0][0][1]
((vector'[0][0][1] * m[parity_ref][parity_pred])//2)
((vector'[0][0][1] * m[parity_ref][parity_pred])//2")" + e[parity_ref][parity_pred]
((vector'[0][0][1] * m[parity_ref][parity_pred])//2")" + dmvector[1]
((vector'[0][0][1] * m[parity_ref][parity_pred])//2")" + e[parity_ref][parity_pred] + dmvector[1]

Table 8-9 – Upper bounds for scalable layers in SNR Scalable, Spatial Scalable, High and Multi-view profiles

Level	Maximum Number of	Profile			
		SNR	Spatial	High	Multi-view
High	All layers (base + enhancement) Spatial enhancement layers SNR enhancement layers Temporal auxiliary layers			3 1 1 0	2 0 0 1
High-1440	All layers (base + enhancement) Spatial enhancement layers SNR enhancement layers Temporal auxiliary layers		3 1 1 0	3 1 1 0	2 0 0 1
Main	All layers (base + enhancement) Spatial enhancement layers SNR enhancement layers Temporal auxiliary layers	2 0 1 0		3 1 1 0	2 0 0 1
Low	All layers (base + enhancement) Spatial enhancement layers SNR enhancement layers Temporal auxiliary layers	2 0 1 0			2 0 0 1

8.4.1 Permissible layer combinations

Table 8-10 is a summary of the permitted combinations, and is subject to the following rules:

- SNR Scalable and Multi-view profile: maximum of 2 layers; Spatial Scalable and High profile: maximum of 3 layers. (See Table 8-9.)
- Only one SNR and one Spatial scale allowed in 3-layer combinations, either SNR/Spatial or Spatial/SNR order is permitted. (See Table 8-9.)
- Chroma simulcast, which allows to add 4:2:2 chroma information to a 4:2:0 base layer and defined in 7.8 is implemented with SNR scalability.
- A 4:2:0 layer is not permitted if the lower layer is 4:2:2. (See 7.7.3.3.)
- (level – 1) is defined as follows:
  - if level is Main, (level – 1) is Low;
  - if level is High – 1440, (level – 1) is Main;
  - if level is High, (level – 1) is High – 1440.

Table 8-10 – Permissible layer combinations

	Scalable mode			Profile/level of simplest base layer decoder (level reference top layer) [a]
Profile	Base layer	Enhancement layer 1	Enhancement layer 2	
SNR	4:2:0	SNR, 4:2:0	–	MP@same level
Spatial	4:2:0	SNR, 4:2:0	–	MP@same level
Spatial	4:2:0	Spatial, 4:2:0	–	MP@(level – 1)
Spatial	4:2:0	SNR, 4:2:0	Spatial, 4:2:0	MP@(level – 1)
Spatial	4:2:0	Spatial, 4:2:0	SNR, 4:2:0	MP@(level – 1)
High	4:2:0	–	–	HP@same level
High	4:2:2	–	–	HP@same level
High	4:2:0	SNR, 4:2:0	–	HP@same level
High	4:2:0	SNR, 4:2:2	–	HP@same level
High	4:2:2	SNR, 4:2:2	–	HP@same level
High	4:2:0	Spatial, 4:2:0	–	HP@(level – 1)
High	4:2:0	Spatial, 4:2:2	–	HP@(level – 1)
High	4:2:2	Spatial, 4:2:2	–	HP@(level – 1) [b]
High	4:2:0	SNR, 4:2:0	Spatial, 4:2:0	HP@(level – 1)
High	4:2:0	SNR, 4:2:0	Spatial, 4:2:2	HP@(level – 1)
High	4:2:0	SNR, 4:2:2	Spatial, 4:2:2	HP@(level – 1) [b]
High	4:2:2	SNR, 4:2:2	Spatial, 4:2:2	HP@(level – 1) [b]
High	4:2:0	Spatial, 4:2:0	SNR, 4:2:0	HP@(level – 1)
High	4:2:0	Spatial, 4:2:0	SNR, 4:2:2	HP@(level – 1)
High	4:2:0	Spatial, 4:2:2	SNR, 4:2:2	HP@(level – 1)
High	4:2:2	Spatial, 4:2:2	SNR, 4:2:2	HP@(level – 1) [b]
Multi-view	4:2:0	Temporal, 4:2:0	–	MP@same level

[a] The simplest compliant decoder to decode the base layer is specified, assuming that bitstream may contain any syntax and parameter value permitted for the stated profile @ level, except scalability. Note that for High profile @ Main level spatially scaled bitstreams, 'HP @ (level – 1)' becomes 'MP @ (level – 1)'. In the event that a base layer bitstream uses fewer syntactic elements or a reduced parameter range than permitted, profile_and_level_indication may indicate a 'simpler' profile @ level.

[b] Note that 4:2:2 chroma format is not supported as a lower spatial layer of High profile @ Main level (see Table 8-12).

Details of the different parameter limits that may be applied in each layer of a bitstream and the corresponding appropriate profile_and_level_indication that should be used are given in Tables E.20 to E.45.

8.4.2 Multi-view Profile specific constraints

Both the enhancement and base layers have the same frame rate.

The picture_mux_enable, picture_mux_order and picture_mux_factor are not used in this profile and shall be ignored.

The reference_select_code should be "00" or "01" for the P-frames in the enhancement layer. The reference_select_code should be "01" for B-frames in the enhancement layer.

If the base layer coded frame is the first frame of the Group Of Pictures then the corresponding frame in the enhancement layer should be either I-frame or P-frame with the reference_select_code value of "01".

In a P-field picture with reference_select_code = "01" and which is the first field of a frame, the following restriction applies:

- Dual prime prediction shall not be used.
- Field prediction in which motion_vertical_field_select indicates the second field of the base layer frame shall not be used.
- If base and enhancement layers do not have the same value for top_field_first, there shall be no macroblocks that are coded with macroblock_motion_forward zero and macroblock_intra zero.
- If base and enhancement layer do not have the same value for top_field_first, there shall be no skipped macroblocks.

In a B-field picture which is the first field of a frame, the prediction shall not make reference to the second field of the corresponding base layer frame.

It is inherent in the Multi-view Profile that the two layers are tightly coupled to one another. It is a requirement that the pictures in enhancement layer shall be decoded immediately after their corresponding required reference pictures are decoded unless this requirement makes one to decode the enhancement layer pictures out of display order. In that case, the pictures in the enhancement layer should be decoded in the display order.

8.5 Parameter values for defined profiles, levels and layers

See Table 8-11.

Table 8-11 - Upper bounds for sampling density

Level	Spatial resolution layer		Profile						
			Simple	Main	SNR	Spatial	High	4:2:2	Multi
High	Enhancement	Samples/line Lines/frame Frames/sec		1920 1088 60			1920 1088 60	1920 1088 60	1920 1088 60
	Lower	Samples/line Lines/frame Frames/sec		–			960 576 30	–	1920 1088 60
High-1440	Enhancement	Samples/line Lines/frame Frames/sec		1440 1088 60		1440 1088 60	1440 1088 60	–	1440 1088 60
	Lower	Samples/line Lines/frame Frames/sec		–		720 576 30	720 576 30	–	1440 1088 60
Main	Enhancement	Samples/line Lines/frame Frames/sec	720 576 30	720 576 30	720 576 30		720 576 30	720 608 [a] 30	720 576 30
	Lower	Samples/line Lines/frame Frames/sec	–	–	–		352 288 30	–	720 576 30
Low	Enhancement	Samples/line Lines/frame Frames/sec		352 288 30	352 288 30			–	352 288 30
	Lower	Samples/line Lines/frame Frames/sec		–	–			–	352 288 30

In the case of single layer or SNR scaled coding, the limits specified by 'Enhancement layer' apply.

[a] 512 lines/frame for 525/60, 608 lines/frame for 625/50

The syntactic elements referenced by this table are as follows:

- samples/line: horizontal_size;
- lines/frame: vertical_size;
- frames/sec: frame_rate.

The upper bound for frame_rate is the same for both progressive_sequence == 0 and progressive_sequence == 1.

Table 8-12 – Upper bounds for luminance sample rate (samples/s)

Level	Spatial resolution layer	Profile						
		Simple	Main	SNR	Spatial	High	4:2:2	Multi-view
High	Enhancement		62 668 800			62 668 800 (4:2:2) 83 558 400 (4:2:0)	62 668 800	62 668 800
	Lower		–			14 745 600 (4:2:2) 19 660 800 (4:2:0)	–	62 668 800
High-1440	Enhancement		47 001 600		47 001 600	47 001 600 (4:2:2) 62 668 800 (4:2:0)	–	47 001 600
	Lower		–		10 368 000	11 059 200 (4:2:2) 14 745 600 (4:2:0)	–	47 001 600
Main	Enhancement	10 368 000	10 368 000	10 368 000		11 059 200 (4:2:2) 14 745 600 (4:2:0)	11 059 200	10 368 000
	Lower	–	–	–		– 3 041 280 (4:2:0)	–	10 368 000
Low	Enhancement		3 041 280	3 041 280			–	3 041 280
	Lower		–	–			–	3 041 280
NOTE – In the case of single layer or SNR scaled coding, the limits specified by "Enhancement layer" apply.								

The luminance sample rate P is defined as follows:

- For progressive_sequence == 1:

$$P = (16 * ((horizontal\_size + 15) / 16)) \times (16 * ((vertical\_size + 15) / 16)) \times frame\_rate$$

- For progressive_sequence == 0:

$$P = (16 * ((horizontal\_size + 15) / 16)) \times (32 * ((vertical\_size + 31) / 32)) \times frame\_rate$$

8.6 Compatibility requirements on decoders

Table 8-15 defines the requirements on compatibility for decoders. There is a requirement that a decoder of a profile and level represented by a column in Table 8-15 be capable of decoding correctly all bitstreams with profile and level indication marked by an X in the column. In case of scalable hierarchy of bitstreams, the profile and level indication are that of the upper layer.

NOTE – For Profiles and Levels which obey a hierarchical structure, it is recommended that each layer of the bitstream contain the profile_and_level_indication of the "simplest" decoder which is capable of successfully decoding that layer of the bitstream. In the case where the profile_and_level_indication Escape bit == 0, this will be the numerically largest of the possible valid values of profile_and_level_indication.

Table 8-13 – Upper bounds for bit rates (Mbit/s)

Level	Profile						
	Simple	Main	SNR	Spatial	High	4:2:2	Multi-view
High		80			100 all layers 80 middle + base layer 25 base layer	300	– 130 both layers 80 base layer
High-1440		60		60 all layers 40 middle + base layers 15 base layer	80 all layers 60 middle + base layers 20 base layer	–	– 100 both layers 60 base layer
Main	15	15	– 15 both layers 10 base layer		20 all layers 15 middle + base layer 4 base layer	50	– 25 both layers 15 base layer
Low		4	– 4 both layers 3 base layer			–	– 8 both layers 4 base layer

NOTE 1 – This table defines the maximum rate of operation of the VBV for a coded bitstream of the given profile and level. This rate is indicated by bit_rate (see 6.3.3).

NOTE 2 – This table defines the maximum permissible data rate for all layers up to and including the stated layer. For multi-layer coding applications, the data rate apportioned between layers is constrained only by the maximum rate permitted for a given layer as stated in this table.

NOTE 3 – 1 Mbit = 1 000 000 bits

Table 8-14 – VBV buffer size requirements (bits)

Level	Layer	Profile						
		Simple	Main	SNR	Spatial	High	4:2:2	Multi-view
High	Enhancement 2 Enhancement 1 Base		 9 781 248			12 222 464 9 781 248 3 047 424	 47 185 920	– 15 898 480 9 787 248
High-1440	Enhancement 2 Enhancement 1 Base		 7 340 032		7 340 032 4 882 432 1 835 008	9 781 248 7 340 032 2 441 216	 –	– 12 222 464 7 340 032
Main	Enhancement 2 Enhancement 1 Base	 1 835 008	 1 835 008	– 1 835 008 1 212 416		2 441 216 1 835 008 475 136	 9 437 184	– 3 047 424 1 835 008
Low	Enhancement 2 Enhancement 1 Base		 475 136	– 475 136 360 448			–	– 950 272 475 136

NOTE 1 – The buffer size is calculated to be proportional to the maximum allowable bit rate, *rounded down* to the nearest multiple of 16 × 1024 bits. The reference value for scaling is the Main profile, Main level buffer size.

NOTE 2 – This table defines the *total* decoder buffer size required to decode all layers up to and including the stated layer. For multi-layer coding applications, the allocation of buffer memory between layers is constrained only by the maximum size permitted for a given layer as stated in this table.

NOTE 3 – The syntactic element corresponding to this table is vbv_buffer_size (see 6.3.3).

Table 8-15 – Forward compatibility between different profiles and levels

Profile and Level indication in bitstream	Decoder																
	HP @ HL	HP @ H-14	HP @ ML	Spatial @ H-14	SNR @ ML	SNR @ LL	MP @ HL	MP @ H-14	MP @ ML	MP @ LL	SP @ ML	4:2:2P @ ML	4:2:2P @ HL	MVP @ HL	MVP @ H-14	MVP @ ML	MVP @ LL
HP@HL	X																
HP@H-14	X	X															
HP@ML	X	X	X														
Spatial@H-14	X	X		X													
SNR@ML	X	X	X	X	X												
SNR@LL	X	X	X	X	X	X											
MP@HL	X						X						X[c)]	X			
MP@H-14	X	X		X			X	X					X[c)]	X	X		
MP@ML	X	X	X	X	X		X	X	X			X[b)]	X[c)]	X	X	X	
MP@LL	X	X	X	X	X	X	X	X	X	X	X[a)]	X[b)]	X[c)]	X	X	X	X
SP@ML	X	X	X	X	X		X	X	X		X	X[b)]	X[c)]	X	X	X	
ISO/IEC 11172-2	X	X	X	X	X	X	X	X	X	X	X	X[b)]	X[c)]	X	X	X	X
4:2:2@ML												X	X[c)]				
4:2:2@HL													X				
MVP@HL														X			
MVP@H-14														X	X		
MVP@ML														X	X	X	
MVP@LL														X	X	X	X

X indicates that the decoder shall be able to decode the bit stream including all relevant lower layers.

a) SP@ML decoders are required to decode MP@LL bitstreams.

b) A 4:2:2 profile@Main level decoder shall be able to decode Main profile@Main level, Main profile@Low level and Simple profile@Main level bitstreams, as well as ISO/IEC 11172-2 constrained system parameter bitstreams.

c) A 4:2:2 profile@High level decoder shall be able to decode 4:2:2P@ML, MP@HL, MP@HL-1440, MP@ML, MP@LL and SP@ML, as well as ISO/IEC 11172-2 constrained system parameter bitstreams.

9 Registration of Copyright Identifiers

9.1 General

Parts 1, 2, and 3 of ISO/IEC 13818 provide support for the management of audiovisual works copyrighting. In ITU-T Rec. H.222.0 | ISO/IEC 13818-1 this is by means of a copyright descriptor, while ITU-T Rec. H.262 | ISO/IEC 13818-2 and ISO/IEC 13818-3 contain fields for identifying copyright holders through syntax fields in the elementary stream syntax. This Recommendation | International Standard presents the method of obtaining and registering copyright identifiers in ITU-T Rec. H.262 | ISO/IEC 13818-2.

ITU-T Rec. H.262 | ISO/IEC 13818-2 specifies a unique 32-bit copyright_identifier which is a work type code identifier (such as ISBN, ISSN, ISRC, etc.) carried in the copyright descriptor. The copyright_identifier enables identification of a wide number of Copyright Registration Authorities. Each Copyright Registration Authority may specify a syntax and semantic for identifying the audiovisual works or other copyrighted works within that particular copyright organization through appropriate use of the variable length additional_copyright_info field which contains the copyright number.

In the following subclause and Annexes G, H and I, the benefits and responsibilities of all parties to the registration of copyright_identifier are outlined.

9.2 Implementation of a Registration Authority (RA)

ISO/IEC JTC 1 shall call for nominations for an international organization which will serve as the Registration Authority for the **copyright_identifier** as defined in ITU-T Rec. H.262 | ISO/IEC 13818-2. The selected organization shall serve as the Registration Authority. The so-named Registration Authority shall execute its duties in compliance with Annex H of the JTC 1 Directives. The registered copyright_identifier is hereafter referred to as the Registered Identifier (RID).

Upon selection of the Registration Authority, JTC 1 shall require the creation of a Registration Management Group (RMG) which will review appeals filed by organizations whose request for an RID to be used in conjunction with ITU-T Rec. H.262 | ISO/IEC 13818-2 has been denied by the Registration Authority.

Annexes G, H and I to this Specification provide information on the procedures for registering a unique copyright_identifier.

Annex A

Inverse discrete transform

(This annex forms an integral part of this Recommendation | International Standard)

The N × N two dimensional DCT is defined as:

$$F(u, v) = \frac{2}{N} C(u)C(v) \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} f(x, y)\cos \frac{(2x + 1)u\pi}{2N} \cos \frac{(2y + 1)v\pi}{2N}$$

with u, v, x, y = 0, 1, 2, … N – 1

where x, y are spatial coordinates in the sample domain

u, v are coordinates in the transform domain

$$C(u), C(v) = \begin{cases} \frac{1}{\sqrt{2}} & \text{for u v} = 0 \\ 1 & \text{otherwise} \end{cases}$$

The definition of the DCT (also called forward DCT) is purely informative. Forward DCT is not used by the decoding process described by this Specification.

The mathematical real-number IDCT is defined as:

$$f(x, y) = \frac{2}{N} \sum_{u=0}^{N-1} \sum_{v=0}^{N-1} C(u)C(v)F(u, v)\cos \frac{(2x + 1)u\pi}{2N} \cos \frac{(2y + 1)v\pi}{2N}$$

f (x, y) is a real number.

The mathematical integer-number IDCT is defined as:

$$f'(x, y) = \text{round}(f(x, y))$$

where round() is the rounding to the nearest integer, with half-integer values rounded away from zero. No clamping or saturation is performed.

The saturated mathematical integer-number IDCT is defined as:

$$f''(x, y) = \text{saturate}(f'(x, y))$$

where saturate() is the saturation in the range [–256, 255], defined as:

$$\text{saturate}(x) = \begin{cases} -256 & x < -256 \\ 255 & x > 255 \\ x & -256 \le x \le 255 \end{cases}$$

The IDCT function f[y][x] used in the decoding process may be any of several approximations of the saturated mathematical integer-number IDCT f ''(x, y), provided that it meets all of the following requirements:

1) The IDCT function f[y][x] used in the decoding process shall have values always in the range [–256, 255].
2) The IDCT function f[y][x] used in the decoding process shall conform to the IEEE Standard Specification for the implementation of 8 by 8 Inverse Discrete Cosine Transform, IEEE Std. 1180-1990, 6 December 1990.
3) This item applies only when input blocks of DCT coefficients cause all the 64 values output of the mathematical integer-number IDCT f '(x, y) to be in the range [–384, 383]. When f '(x, y) > 256, f[y][x] shall be equal to 255 and when f '(x, y) < –257, f[y][x] shall be equal to –256. For all values of f '(x, y) in the range [–257, 256] the absolute difference between f[y][x] and f ''(x, y) shall not be larger than 2.

4) Let F be the set of 4096 blocks Bi[y][x] (i = 0 … 4095) defined as follows:

   a) Bi[0][0] = i – 2048.

   b) Bi[7][7] = 1 if Bi[0][0] is even, Bi[7][7] = 0 if Bi[0][0] is odd.

   c) All other coefficients Bi[y][x] other than Bi[0][0] and Bi[7][7] are equal to 0.

   For each block Bi[y][x] that belongs to set F defined above, an IDCT that conforms to this specification (see Annex A) shall output a block f[y][x] that has a peak error of 1 or less compared to the reference saturated mathematical integer-number IDCT f "(x, y). In other words, | f[y][x] –f "(x, y) | shall be < = 1 for all x and y.

In addition to these requirements, the following is a recommendation on the accuracy of the IDCT function f[y][x].

5) When item 3) does not apply, i.e. for input blocks of DCT coefficients causing the output of the mathematical integer-number IDCT f '(x, y) to contain one or more values out of the range [–384, 383], it is desirable that f[y][x] be as close as possible to f "(x, y) for all bitstreams produced by reasonably well-designed encoders.

NOTE – Clause 2.3 IEEE Standard 1180-1990 "Considerations of Specifying IDCT Mismatch Errors" requires the specification of periodic intra-picture coding in order to control the accumulation of mismatch errors. Every macroblock is required to be refreshed before it is coded 132 times as predictive macroblocks. Macroblocks in B-pictures (and skipped macroblocks in P-pictures) are excluded from the counting because they do not lead to the accumulation of mismatch errors. This requirement is the same as indicated in 1180-1990 for visual telephony according to Recommendation H.261.

Annex B

Variable length code tables

(This annex forms an integral part of this Recommendation | International Standard)

B.1 Macroblock addressing

See Table B.1.

Table B.1 – Variable length codes for macroblock_address_increment

macroblock_address_ increment VLC code	Increment value	**macroblock_address_ increment** VLC code	Increment value
1	1	0000 0101 01	18
011	2	0000 0101 00	19
010	3	0000 0100 11	20
0011	4	0000 0100 10	21
0010	5	0000 0100 011	22
0001 1	6	0000 0100 010	23
0001 0	7	0000 0100 001	24
0000 111	8	0000 0100 000	25
0000 110	9	0000 0011 111	26
0000 1011	10	0000 0011 110	27
0000 1010	11	0000 0011 101	28
0000 1001	12	0000 0011 100	29
0000 1000	13	0000 0011 011	30
0000 0111	14	0000 0011 010	31
0000 0110	15	0000 0011 001	32
0000 0101 11	16	0000 0011 000	33
0000 0101 10	17	0000 0001 000	macroblock_escape

NOTE – The "macroblock stuffing" entry that is available in ISO/IEC 11172-2 is not available in this Specification.

B.2 Macroblock type

The properties of the macroblock are determined by the macroblock type VLC according to Tables B.2 to B.8.

Table B.2 – Variable length codes for macroblock_type in I-pictures

macroblock_type VLC code	**macroblock_quant**	**macroblock_motion_forward**	**macroblock_motion_backward**	**macroblock_pattern**	**macroblock_intra**	**spatial_temporal_weight_code_flag**	**permitted spatial_temporal_weight_classes** Description	
1	0	0	0	0	1	0	Intra	0
01	1	0	0	0	1	0	Intra, Quant	0

Table B.3 – Variable length codes for macroblock_type in P-pictures

macroblock_type VLC code	**macroblock_quant**	**macroblock_motion_forward**	**macroblock_motion_backward**	**macroblock_pattern**	**macroblock_intra**	**spatial_temporal_weight_code_flag**	**permitted spatial_temporal_weight_classes** Description	
1	0	1	0	1	0	0	MC, Coded	0
01	0	0	0	1	0	0	No MC, Coded	0
001	0	1	0	0	0	0	MC, Not Coded	0
0001 1	0	0	0	0	1	0	Intra	0
0001 0	1	1	0	1	0	0	MC, Coded, Quant	0
0000 1	1	0	0	1	0	0	No MC, Coded, Quant	0
0000 01	1	0	0	0	1	0	Intra, Quant	0

Table B.4 – Variable length codes for macroblock_type in B-pictures

macroblock_type VLC code	macroblock_quant	macroblock_motion_forward	macroblock_motion_backward	macroblock_pattern	macroblock_intra	spatial_temporal_weight_code_flag	permitted spatial_temporal_weight_classes	
							Description	
10	0	1	1	0	0	0	Interp, Not Coded	0
11	0	1	1	1	0	0	Interp, Coded	0
010	0	0	1	0	0	0	Bwd, Not Coded	0
011	0	0	1	1	0	0	Bwd, Coded	0
0010	0	1	0	0	0	0	Fwd, Not Coded	0
0011	0	1	0	1	0	0	Fwd, Coded	0
0001 1	0	0	0	0	1	0	Intra	0
0001 0	1	1	1	1	0	0	Interp, Coded, Quant	0
0000 11	1	1	0	1	0	0	Fwd, Coded, Quant	0
0000 10	1	0	1	1	0	0	Bwd, Coded, Quant	0
0000 01	1	0	0	0	1	0	Intra, Quant	0

Table B.5 – Variable length codes for macroblock_type in I-pictures with spatial scalability

macroblock_type VLC code	macroblock_quant	macroblock_motion_forward	macroblock_motion_backward	macroblock_pattern	macroblock_intra	spatial_temporal_weight_code_flag	permitted spatial_temporal_weight_classes	
							Description	
1	0	0	0	1	0	0	Coded, Compatible	4
01	1	0	0	1	0	0	Coded, Compatible, Quant	4
0011	0	0	0	0	1	0	Intra	0
0010	1	0	0	0	1	0	Intra, Quant	0
0001	0	0	0	0	0	0	Not Coded, Compatible	4

Table B.6 – Variable length codes for macroblock_type in P-pictures with spatial scalability

macroblock_type VLC code	**macroblock_quant**	**macroblock_motion_forward**	**macroblock_motion_backward**	**macroblock_pattern**	**macroblock_intra**	**spatial_temporal_weight_code_flag**	**permitted spatial_temporal_weight_classes** Description	
10	0	1	0	1	0	0	MC, Coded	0
011	0	1	0	1	0	1	MC, Coded, Compatible	1,2,3
0000 100	0	0	0	1	0	0	No MC, Coded	0
0001 11	0	0	0	1	0	1	No MC, Coded, Compatible	1,2,3
0010	0	1	0	0	0	0	MC, Not Coded	0
0000 111	0	0	0	0	1	0	Intra	0
0011	0	1	0	0	0	1	MC, Not coded, Compatible	1,2,3
010	1	1	0	1	0	0	MC, Coded, Quant	0
0001 00	1	0	0	1	0	0	No MC, Coded, Quant	0
0000 110	1	0	0	0	1	0	Intra, Quant	0
11	1	1	0	1	0	1	MC, Coded, Compatible, Quant	1,2,3
0001 01	1	0	0	1	0	1	No MC, Coded, Compatible,Quant	1,2,3
0001 10	0	0	0	0	0	1	No MC, Not Coded, Compatible	1,2,3
0000 101	0	0	0	1	0	0	Coded, Compatible	4
0000 010	1	0	0	1	0	0	Coded, Compatible, Quant	4
0000 011	0	0	0	0	0	0	Not Coded, Compatible	4

Table B.7 – Variable length codes for macroblock_type in B-pictures with spatial scalability

macroblock_type VLC code	**macroblock_quant**	**macroblock_motion_forward**	**macroblock_motion_backward**	**macroblock_pattern**	**macroblock_intra**	**spatial_temporal_weight_code_flag**	**permitted spatial_temporal_weight_classes** Description	
10	0	1	1	0	0	0	Interp, Not coded	0
11	0	1	1	1	0	0	Interp, Coded	0
010	0	0	1	0	0	0	Back, Not coded	0
011	0	0	1	1	0	0	Back, Coded	0
0010	0	1	0	0	0	0	For, Not coded	0
0011	0	1	0	1	0	0	For, Coded	0
0001 10	0	0	1	0	0	1	Back, Not Coded, Compatible	1,2,3
0001 11	0	0	1	1	0	1	Back, Coded, Compatible	1,2,3
0001 00	0	1	0	0	0	1	For, Not Coded, Compatible	1,2,3
0001 01	0	1	0	1	0	1	For, Coded, Compatible	1,2,3
0000 110	0	0	0	0	1	0	Intra	0
0000 111	1	1	1	1	0	0	Interp, Coded, Quant	0
0000 100	1	1	0	1	0	0	For, Coded, Quant	0
0000 101	1	0	1	1	0	0	Back, Coded, Quant	0
0000 0100	1	0	0	0	1	0	Intra, Quant	0
0000 0101	1	1	0	1	0	1	For, Coded, Compatible, Quant	1,2,3
0000 0110 0	1	0	1	1	0	1	Back, Coded, Compatible, Quant	1,2,3
0000 0111 0	0	0	0	0	0	0	Not Coded, Compatible	4
0000 0110 1	1	0	0	1	0	0	Coded, Compatible, Quant	4
0000 0111 1	0	0	0	1	0	0	Coded, Compatible	4

Table B.8 – Variable length codes for macroblock_type in I-pictures, P-pictures and B-pictures with SNR scalability

macroblock_type VLC code	macroblock_quant	macroblock_motion_forward	macroblock_motion_backward	macroblock_pattern	macroblock_intra	spatial_temporal_weight_code_flag	permitted spatial_temporal_weight_classes	
							Description	
1	0	0	0	1	0	0	Coded	0
01	1	0	0	1	0	0	Coded, Quant	0
001	0	0	0	0	0	0	Not Coded	0

NOTE – There is no differentiation between picture types, since macroblocks are processed identically in I-, P- and B-pictures. The "Not coded" type is needed, since skipped macroblocks are not allowed at beginning and end of a slice.

B.3 Macroblock pattern

See Table B.9.

Table B.9 – Variable length codes for coded_block_pattern

coded_block_pattern VLC code	cbp	**coded_block_pattern** VLC code	cbp
111	60	0001 1100	35
1101	4	0001 1011	13
1100	8	0001 1010	49
1011	16	0001 1001	21
1010	32	0001 1000	41
1001 1	12	0001 0111	14
1001 0	48	0001 0110	50
1000 1	20	0001 0101	22
1000 0	40	0001 0100	42
0111 1	28	0001 0011	15
0111 0	44	0001 0010	51
0110 1	52	0001 0001	23
0110 0	56	0001 0000	43
0101 1	1	0000 1111	25
0101 0	61	0000 1110	37
0100 1	2	0000 1101	26
0100 0	62	0000 1100	38
0011 11	24	0000 1011	29
0011 10	36	0000 1010	45
0011 01	3	0000 1001	53
0011 00	63	0000 1000	57
0010 111	5	0000 0111	30
0010 110	9	0000 0110	46
0010 101	17	0000 0101	54
0010 100	33	0000 0100	58
0010 011	6	0000 0011 1	31
0010 010	10	0000 0011 0	47
0010 001	18	0000 0010 1	55
0010 000	34	0000 0010 0	59
0001 1111	7	0000 0001 1	27
0001 1110	11	0000 0001 0	39
0001 1101	19	0000 0000 1	0 (Note)
NOTE – This entry shall not be used with 4:2:0 chrominance structure.			

B.4 Motion vectors

See Tables B.10 and B.11.

Table B.10 – Variable length codes for motion_code

Variable length code	**motion_code[r][s][t]**
0000 0011 001	–16
0000 0011 011	–15
0000 0011 101	–14
0000 0011 111	–13
0000 0100 001	–12
0000 0100 011	–11
0000 0100 11	–10
0000 0101 01	–9
0000 0101 11	–8
0000 0111	–7
0000 1001	–6
0000 1011	–5
0000 111	–4
0001 1	–3
0011	–2
011	–1
1	0
010	1
0010	2
0001 0	3
0000 110	4
0000 1010	5
0000 1000	6
0000 0110	7
0000 0101 10	8
0000 0101 00	9
0000 0100 10	10
0000 0100 010	11
0000 0100 000	12
0000 0011 110	13
0000 0011 100	14
0000 0011 010	15
0000 0011 000	16

Table B.11 – Variable length codes for dmvector[t]

Code	Value
11	–1
0	0
10	1

B.5 DCT coefficients

See Tables B.12 to B.16.

Table B.12 – Variable length codes for dct_dc_size_luminance

Variable length code	**dct_dc_size_luminance**
100	0
00	1
01	2
101	3
110	4
1110	5
1111 0	6
1111 10	7
1111 110	8
1111 1110	9
1111 1111 0	10
1111 1111 1	11

Table B.13 – Variable length codes for dct_dc_size_chrominance

Variable length code	**dct_dc_size_chrominance**
00	0
01	1
10	2
110	3
1110	4
1111 0	5
1111 10	6
1111 110	7
1111 1110	8
1111 1111 0	9
1111 1111 10	10
1111 1111 11	11

Table B.14 – DCT coefficients Table zero

Variable length code (Note 1)	Run	Level
10 (Note 2)	End of Block	
1 s (Note 3)	0	1
11 s (Note 4)	0	1
011 s	1	1
0100 s	0	2
0101 s	2	1
0010 1 s	0	3
0011 1 s	3	1
0011 0 s	4	1
0001 10 s	1	2
0001 11 s	5	1
0001 01 s	6	1
0001 00 s	7	1
0000 110 s	0	4
0000 100 s	2	2
0000 111 s	8	1
0000 101 s	9	1
0000 01	Escape	
0010 0110 s	0	5
0010 0001 s	0	6
0010 0101 s	1	3
0010 0100 s	3	2
0010 0111 s	10	1
0010 0011 s	11	1
0010 0010 s	12	1
0010 0000 s	13	1
0000 0010 10 s	0	7
0000 0011 00 s	1	4
0000 0010 11 s	2	3
0000 0011 11 s	4	2
0000 0010 01 s	5	2
0000 0011 10 s	14	1
0000 0011 01 s	15	1
0000 0010 00 s	16	1

Table B.14 – DCT coefficients Table zero *(continued)*

Variable length code (Note 1)	Run	Level
0000 0001 1101 s	0	8
0000 0001 1000 s	0	9
0000 0001 0011 s	0	10
0000 0001 0000 s	0	11
0000 0001 1011 s	1	5
0000 0001 0100 s	2	4
0000 0001 1100 s	3	3
0000 0001 0010 s	4	3
0000 0001 1110 s	6	2
0000 0001 0101 s	7	2
0000 0001 0001 s	8	2
0000 0001 1111 s	17	1
0000 0001 1010 s	18	1
0000 0001 1001 s	19	1
0000 0001 0111 s	20	1
0000 0001 0110 s	21	1
0000 0000 1101 0 s	0	12
0000 0000 1100 1 s	0	13
0000 0000 1100 0 s	0	14
0000 0000 1011 1 s	0	15
0000 0000 1011 0 s	1	6
0000 0000 1010 1 s	1	7
0000 0000 1010 0 s	2	5
0000 0000 1001 1 s	3	4
0000 0000 1001 0 s	5	3
0000 0000 1000 1 s	9	2
0000 0000 1000 0 s	10	2
0000 0000 1111 1 s	22	1
0000 0000 1111 0 s	23	1
0000 0000 1110 1 s	24	1
0000 0000 1110 0 s	25	1
0000 0000 1101 1 s	26	1

Table B.14 – DCT coefficients Table zero *(continued)*

Variable length code (Note 1)	Run	Level
0000 0000 0111 11 s	0	16
0000 0000 0111 10 s	0	17
0000 0000 0111 01 s	0	18
0000 0000 0111 00 s	0	19
0000 0000 0110 11 s	0	20
0000 0000 0110 10 s	0	21
0000 0000 0110 01 s	0	22
0000 0000 0110 00 s	0	23
0000 0000 0101 11 s	0	24
0000 0000 0101 10 s	0	25
0000 0000 0101 01 s	0	26
0000 0000 0101 00 s	0	27
0000 0000 0100 11 s	0	28
0000 0000 0100 10 s	0	29
0000 0000 0100 01 s	0	30
0000 0000 0100 00 s	0	31
0000 0000 0011 000 s	0	32
0000 0000 0010 111 s	0	33
0000 0000 0010 110 s	0	34
0000 0000 0010 101 s	0	35
0000 0000 0010 100 s	0	36
0000 0000 0010 011 s	0	37
0000 0000 0010 010 s	0	38
0000 0000 0010 001 s	0	39
0000 0000 0010 000 s	0	40
0000 0000 0011 111 s	1	8
0000 0000 0011 110 s	1	9
0000 0000 0011 101 s	1	10
0000 0000 0011 100 s	1	11
0000 0000 0011 011 s	1	12
0000 0000 0011 010 s	1	13
0000 0000 0011 001 s	1	14

Table B.14 – DCT coefficients Table zero *(concluded)*

Variable length code (Note 1)	Run	Level
0000 0000 0001 0011 s	1	15
0000 0000 0001 0010 s	1	16
0000 0000 0001 0001 s	1	17
0000 0000 0001 0000 s	1	18
0000 0000 0001 0100 s	6	3
0000 0000 0001 1010 s	11	2
0000 0000 0001 1001 s	12	2
0000 0000 0001 1000 s	13	2
0000 0000 0001 0111 s	14	2
0000 0000 0001 0110 s	15	2
0000 0000 0001 0101 s	16	2
0000 0000 0001 1111 s	27	1
0000 0000 0001 1110 s	28	1
0000 0000 0001 1101 s	29	1
0000 0000 0001 1100 s	30	1
0000 0000 0001 1011 s	31	1

NOTE 1 – The last bit 's' denotes the sign of the level: '0' for positive, '1' for negative.

NOTE 2 – "End of Block" shall not be the only code of the block.

NOTE 3 – This code shall be used for the first (DC) coefficient in the block.

NOTE 4 – This code shall be used for all other coefficients.

Table B.15 – DCT coefficients Table one

Variable length code (Note 1)	Run	Level
0110 (Note 2)	End of Block	
10s	0	1
010 s	1	1
110 s	0	2
0010 1 s	2	1
0111 s	0	3
0011 1 s	3	1
0001 10 s	4	1
0011 0 s	1	2
0001 11 s	5	1
0000 110 s	6	1
0000 100 s	7	1
1110 0 s	0	4
0000 111 s	2	2
0000 101 s	8	1
1111 000 s	9	1
0000 01	Escape	
1110 1 s	0	5
0001 01 s	0	6
1111 001 s	1	3
0010 0110 s	3	2
1111 010 s	10	1
0010 0001 s	11	1
0010 0101 s	12	1
0010 0100 s	13	1
0001 00 s	0	7
0010 0111 s	1	4
1111 1100 s	2	3
1111 1101 s	4	2
0000 0010 0 s	5	2
0000 0010 1 s	14	1
0000 0011 1 s	15	1
0000 0011 01 s	16	1

Table B.15 – DCT coefficients Table one *(continued)*

Variable length code (Note 1)	Run	Level
1111 011 s	0	8
1111 100 s	0	9
0010 0011 s	0	10
0010 0010 s	0	11
0010 0000 s	1	5
0000 0011 00 s	2	4
0000 0001 1100 s	3	3
0000 0001 0010 s	4	3
0000 0001 1110 s	6	2
0000 0001 0101 s	7	2
0000 0001 0001 s	8	2
0000 0001 1111 s	17	1
0000 0001 1010 s	18	1
0000 0001 1001 s	19	1
0000 0001 0111 s	20	1
0000 0001 0110 s	21	1
1111 1010 s	0	12
1111 1011 s	0	13
1111 1110 s	0	14
1111 1111 s	0	15
0000 0000 1011 0 s	1	6
0000 0000 1010 1 s	1	7
0000 0000 1010 0 s	2	5
0000 0000 1001 1 s	3	4
0000 0000 1001 0 s	5	3
0000 0000 1000 1 s	9	2
0000 0000 1000 0 s	10	2
0000 0000 1111 1 s	22	1
0000 0000 1111 0 s	23	1
0000 0000 1110 1 s	24	1
0000 0000 1110 0 s	25	1
0000 0000 1101 1 s	26	1

Table B.15 – DCT coefficients Table one *(continued)*

Variable length code (Note 1)	Run	Level
0000 0000 0111 11 s	0	16
0000 0000 0111 10 s	0	17
0000 0000 0111 01 s	0	18
0000 0000 0111 00 s	0	19
0000 0000 0110 11 s	0	20
0000 0000 0110 10 s	0	21
0000 0000 0110 01 s	0	22
0000 0000 0110 00 s	0	23
0000 0000 0101 11 s	0	24
0000 0000 0101 10 s	0	25
0000 0000 0101 01 s	0	26
0000 0000 0101 00 s	0	27
0000 0000 0100 11 s	0	28
0000 0000 0100 10 s	0	29
0000 0000 0100 01 s	0	30
0000 0000 0100 00 s	0	31
0000 0000 0011 000 s	0	32
0000 0000 0010 111 s	0	33
0000 0000 0010 110 s	0	34
0000 0000 0010 101 s	0	35
0000 0000 0010 100 s	0	36
0000 0000 0010 011 s	0	37
0000 0000 0010 010 s	0	38
0000 0000 0010 001 s	0	39
0000 0000 0010 000 s	0	40
0000 0000 0011 111 s	1	8
0000 0000 0011 110 s	1	9
0000 0000 0011 101 s	1	10
0000 0000 0011 100 s	1	11
0000 0000 0011 011 s	1	12
0000 0000 0011 010 s	1	13
0000 0000 0011 001 s	1	14

Table B.15 – DCT coefficients Table one *(concluded)*

Variable length code (Note 1)	Run	Level
0000 0000 0001 0011 s	1	15
0000 0000 0001 0010 s	1	16
0000 0000 0001 0001 s	1	17
0000 0000 0001 0000 s	1	18
0000 0000 0001 0100 s	6	3
0000 0000 0001 1010 s	11	2
0000 0000 0001 1001 s	12	2
0000 0000 0001 1000 s	13	2
0000 0000 0001 0111 s	14	2
0000 0000 0001 0110 s	15	2
0000 0000 0001 0101 s	16	2
0000 0000 0001 1111 s	27	1
0000 0000 0001 1110 s	28	1
0000 0000 0001 1101 s	29	1
0000 0000 0001 1100 s	30	1
0000 0000 0001 1011 s	31	1
NOTE 1 –The last bit 's' denotes the sign of the level: '0' for positive, '1' for negative. NOTE 2 – "End of Block" shall not be the only code of the block.		

Table B.16 – Encoding of run and level following an ESCAPE code

Fixed length code	Run
0000 00	0
0000 01	1
0000 10	2
…	…
…	…
…	…
…	…
1111 11	63

Fixed length code	**signed_level**
1000 0000 0000	reserved
1000 0000 0001	–2047
1000 0000 0010	–2046
…	…
1111 1111 1111	–1
0000 0000 0000	Forbidden
0000 0000 0001	+1
…	…
0111 1111 1111	+2047

Annex C

Video buffering verifier

(This annex forms an integral part of this Recommendation | International Standard)

Coded video bitstreams shall meet constraints imposed through a Video Buffering Verifier (VBV) defined in this annex. Each bitstream in a scalable hierarchy shall not violate the VBV constraints defined in this annex.

The VBV is a hypothetical decoder, which is conceptually connected to the output of an encoder. It has an input buffer known as the VBV buffer. Coded data is placed in the buffer as defined below in C.3 and is removed from the buffer as defined in C.5, C.6, and C.7. It is required that a bitstream that conforms to this Specification shall not cause the VBV buffer to overflow. When low_delay equals zero, the bitstream shall not cause the VBV buffer to underflow. When low_delay equals one, decoding a picture at the normally expected time might cause the VBV buffer to underflow. If this is the case, the picture is not decoded and the VBV buffer is re-examined at a sequence of later times specified in C.7 and C.8 until it is all present in the VBV buffer.

All the arithmetic in this annex is done with real-values, so that no rounding errors can propagate. For example, the number of bits in the VBV buffer is not necessarily an integer.

C.1 The VBV and the video encoder have the same clock frequency as well as the same frame rate, and are operated synchronously.

C.2 The VBV buffer is of size B, where B is the vbv_buffer_size coded in the sequence header and sequence extension if present.

C.3 This subclause defines the input of data to the VBV buffer. Two mutually exclusive cases are defined in C.3.1 and C.3.2. In both cases the VBV buffer is initially empty. Let R_{max} be the bitrate specified in the bit_rate field.

C.3.1 In the case where vbv_delay is coded with a value not equal to hexadecimal FFFF, the picture data of the n-th coded picture enters the buffer at a rate R(n) where:

$$R(n) = d^*_n / (\tau(n) - \tau(n + 1) + t(n + 1) - t(n))$$

Where

R(n) is the rate, in bits/s, that the picture data for the n-th coded picture enters the VBV.

d^*_n is the number of bits after the final bit of the n-th picture start code and before and including the final bit of the (n + 1)-th picture start code.

τ (n) is the decoding delay coded in vbv_delay for the n-th coded picture, measured in seconds.

t(n) Is the time, measured in seconds, when the n-th coded picture is removed from VBV buffer. t(n) is defined in C.9, C.10, C.11, and C.12.

Ambiguity at the beginning of a sequence:

The interval of time $t_{n+1} - t_n$ between removal of two consecutive pictures can normally be derived from the bitstream as described in C.9, C.10, C.11 and C.12.

When random access is made in a sequence, $t_{n+1} - t_n$ cannot be determined from the video bitstream alone for the first picture(s) after the sequence header since the previous coded P- or I-frame does not exist in the decoded sequence. If the bitstream is multiplexed as part of a systems bitstream according to ITU-T Rec. H.222.0 | ISO/IEC 13818-1, then it is possible (but not certain) that information in the systems bitstream may be used to determine unambiguously this interval of time. This information is available if Decoding Time Stamps (DTS) are transmitted for pictures n and n+1.

If the rate R(n) cannot be determined unambiguously, it is not possible for the VBV to precisely determine the fullness in trajectories in the VBV buffer during a limited period (always less than the maximum value for vbv_delay, which is approximately 0.73 seconds), therefore strict VBV verification of the entire bitstream is not always possible. Note that an encoder always knows the values of $t_{n+1} - t_n$ after each repeated sequence headers and therefore knows how to generate a bitstream that does not violate the VBV constraints at those points.

The ambiguity may become a problem when the video bitstream is remultiplexed and delivered at a rate different from the intended piecewise constant rate R(n).

It should also be noted that the input rate for the bits preceding the first picture header cannot be determined from the bitstream.

Ambiguity at the end of a sequence:

The input of all the bits following the picture start code of the picture preceding an end of sequence code cannot be determined from the bitstream. There shall exist an input rate for these bits that does not lead to an overflow or, if low_delay is equal to 1, an underflow of the VBV buffer. This rate shall be less than the maximum rate specified in the sequence header.

After filling the VBV buffer with all the data that precedes the first picture start code of the sequence and the picture start code itself, the VBV buffer is filled from the bitstream for the time specified by the vbv_delay field in the picture header. At this time decoding begins. The data input continues at the rates specified in this subclause.

For all bitstreams R(n) <= R_{max} for all picture data.

NOTE – For constant rate video the sequence of values R(n) are constant throughout the sequence to within the accuracy permitted by the quantisation of vbv_delay.

C.3.2 In the case where vbv_delay is coded with the value hexadecimal FFFF, data enters the VBV buffer as specified in this subclause.

If the VBV buffer is not full, data enters the buffer at R_{max}.

If the VBV buffer becomes full after filling at R_{max} for some time, no more data enters the buffer until some data is removed from the buffer.

After filling the VBV buffer with all the data that precedes the first picture start code of the sequence and the picture start code itself, the VBV buffer is filled from the bitstream until it is full. At this time decoding begins. The data input continues at the rate specified in this subclause.

C.4 Starting at the time defined in C.3, the VBV buffer is examined at successive times defined in C.9 to C.12. C.5 to C.8 defines the actions to be taken at each time the VBV buffer is examined.

C.5 This subclause defines a requirement on all video bitstreams.

At the time the VBV buffer is examined *before* removing any picture data, the number of bits in the buffer shall lie between zero bits and B bits where B is the size of the VBV buffer indicated by vbv_buffer_size.

For the purpose of this annex, picture data is defined as all the bits of the coded picture, all the header(s) and user data immediately preceding it if any (including any stuffing between them) and all the stuffing following it, up to (but not including) the next start code, except in the case where the next start code is an end of sequence code, in which case it is included in the picture data.

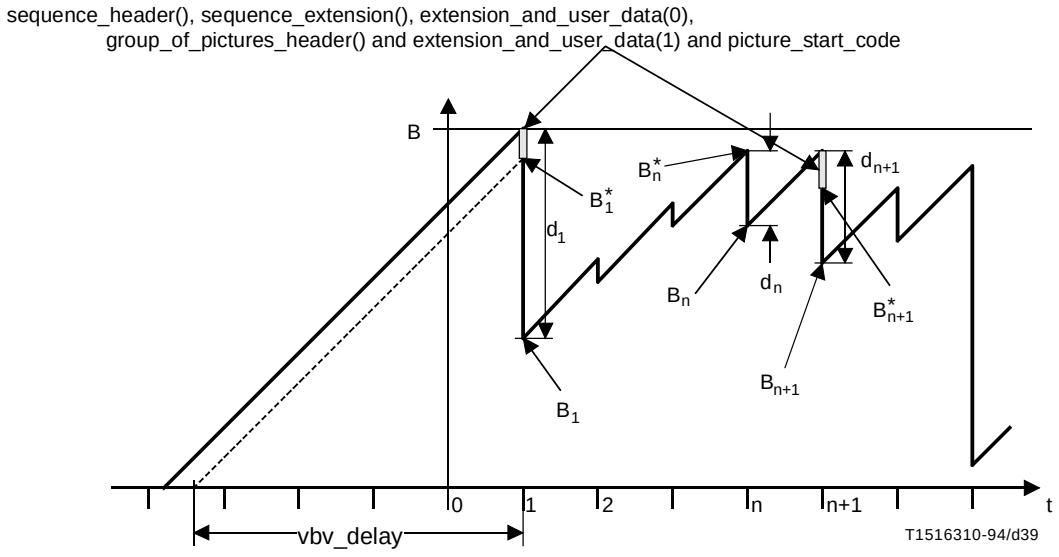


Figure C.1 – VBV Buffer Occupancy – Constant bit-rate operation

C.6 This subclause defines a requirement on the video bitstreams when the low_delay flag is equal to zero.

At each time the VBV buffer is examined and before any bits are removed, all of the data for the picture which (at that time) has been in the buffer longest shall be present in the VBV buffer. This picture data shall be removed instantaneously at this time.

VBV buffer underflow shall not occur when the low_delay flag is equal to 0. This requires that all picture data for the n-th picture shall be present in the VBV buffer at the decoding time, t_n.

C.7 This subclause only applies when the low_delay flag is equal to one.

When low_delay is equal to one, there may be situations where the VBV buffer shall be re-examined several times before removing a coded picture from the VBV buffer. It is possible to know if the VBV buffer has to be re-examined and how many times by looking at the temporal_reference of the next picture (the one that follows the picture currently to be decoded), see 6.3.10. If the VBV buffer has to be re-examined, the picture currently to be decoded is referred to as a big picture.

If picture currently to be decoded is a big picture, the VBV buffer is re-examined at intervals of 2 field-periods before removing the big picture, and no picture data is removed until the final re-examination.

At this time, the number of bits the VBV buffer immediately before removing the big picture shall be less than B, all the picture data for the picture that has been in the buffer longest (the big picture) shall be present in the buffer and shall be removed instantaneously. Then, normal operation of the VBV resumes, and C.5 applies.

The last coded picture of a sequence shall not be a big picture.

C.8 This subclause is informative only.

The situation where the VBV buffer would underflow (see C.7) can happen when low-delay applications transmit occasionally large pictures, for example in case of scene-cuts.

Decoding such bitstreams will cause the display process associated with a decoder to repeat a previously decoded field or frame until normal operation of the VBV can resume. This process is sometimes referred to as the occurrence of "skipped pictures". Note that this situation should normally not occur except occasionally. It shall not occur when low_delay is equal to 0.

C.9 This subclause defines the time intervals between successive examination of the VBV buffer in the case where progressive_sequence equals to 1 and low_delay equals to 0. In this case, the frame re-ordering delay always exists and B-pictures can occur.

The time interval $t_{n+1} - t_n$ between two successive examinations of the VBV buffer is a multiple of T, where T is the inverse of the frame rate.

If the n-th picture is a B-picture with repeat_first_field equals to 0, then $t_{n+1} - t_n$ is equal to T.

If the n-th picture is a B-Picture with repeat_first_field equal to 1 and top_field_first equals 0, then $t_{n+1} - t_n$ is equal to 2*T.

If the n-th picture is a B-Picture with repeat_first_field equal to 1 and top_field_first equals 1, then $t_{n+1} - t_n$ is equal to 3*T.

If the n-th picture is a P-Picture or I-Picture and if the previous P-Picture or I-Picture has repeat_first_field equal to 0, then $t_{n+1} - t_n$ is equal to T.

If the n-th picture is a P-Picture or I-Picture and if the previous P-Picture or I-Picture has repeat_first_field equal to 1 and top_field_first equal to 0, then $t_{n+1} - t_n$ is equal to 2*T.

If the n-th picture is a P-Picture or I-Picture and if the previous P-Picture or I-Picture has repeat_first_field equal to 1 and top_field_first equal to 1, then $t_{n+1} - t_n$ is equal to 3*T.

C.10 This subclause defines the time intervals between successive examination of the VBV buffer in the case where progressive_sequence equals to 1 and low_delay equals to 1. In this case the sequence contains no B-Pictures and there is no frame re-ordering delay.

The time interval $t_{n+1} - t_n$ between two successive examinations of the VBV buffer is a multiple of T, where T is the inverse of the frame rate.

If the n-th picture is a P-Picture or I-Picture with repeat_first_field equal to 0, then $t_{n+1} - t_n$ is equal to T.

If the n-th picture is a P-Picture or I-Picture with repeat_first_field equal to 1 and top_field_first equal to 0, then $t_{n+1} - t_n$ is equal to 2*T.

If the n-th picture is a P-Picture or I-Picture with repeat_first_field equal to 1 and top_field_first equal to 1, then $t_{n+1} - t_n$ is equal to 3*T.

C.11 This subclause defines the time intervals between successive examination of the VBV buffer in the case where progressive_sequence equals to 0 and low_delay equals to 0. In this case, the frame re-ordering delay always exists and B-pictures can occur.

The time interval $t_{n+1} - t_n$ between two successive examinations of the VBV input buffer is a multiple of T, where T is the inverse of two times the frame rate.

If the n-th picture is a *frame-structure* coded B-frame with repeat_first_field equal to 0, then $t_{n+1} - t_n$ is equal to 2*T.

If the n-th picture is a *frame-structure* coded B-frame with repeat_first_field equal to 1, then $t_{n+1} - t_n$ is equal to 3*T.

If the n-th picture is a *field-structure* B-picture (B-field picture), then $t_{n+1} - t_n$ is equal to T.

If the n-th picture is a *frame-structure* coded P-frame or coded I-Frame and if the previous coded P-Frame or coded I-Frame has repeat_first_field equal to 0, then $t_{n+1} - t_n$ is equal to 2*T.

If the n-th picture is a *frame-structure* coded P-Frame or coded I-Frame and if the previous coded P-Frame or coded I-Frame has repeat_first_field equal to 1, then $t_{n+1} - t_n$ is equal to 3*T.

If the n-th picture is the *first* field of a *field-structure* coded P-frame or coded I-Frame, then $t_{n+1} - t_n$ is equal to T.

If the n-th picture is the *second* field of a *field-structure* coded P-Frame or coded I-Frame and if the previous coded P-Frame or coded I-Frame is using field-structure or has *repeat_first_field* equal to 0, then $t_{n+1} - t_n$ is equal to (2*T – T).

If the n-th picture is the *second* field of a *field-structure* coded P-Frame or coded I-Frame and if the previous coded P-Frame or coded I-Frame is using frame-structure and has *repeat_first_field* equal to 1, then $t_{n+1} - t_n$ is equal to (3*T – T).

Figure C.2 shows the VBV in a simple case with only frame-pictures. Frames P_0, B_2 and B_4 have a display duration of 3 fields.

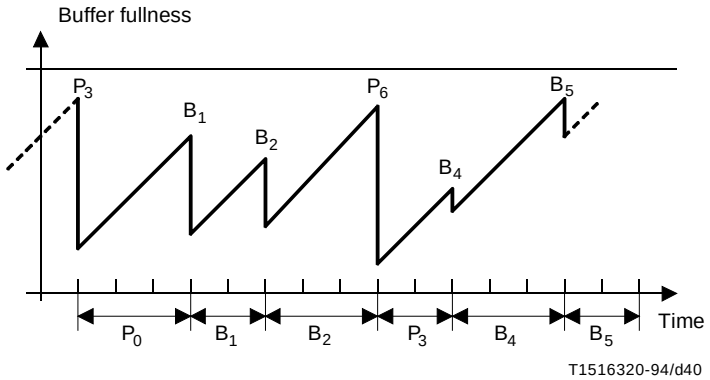


Figure C.2

C.12 This clause defines the time intervals between successive examination of the VBV buffer in the case where progressive_sequence equals to 0 and low_delay equals to 1. In this case the sequence contains no B-Pictures and there is no frame re-ordering delay.

The time interval $t_{n+1} - t_n$ between two successive examinations of the VBV input buffer is a multiple of T, where T is the inverse of two times the frame rate.

If the n-th picture is a *frame-structure* coded P-Frame or coded I-Frame with repeat_first_field equal to 0, then $t_{n+1} - t_n$ is equal to 2*T.

If the n-th picture is a *frame-structure* coded P-Frame or coded I-Frame with repeat_first_field equal to 1, then $t_{n+1} - t_n$ is equal to 3*T.

If the n-th picture is a *field-structure* coded P-Frame or coded I-Frame, then $t_{n+1} - t_n$ is equal to T.

Figure C.3 shows the VBV in a simple case with only frame-pictures. Frames I_0, P_2 and P_4 have repeat_first_field equal to 1.

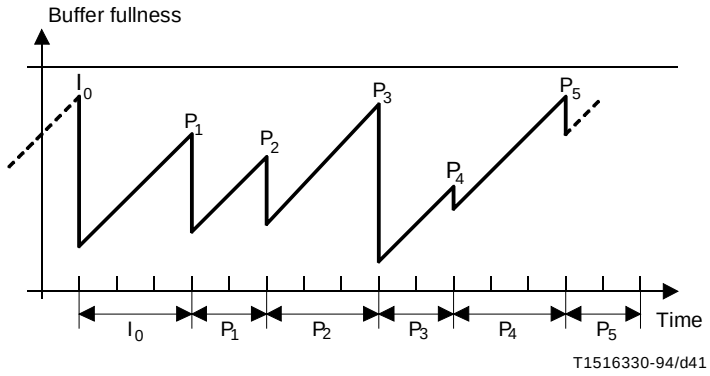


Figure C.3

Annex D

Features supported by the algorithm

(This annex does not form an integral part of this Recommendation | International Standard)

D.1 Overview

The following non-exhaustive list of features is included in this Specification:

1) Different chrominance sampling formats (i.e. 4:2:0, 4:2:2 and 4:4:4) can be represented.
2) Video in both the progressive and interlaced scan formats can be encoded.
3) The decoder can use 3:2 pull down to represent a ~24 fps film as ~30 fps video.
4) The displayed video can be selected by a movable pan-scan window within a larger raster.
5) A wide range of picture qualities can be used.
6) Both constant and variable bitrate channels are supported.
7) A low delay mode for face-to-face applications is available.
8) Random access (for DSM, channel acquisition, and channel hopping) is available.
9) ISO/IEC 11172-2 constrained parameter bitstreams are decodable.
10) Bitstreams for high and low (hardware) complexity decoders can be generated.
11) Editing of encoded video is supported.
12) Fast-forward and fast-reverse playback recorded bitstreams can be implemented.
13) The encoded bitstream is resilient to errors.

D.2 Video formats

D.2.1 Sampling formats and colour

This Specification video coding supports both interlaced and progressive video. The respective indication is provided with a progressive_sequence flag transmitted in the Sequence Extension code.

Allowed raster sizes are between 1 and (2^14 – 1) luminance samples each of the horizontal and vertical directions. The video is represented in a luminance/chrominance colour space with selectable colour primaries. The chrominance can be sampled in either the 4:2:0 (half as many samples in the horizontal and vertical directions), 4:2:2 (half as many samples in the horizontal direction only). Furthermore, application specific sample aspect ratios and image aspect ratios are flexibly supported. A chroma_format parameter is contained in the Sequence Extension code.

Sample aspect ratio information is provided by means of aspect_ratio_information and (optional) display_horizontal_size and display_vertical_size in the sequence_display_extension(). Examples of appropriate values for signals sampled in accordance with Recommendation ITU-R BT. 601 are given in Table D.1.

This Specification implements tools to support 4:4:4 chrominance, for possible future use. However, this is currently not supported in any profile.

Table D.1 – Example display size values

Signal Format	**display_horizontal_size**	**display_vertical_size**
525-line	711	483
625-line	702	575

D.2.2 Movie timing

A decoder can implement 3:2 pull down when a sequence of progressive pictures is encoded. Each encoded movie picture can independently specify whether it is displayed for two or three video field periods, so "irregular" 3:2 pull down source material can be transmitted as progressive video. Two flags, top_field_first and repeat_first_field, are transmitted with the Picture Coding Extensions and adequately describe the necessary display timing.

D.2.3 Display format control

The display process converts a sequence of digital frames (in the case of progressive video) or fields (in the case of interlaced video) to output video. It is not a normative part of this Recommendation | International Standard. The video syntax of this Specification does communicate certain display parameters for use in reconstructing the video. Optional information (in the sequence display extension) specifies the chromaticities, the display primaries, the opto-electronic transfer characteristics (e.g. the value of gamma) and the RGB-to-luminance/chrominance conversion matrix.

Moreover, a display window within the encoded raster may be defined as, e.g. in the case of pan and scan. Alternatively the encoded raster may be defined as a window on a large area display device. In the case of pan-scan the position of the window representing the displayed region of a larger picture can be specified on a field-by-field basis. It is specified in the Picture display extension described in 6.3.12. A typical use for the pan-scan window is to describe the "important" 4:3 aspect ratio rectangle within a 16:9 video sequence. Similarly, in the case of small encoded pictures on a large display, the size of the display and the position of the window within that display may be specified.

D.2.4 Transparent coding of composite video

Decoding from PAL/NTSC before transmission and re-coding to PAL/NTSC after transmission of composite source signals in non-low quality applications, such as contribution and distribution, requires a precise reconstruction of the carrier amplitude and phase reference signal (and v-axis switch for PAL).

The input format can be indicated in the sequence header using the video_format bits. Possible source formats are: PAL, NTSC, SECAM and MAC. Reconstruction of the carrier signal is possible by using the carrier parameters: v_axis, field_sequence, sub_carrier, burst_amplitude and sub_carrier_phase that are enabled by setting the composite_display_flag in the picture_coding_extension().

D.3 Picture quality

High picture quality is provided according to the bitrate used. Provision for very high picture quality is made by sufficiently high bitrate limits relating to a certain level in a particular profile. High chrominance band quality can be achieved by using 4:2:2 chrominance

Quantiser matrices can be downloaded and used with a small a quantiser_scale_code to achieve near lossless coding.

Moreover, scalable coding with flexible bitrate allows for service or quality hierarchy and graceful degradation. E.g. decoding a subset of the bitstream carrying a lower resolution picture allows for decoding this signal in a low-cost receiver with related quality; decoding the complete bitstream allows to obtain the high overall quality.

Furthermore, operation at low bitrates can be accommodated by using low frame rates (by either pre-processing before coding or frame skipping indicated by the temporal_reference in the picture header) and low spatial resolution.

D.4 Data rate control

The number of transmitted bits per unit time, which is selectable in a wide range, may be controlled in two ways, which are both supported by this Specification. A bit_rate description is transmitted with the Sequence Header Code.

For Constant Bitrate (CBR) coding, the number of transmitted bits per unit time is constant on the channel. Since the encoder output rate generally varies depending on the picture content, it shall regulate the rate constant by buffering, etc. In CBR, picture quality may vary depending on its content.

The other mode is the Variable Bitrate (VBR) coding, in which case the number of transmitted bits per unit time may vary on the channel under some constriction. VBR is meant to provide constant quality coding. A model for VBR application is near-constant-quality coding over B-ISDN channels subject to Usage Parameter Control (UPC).

D.5 Low delay mode

A low encoding and decoding delay mode is accommodated for real-time video communications such as visual telephony, video-conferencing, monitoring. Total encoding and decoding delay of less than 150 milliseconds can be achieved for low delay mode operation of this Specification. Setting the low_delay flag in the Sequence Header code defines a low delay bitstream.

The total encoding and decoding delay can be kept low by generating a bitstream which does not contain B-pictures. This prevents frame re-ordering delay. By using dual-prime prediction for coded P-frames, the picture quality can still be high.

A low buffer occupancy for both encoder and decoder is needed for low delay. Large coded pictures should be avoided by the encoder. By using intra update on the basis of one or more slices per frame (intra slices) instead of intra frames this can be accommodated.

In case of exceeding, for low delay operation, the desired number of bits per frame the encoder can skip one or more frames. This action is indicated by a discontinuity in the value of temporal_reference for the next picture (see the semantic definition in 6.3.9) and may cause C.7 of the VBV to apply, i.e. the decoder buffer would underflow if some frames are not repeated by the decoder.

D.6 Random access/channel hopping

The syntax of this Specification supports random access and channel hopping. Sufficient random access/channel hopping functionality is possible by encoding suitable random access points into the bitstream without significant loss of image quality.

Random access is an essential feature for video on a storage medium. It requires that any picture can be accessed and decoded in a limited amount of time. It implies the existence of access points in the bitstream – that is segments of information that are identifiable and can be decoded without reference to other segments of data. In this Specification access points are provided by sequence_header() and this is then followed by intra information (picture data that can be decoded without access to previously decoded pictures). A spacing of two random access points per second can be achieved without significant loss of picture quality.

Channel hopping is the similar situation in transmission applications such as broadcasting. As soon as a new channel has been selected and the bitstream of the selected channel is available to the decoder, the next data entry, i.e. random access point has to be found to start decoding the new program in the manner outlined in the previous paragraph.

D.7 Scalability

The syntax of this Specification supports bitstream scalability. To accommodate the diverse functionality requirements of the applications envisaged by this Specification, a number of bitstream scalability tools have been developed:

- **SNR scalability** mainly targets for applications which require graceful degradation.
- **Chroma simulcast** targets at applications with high chrominance quality requirements.
- **Data partitioning** is primarily targeted for cell loss resilience in ATM networks.
- **Temporal scalability** is a method suitable for interworking of services using high temporal resolution progressive video formats. Also suitable for high quality graceful degradation in the presence of channel errors.
- **Spatial scalability** allows multiresolution coding technique suitable for video service interworking applications. This tool can also provide coding modes to achieve compatibility with existing coding standards, i.e. ISO/IEC 11172-2, at the lower layer.

D.7.1 Use of SNR scalability at a single spatial resolution

The aim of SNR scalability is primarily to provide a mechanism for transmission of a two layer service, these two layers providing the same picture resolution but different quality level. For example, the transmission of service with two different quality levels is expected to become useful in the future for some TV broadcast applications, especially when very good picture quality is needed for large size display receivers. The sequence is encoded into two bitstreams called lower and enhancement layer bitstreams. The lower layer bitstream can be decoded independently from the enhancement layer bitstream. The lower layer, at 3 to 4 Mbit/s, would provide a picture quality equivalent to the current NTSC/PAL/SECAM quality. Then, by using both the lower and the enhancement layer bitstreams, an enhanced decoder can deliver a picture quality subjectively close to the studio quality, with a total bitrate of 7 to 12 Mbit/s.

D.7.1.1 Additional features

D.7.1.1.1 Error resilience

As described in D.13, the SNR scalable scheme can be used as a mechanism for error resilience. If the two layer bitstreams are received with different error rate, the lower layer, better protected, stands as a good substitute to fall back on, if the enhancement layer is damaged.

D.7.1.1.2 Chroma simulcast

The SNR scalable syntax can be used in a chroma simulcast system. The goal of such a scheme would be to provide a mechanism for simultaneous distribution of services with the same luminance resolution but different chrominance sampling format (e.g. 4:2:0 in the lower layer and 4:2:2, when adding the enhancement layer and the simulcast chrominance components) for applications which would require such a feature. The SNR scalable enhancement layer contains some luminance refinement. The 4:2:2 chrominance is sent in simulcast. Only chrominance DC is predicted from the lower layer. The combination of both layer luminance and of the 4:2:2 chrominance constitutes the high quality level.

D.7.1.2 SNR scalable encoding process

D.7.1.2.1 Description

In the lower layer, the encoding is similar to the non scalable situation in terms of decisions, adaptive quantisation, buffer regulation. The intra or error prediction macroblocks are DCT transformed. The coefficients are then quantised using a first rather coarse quantiser. The quantised coefficients are then VLC coded and sent together with the required side information (macroblock_type, motion vectors, coded_block_pattern()).

In parallel, the quantised DCT coefficients coming from the lower layer, are dequantised. The residual error between the coefficients and the dequantised coefficients is then re-quantised, using a second finer quantiser. The resulting refinement coefficients are VLC coded and form the additional enhancement layer, together with a marginal amount of side information (quantiser_scale_code, coded_block_pattern() …). The non-intra VLC table is used for all the coefficients in the enhancement layer, since it is of differential nature.

D.7.1.2.2 A few important remarks

Since the prediction is the same for both layers, it is recommended to use the refined images in the motion estimation loop (e.g. the images obtained by the conjunction of the lower and the enhancement layer). Thus, there is a drift between the prediction used at the encoder side and what the low level decoder can get as a prediction. This drift does accumulate from P-picture to P-picture and is reset to zero at each I-Picture. However, the drift has been found to have little visual effect when there is an I- picture every 15 pictures or so.

Since the enhancement layer only contains refinement coefficients, the needed overhead is quite reduced: most of the information about the macroblocks (macroblock types, motion vectors …) are included in the lower layer. Therefore the syntax of this stream is very much simplified:

- the macroblock type table only indicates if the quantiser_scale_code in the enhancement layer has changed and if the macroblock is NOT-CODED (for first and last macroblock of the slices), which amounts to three VLC words.
- quantiser_scale_code in the enhancement layer is sent if the value has changed.
- coded_block_pattern() is transmitted for all coded macroblocks.

All NON-CODED macroblocks that are not at the beginning or end of a slice are skipped, since the overhead information can be deduced from the lower layer.

It is recommended to use different weighting matrices for the lower and the enhancement layer. Some better results are obtained when the first quantisation is steeper than the second one. However, it is recommended not to quantise too coarsely the DCT coefficient that corresponds to the interlace motion, to avoid juddering effects.

D.7.2 Multiple resolution scalability bitstreams using SNR scalability

The aim of resolution scalability is to decode the base layer video suitable for display at reduced spatial resolution. In addition, it is desirable to implement a decoder with reduced complexity for this purpose. This functionality is useful for applications where the receiver display is either not capable or willing to display the full spatial resolution supported by both layers and for applications where software decoding is targeted. The method described in this subclause uses the SNR Scalability syntax outlined in clause 7 to transmit the video in two layers. Note that none of the options suggested in this subclause changes the structure of the highest resolution decoder, which remains identical to the one outlined in Figure 7-14. The bitstream generated on both layers is compatible with the HIGH profile. However, the base layer decoder could be implemented differently with reduced implementation complexity suitable to software decoding.

D.7.2.1 Decoder implementation

In decoding to a smaller spatial resolution, an inverse DCT of reduced size could be used when decoding the base layer. The frame memory requirement in the decoder MC loop would also be reduced accordingly.

If the bitstream of the two SNR Scalability layers was generated with only one MC loop at the encoder the base video will be subject to drift. This drift may or may not be acceptable depending on the application. Image quality will, to a large extent, depend on the sub-sample accuracy used for motion compensation in the decoder. It is possible to use the full precision motion vector as transmitted in the base layer for motion compensation with a sub-sample accuracy comparable to that of the higher layer. Drift can be minimised by using advanced sub-sample interpolation filters (see [12], [13] and [16] in the Bibliography of Annex F).

D.7.2.2 Encoder implementation

It is possible to tailor the base layer SNR Scalability bitstream to the particular requirements of the resolution scaled decoder. A smaller DCT size can be more easily supported by only transmitting the appropriate DCT-coefficients belonging to the appropriate subset in the base layer bitstream.

Finally it is possible to support a drift-free decoding at lower resolution scale by incorporating more than one MC loop in the encoder scheme. An identical reconstruction process is used in the encoder and decoder.

D.7.3 Bitrate allocation in data partitioning

Data partitioning allows splitting a bitstream for increased error resilience when two channels with different error performance are available. It is often required to constrain the bitrate of each partition. This can be achieved at the encoder by adaptively changing priority breakpoint at each slice.

The encoder can use two virtual buffers for the two bitstreams, and implement feedback rate control by picking a priority breakpoint that approximately meets the target rate for each channel. Difference between target and actual rates is used to revise the target for the next frame in a feedback loop.

It is desirable to vary the bitrate split from frame to frame for higher error resilience. Typically, I-pictures benefit from having more of the data in partition 0 than the P-pictures while B-pictures could be placed entirely in partition 1.

D.7.4 Temporal scalability

A two layer temporally scalable coding structure consisting of a base and an enhancement layer is shown in Figure D.1. Consider video input at full temporal rate to temporal demultiplexer; in our example it is temporally demultiplexed to form two video sequences, one input to the base layer encoder and the other input to the enhancement layer encoder. The base layer encoder is a non-hierarchical encoder operating at half temporal rate, the enhancement layer encoder is like a MAIN profile encoder and also operates at half temporal rate except that it uses base layer decoded pictures for motion compensated prediction. The encoded bitstreams of base and enhancement layers are multiplexed as a single stream in the systems multiplexer. The systems demultiplexer extracts two bitstreams and inputs corresponding bitstreams to base and enhancement layer decoders. The output of the base layer decoder can be shown standalone at half temporal rate or after multiplexing with enhancement layer decoded frames and shown at full temporal rate.

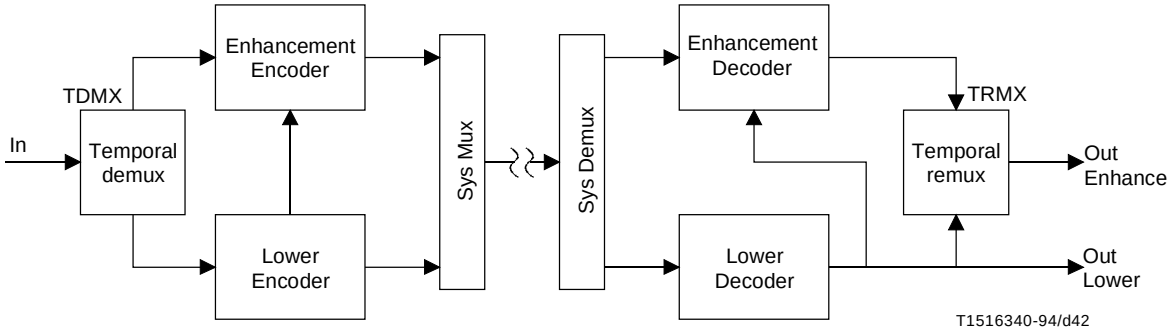


Figure D.1 – A two-layer codec structure for temporal scalability

The following forms of temporal scalability are supported and are expressed as higher layer: base layer-to-enhancement layer picture formats.

1) Progressive: progressive-to-progressive Temporal Scalability.
2) Progressive: interlace-to-interlace Temporal Scalability.
3) Interlace: interlace-to-interlace Temporal Scalability.

D.7.4.1 Progressive – Progressive-to-progressive temporal scalability

Assuming progressive video input, if it is necessary to code progressive- format video in base and enhancement layers, the operation of *temporal demux* may be relatively simple and involve temporal demultiplexing of input frames into two progressive sequences. The operation of *temporal remux* is inverse, i.e. it performs re-multiplexing of two progressive sequences to generate full temporal rate progressive output (see Figure D.2).

D.7.4.2 Progressive – Interlace-to-interlace temporal scalability

Again, assuming full temporal rate progressive video input, if it is necessary to code interlaced format video in base layer, the operation of *temporal demux* may involve progressive to two interlace conversion; this process involves extraction of a normal interlaced- and a complementary interlaced sequence from progressive input video. The operation of *temporal remux* is inverse, i.e. it performs two interlace to progressive conversion to generate full temporal rate progressive output. Figures D.3 and D.4 show operations required in progressive to two interlace and two interlace to progressive conversion.

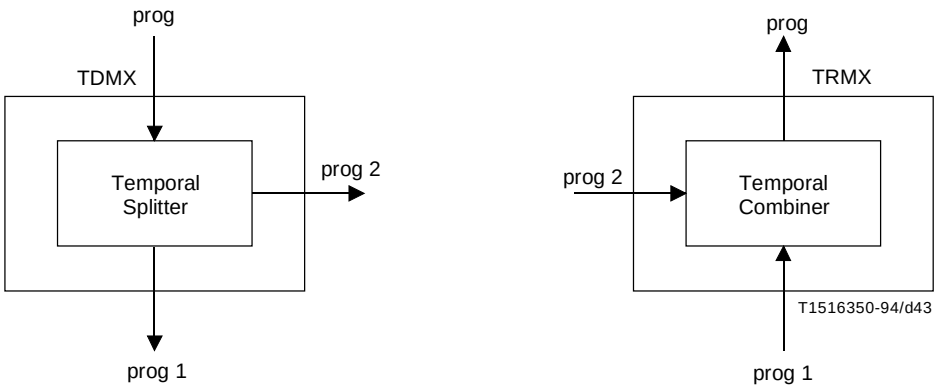


Figure D.2 – Temporal demultiplexer and remultiplexer for progressive – Progressive-to-progressive temporal scalability

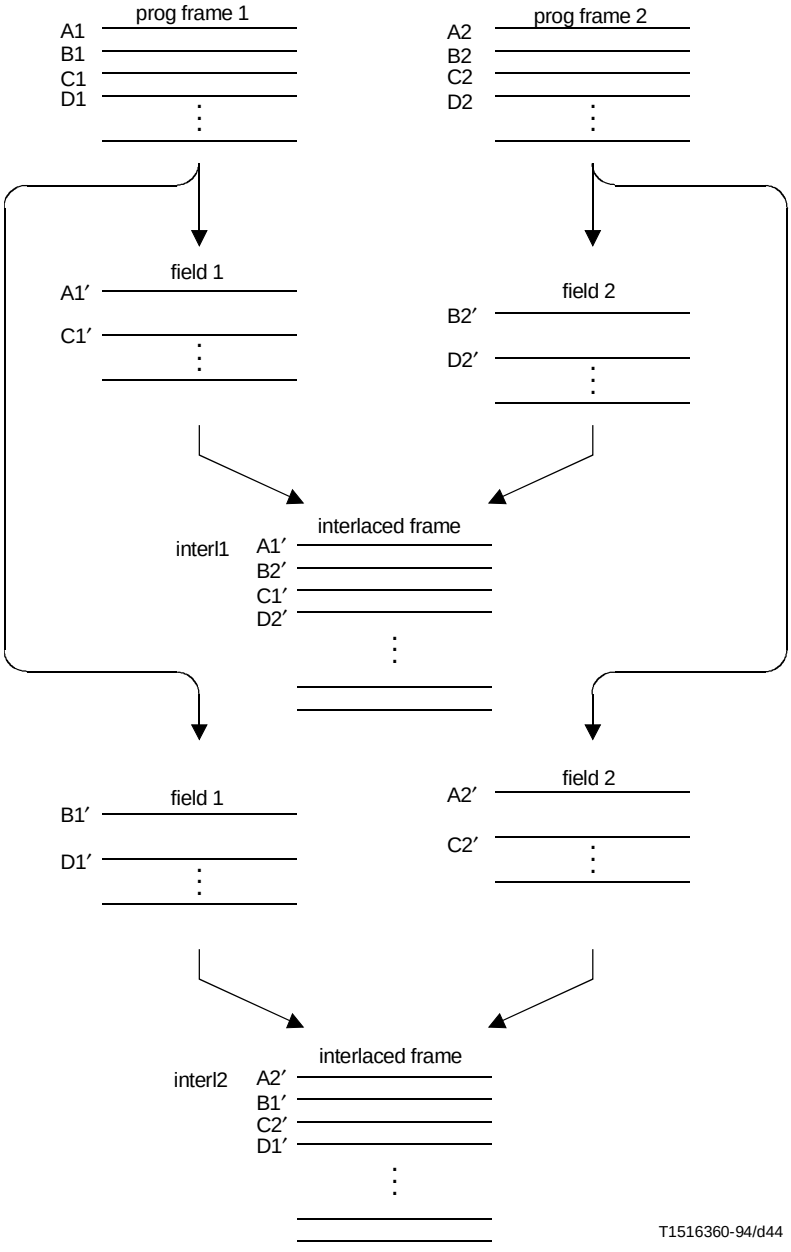


Figure D.3 – Progressive to two-interlace conversion

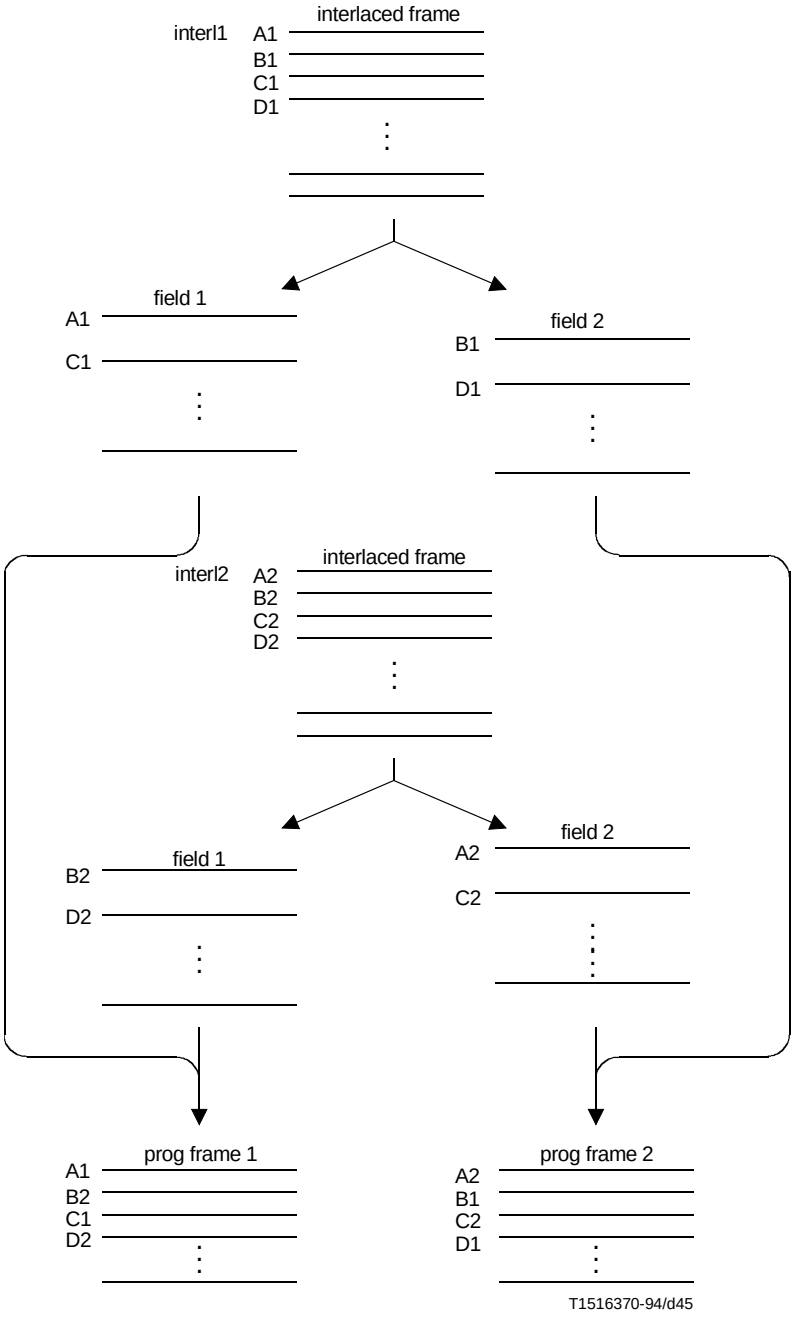


Figure D.4 – Two-interlace to progressive conversion

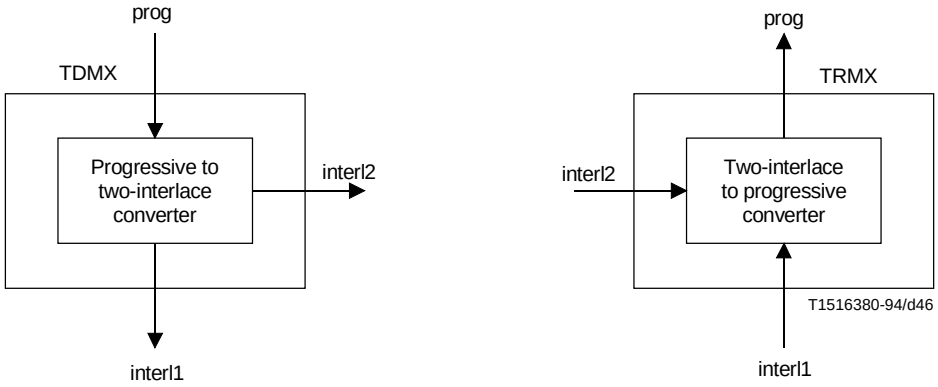


Figure D.5 – Temporal demultiplexer and remultiplexer for progressive – Interface-to-interface temporal scalability

D.7.4.3 Interlace – Interlace-to-interlace temporal scalability

Assuming interlaced video input, if it is necessary to code interlaced- format video in base and enhancement layers, the operation of *temporal demux* may be relatively simple and involve temporal demultiplexing of input frames into two interlaced sequences. The operation of *temporal remux* is inverse, i.e. it performs re-multiplexing of two interlaced sequences to generate full temporal rate interlaced output. The demultiplexing and re-multiplexing is similar to that in Figure D.2.

D.7.5 Hybrids of the spatial, the SNR and the temporal scalable extensions

This Recommendation | International Standard also allows combinations of scalability tools to produce more than 2 video layers as may be useful and practical to support more demanding applications. Taken two at a time, 3 explicit combinations result. Moreover, within each combination, the order in which each scalability is applied, when interchanged, results in distinct applications. In the hybrid scalabilities involving three layers, the layers are referred to as base layer, enhancement layer 1 and enhancement layer 2.

D.7.5.1 Spatial and SNR hybrid scalability applications

a) *HDTV with standard TV at two qualities:*

Base layer provides standard TV resolution at basic quality, enhancement layer 1 helps generate standard TV resolution but at higher quality by SNR scalability and the enhancement layer 2 employs HDTV resolution and format which is coded with spatial scalability with respect to high quality standard TV resolution generated by using enhancement layer 1.

b) *Standard TV at two qualities and low definition TV/videophone:*

Base layer provides videophone/low definition quality, using spatial scalability enhancement layer 1 provides standard TV resolution at a basic quality and enhancement layer 2 uses SNR scalability to help generate high quality standard TV.

c) *HDTV at two qualities and standard TV:*

Base layer provides standard TV resolution, using spatial scalability enhancement layer 1 provides basic quality HDTV and enhancement layer 2 uses SNR scalability to help generate high quality HDTV.

D.7.5.2 Spatial and temporal hybrid scalability applications

a) *High temporal resolution progressive HDTV with basic interlaced HDTV and standard TV:*

Base layer provides standard TV resolution, using spatial scalability enhancement layer 1 provides basic HDTV of interlaced format and enhancement layer 2 uses temporal scalability to help generate full temporal resolution progressive HDTV.

b) *High resolution progressive HDTV with enhanced progressive HDTV and basic progressive HDTV:*

Base layer provides basic progressive HDTV format at temporal resolution, using temporal scalability enhancement layer 1 helps generate progressive HDTV at full temporal resolution and enhancement layer 2 uses spatial scalability to provide high spatial resolution progressive HDTV (at full temporal resolution).

c) *High resolution progressive HDTV with enhanced progressive HDTV and basic interlaced HDTV:*

Base layer provides basic interlaced HDTV format, using temporal scalability enhancement layer 1 helps generate progressive HDTV at full temporal resolution and enhancement layer 2 uses spatial scalability to provide high spatial resolution progressive HDTV (at full temporal resolution).

D.7.5.3 Temporal and SNR hybrid scalability applications

a) *Enhanced progressive HDTV with basic progressive HDTV at two qualities:*

Base layer provides basic progressive HDTV at lower temporal rate, using temporal scalability enhancement layer 1 helps generate progressive HDTV at full temporal rate but with basic quality and enhancement layer 2 uses SNR scalability to help generate progressive HDTV with high quality (at full temporal resolution).

b) *Enhanced progressive HDTV with basic interlaced HDTV at two qualities:*

Base layer provides interlaced HDTV of basic quality, using SNR scalability enhancement layer 1 helps generate interlaced HDTV at high quality and enhancement layer 2 uses temporal scalability to help generate progressive HDTV at full temporal resolution (at high quality).

D.8 Compatibility

This Recommendation | International Standard supports compatibility between different resolution formats as well as compatibility with ISO/IEC 11172-2 (and Recommendation H.261).

D.8.1 Compatibility with higher and lower resolution formats

This Specification supports compatibility between different resolution video formats. Compatibility is provided for spatial and temporal resolutions with the Spatial Scalability and Temporal Scalability tools. The video is encoded into two resolution layers. A decoder only capable or willing to display a lower resolution video accepts and decodes the lower layer bitstream. The full resolution video can be reconstructed by accepting and decoding both resolution layers provided.

D.8.2 Compatibility with ISO/IEC 11172-2 (and Recommendation H.261)

The syntax of this Specification supports both backward and forward compatibility with ISO/IEC 11172-2. Forward compatibility with ISO/IEC 11172-2 is provided since the syntax of this Specification is a superset of the ISO/IEC 11172-2 syntax. The Spatial Scalability tool provided by this Specification allows using ISO/IEC 11172-2 coding in the lower resolution, i.e. base layer, thus achieving backward compatibility.

The video syntax contains tools that are needed to implement H.261 compatibility that may be needed for possible future use, however, this is currently not supported by any profile.

Simulcast serves as a simple alternative method to provide backward compatibility with both Recommendation H.261 and ISO/IEC 11172-2.

D.9 Differences between this Specification and ISO/IEC 11172-2

This subclause lists the differences between MPEG-1 Video and MPEG-2 Video.

All MPEG-2 Video decoders that comply with currently defined profiles and levels are required to decode MPEG-1 constrained bitstreams.

In most instances, MPEG-2 represents a super-set of MPEG-1. For example, the MPEG-1 coefficient zigzag scanning order is one of the two coefficient scanning modes of MPEG-2. However, in some cases, there are syntax elements (or semantics) of MPEG-1 that does not have a direct equivalent in MPEG-2. This Specification lists all those elements.

This Specification may help implementers identify those elements of the MPEG-1 video syntax (or semantics) that do not have their direct equivalent in MPEG-2, and therefore require a special care in order to have guarantee MPEG-1 compatibility.

In this subclause, MPEG-1 refers to ISO/IEC 11172-2 whilst MPEG-2 refers to this Specification.

D.9.1 IDCT mismatch

MPEG-1 – The IDCT mismatch control consists in adding (or removing) one to each non-zero coefficient that would have been even after inverse quantisation. This is described as part of the inverse quantisation process, in 2.4.4.1, 2.4.4.2 and 2.4.4.3 of ISO/IEC 11172-2 (MPEG-1).

MPEG-2 – The IDCT mismatch control consists in adding (or removing) one to coefficient [7] [7] if the sum of all coefficients is even after inverse quantisation. This is described in 7.4.4 of MPEG-2.

D.9.2 Macroblock stuffing

MPEG-1 – The VLC code '0000 0001 111' (macroblock_stuffing) can be inserted any number of times before each macroblock_address_increment. This code must be discarded by the decoder. This is described in 2.4.2.7 of MPEG-1.

MPEG-2 – This VLC code is reserved and not used in MPEG-2. In MPEG-2, stuffing can be generated only by inserting zero bytes before a start-code. This is described in 5.2.3 of MPEG-2.

D.9.3 Run-level escape syntax

MPEG-1 – Run-level values that cannot be coded with a VLC are coded by the escape code '0000 01' followed by either a 14-bit FLC (–127 <= level <= 127), or a 22-bit FLC (–255 <= level <= 255). This is described in Annex B, 2-B5 of MPEG-1.

MPEG-2 – Run-level values that cannot be coded with a VLC are coded by the escape code '0000 01' followed by a 18-bit FLC (–2047 <= level <= 2047). This is described in 7.2.2.3 of MPEG-2.

D.9.4 Chrominance samples horizontal position

MPEG-1 – The horizontal position of chrominance samples is half the way between luminance samples. This is described in 2.4.1 of MPEG-1.

MPEG-2 – The horizontal position of chrominance samples is co-located with luminance samples. This is described in 6.1.1.8 of MPEG-2.

D.9.5 Slices

MPEG-1 – Slices do not have to start and end on the same horizontal row of macroblocks. Consequently it is possible to have all the macroblocks of a picture in a single slice. This is described in 2.4.1 of MPEG-1.

MPEG-2 – Slices always start and end on the same horizontal row of macroblocks. This is described in 6.1.2 of MPEG-2.

D.9.6 D-Pictures

MPEG-1 – A special syntax is defined for D-pictures (picture_coding_type = 4). D-pictures are like I-pictures with only Intra-DC coefficients, no End of Block, and a special end_of_macroblock code '1'.

MPEG-2 – D-pictures (picture_coding_type = 4) are not permitted. This is described in 6.3.9 of MPEG-2.

D.9.7 Full-pel motion vectors

MPEG-1 – The syntax elements full_pel_forward_vector and full_pel_backward_vector can be set to '1'. When this is the case, the motion vectors that are coded are in integer-sample units instead of half-sample units. Motion vector coordinates must be multiplied by two before being used for the prediction. This is described in 2.4.4.2 and 2.4.4.3 of MPEG-1.

MPEG-2 – The syntax elements full_pel_forward_vector and full_pel_backward_vector must be equal to '0'. Motion vectors are always coded in half-sample units.

D.9.8 Aspect ratio information

MPEG-1 – The 4-bit pel_aspect_ratio value coded in the sequence header specifies the sample aspect ratio. This is described in 2.4.3.2 of MPEG-1.

MPEG-2 – The 4-bit aspect_ratio_information value coded in the sequence header specifies the display aspect ratio. The sample aspect ratio is derived from this and from the frame size and display size. This is described in 6.3.3 of MPEG-2.

D.9.9 forward_f_code and backward_f_code

MPEG-1 – The f_code values used for decoding the motion vectors are forward_f_code and backward_f_code, located in the picture_header().

MPEG-2 – The f_code values used for decoding the motion vectors are f_code[s][t], located in the picture_coding_extension(). The values of forward_f_code and backward_f_code must be '111' and are ignored. This is described in 6.3.9 of MPEG-2.

D.9.10 constrained_parameter_flag and maximum horizontal_size

MPEG-1 – When the constrained_parameter_flag is set to '1', this indicates that a certain number of constraints are verified. One of those constraints is that horizontal_size <= 768. It should be noted that a constrained MPEG-1 video bitstream can have pictures with an horizontal size of up to 768 luminance samples. This is described in 2.4.3.2 of MPEG-1.

MPEG-2 – The constrained_parameter_flag mechanism has been replaced by the profile and level mechanism. However, it should be noted that MP @ ML bitstreams cannot have horizontal size larger than 720 luminance samples. This is described in 8.2.3.1 of MPEG-2.

D.9.11 Bit_rate and vbv_delay

MPEG-1 – Bit_rate and vbv_delay are set to 3FFFF and FFFF (hex) respectively to indicate variable bitrate. Other values are for constant bitrate.

MPEG-2 – The semantics for bit_rate are changed. In variable bitrate operation, vbv_delay may be set to FFFF (hex), but a different value does not necessarily mean that the bitrate is constant. Constant bitrate operation is simply a special case of variable bitrate operation. There is no way to tell that a bitstream is constant bitrate without examining all of the vbv_delay values and making complicated computations.

Even if the bitrate is constant the value of bit_rate may not be the actual bitrate since bit_rate need only be an upper bound to the actual bitrate.

D.9.12 VBV

MPEG-1 – VBV is only defined for constant bitrate operation. The STD supersedes the VBV model for variable bitrate operation.

MPEG-2 – VBV is only defined for variable bitrate operation. Constant bitrate operation is viewed as a special case of variable bitrate operation.

D.9.13 temporal_reference

MPEG-1 – Temporal_reference is incremented by one modulo 1024 for each coded picture, and reset to zero at each group of pictures header.

MPEG-2 – If there are no big pictures, temporal_reference is incremented by one modulo 1024 for each coded picture, and reset to zero at each group of pictures header (as in MPEG-1). If there are big pictures (in low delay bitstreams), then temporal_reference follows different rules.

D.9.14 MPEG-2 syntax versus MPEG-1 syntax

It is possible to make MPEG-2 bitstreams that have a syntax very close to MPEG-1, by using particular values for the various MPEG-2 syntax elements that do not exist in the MPEG-1 syntax.

In other words, the MPEG-1 decoding process is the same (except for the particular points mentioned earlier) as the MPEG-2 decoding process when :

progressive_sequence = '1' (progressive sequence)

chroma_format = '01' (4:2:0)

frame_rate_extension_n = 0 and frame_rate_extension_d = 0 (MPEG-1 frame-rate)

intra_dc_precision = '00' (8-bit Intra-DC precision)

picture_structure = '11' (frame-picture, because progressive_sequence = '1')

frame_pred_frame_dct = 1 (only frame-based prediction and frame DCT)

concealment_motion_vectors = '0' (no concealment motion vectors)

q_scale_type = '0' (linear quantiser_scale)

intra_vlc_format = '0' (MPEG-1 VLC table for Intra MBs)

alternate_scan = '0' (MPEG-1 zigzag scanning order)

repeat_first_field = '0' (because progressive_sequence = '1')

chroma_420_type = '1' (chrominance is "frame-based", because

progressive_sequence = '1')

progressive_frame = '1' (because progressive_sequence = '1')

D.10 Complexity

The MPEG-2 Standard supports combinations of high performance/high complexity and low performance/low complexity decoders. This is accommodated by MPEG-2 with the Profiles and Levels definitions which introduce new sets of tool and functionality with every new profile. It is thus possible to trade-off performance of the MPEG-2 coding schemes by decreasing implementation complexity.

Moreover, certain restrictions could allow reducing decoder implementation cost.

D.11 Editing encoded bitstreams

Many operations on the encoded bitstream are supported to avoid the expense and quality costs of re-coding. Editing, and concatenation of encoded bitstreams with no re-coding and no disruption of the decoded image sequence is possible.

There is a conflict between the requirement for high compression and easy editing. The coding structure and syntax have not been designed with the primary aim of simplifying editing at any picture. Nevertheless, a number of features have been included that enable editing of coded data.

Editing of encoded MPEG-2 bitstreams is supported due to the syntactic hierarchy of the encoded video bitstream. Unique start codes are encoded with different level in the hierarchy (i.e. video sequence, group of pictures, etc.). Video can be encoded with Intra-picture/intra-slices access points in the bitstream. This enables the identification, access and editing of parts of the bitstream without the necessity to decode the entire video.

D.12 Trick modes

Certain Digital Storage Media (DSM) provide the capability of trick modes, such as Fast Forward/Fast Reverse (FF/FR). The MPEG-2 syntax supports all special access, search and scan modes of ISO/IEC 11172-2. This functionality is supported with the syntactic hierarchy of the video bitstream which enables the identification of relevant parts within a video sequence. It can be assisted by MPEG-2 tools which provide bitstream scalability to limit the access bitrate (i.e. Data Partitioning and the general slice structure). This subclause provides some guideline for decoding a bitstream provided by a DSM.

The decoder is informed by means of a 1-bit flag (DSM_trick_mode_flag) in the PES packet header. This flag indicates that the bitstream is reconstructed by DSM in trick mode, and the bitstream is valid from syntax point of view, but invalid from semantics point of view. When this bit is set, an 8-bit field (DSM_trick_modes) follows. The semantics of DSM_trick_modes are in the ITU-T Rec. H.220.0 | ISO/IEC 13818-1.

D.12.1 Decoder

While the decoder is decoding PES Packet whose DSM_trick_mode_flag is set to 1, the decoder is recommended to:

– Decode bitstream and display according to DSM_trick_modes.

Pre-processing

When the decoder encounters PES Packet whose DSM_trick_mode_flag is set to 1, the decoder is recommended to:

– Clear non trick mode bitstream from buffer.

Post-processing

When the decoder encounters PES Packet whose DSM_trick_mode_flag is set to 0, the decoder is recommended to:

– Clear trick mode bitstream from buffer.

Video Part

While the decoder is decoding PES Packet whose DSM_trick_mode_flag is set to 1, the decoder is recommended to:

– Neglect vbv_delay and temporal_reference value.

– Decode one picture and display it until next picture is decoded.

The bitstream in trick mode may have a gap between slices. When the decoder encounters a gap between slices, the decoder is recommended to:

– Decode the slice and display it according to the slice vertical position in slice header.

– Fill up the gap with co-sited part of the last displayed picture.

D.12.2 Encoder

The encoder is recommended to:

- Encode with short size of slice with intra macroblocks.
- Encode with short periodic refreshment by intra picture or intra slice.

DSM

DSM is recommended to provide the bitstream in trick mode with perfect syntax.

Pre-processing

DSM is recommended to:

- Complete "normal" bitstream at picture_header() and higher syntactic structures.

System Part

DSM is recommended to:

- Set DSM_trick_mode_flag to 1 in a PES Packet header.
- Set DSM_trick_modes(8-bit) according to the trick mode.

Video Part

DSM is recommended to:

- Insert a sequence_header() with the same parameters as a normal bitstream.
- Insert a sequence_extension() with the same parameters as a normal bitstream.
- Insert a picture_header() with the same parameters as a normal bitstream except that it may be preferable to indicate variable bit rate operation. One way to achieve this is to set vbv_delay to FFFF (hex).

  NOTE – In most cases temporal_reference and vbv_delay are ignored in a decoder, therefore the DSM may not need to set temporal_reference and vbv_delay to correct values.
- Concatenate slices which consists of intra coded macroblocks. The concatenated slices should have slice vertical positions in increasing order.

D.13 Error resilience

Most digital storage media and communication channels are not error-free. Appropriate channel coding schemes should be used and are beyond the scope of this Specification. Nevertheless the MPEG-2 syntax supports error resilient modes relevant to cell loss in ATM networks and bit errors (isolated and in bursts) in transmissions. The slice structure of the compression scheme defined in this Specification allows a decoder to recover after a residual data error and to re-synchronise its decoding. Therefore, bit errors in the coded data will cause errors in the decoded pictures to be limited in area. Decoders may be able to use concealment strategies to disguise these errors. Error resilience includes graceful degradation in proportion to bit error rate (BER) and graceful recovery in the face of missing video bits or data packets. It has to be noted that all items may require additional support at the system level.

Being an example of a packet-based system, B-ISDN with its Asynchronous Transfer Mode (ATM) is addressed in some detail in the following. Similar statements can be made for other systems where certain packets of data are protected individually by means of forward error-correcting coding.

ATM uses short, fixed length packets, called cells, consisting of a 5 byte header containing routing information, and a user payload of 48 bytes. The nature of errors on ATM is such that some cells may be lost, and the user payload of some cells may contain bit errors. Depending on AAL (ATM Adaptation layer) functionality, indications of lost cells and cells containing bit errors may be available.

As an indication of the impact of cell loss in an ATM environment Table D.2 summarises the average interval between cell losses for a range of CLR and service bitrates based on simple statistical modelling. (A cell payload must be assumed for this. Allowing 1 byte/cell for AAL functions leaves 376 bits = 47 bytes). Note, however, that this summary ignores cell loss bursts and other shorter term temporal statistics.

Bit Error Ratios (BER) corresponding to the above mean times between errors can be calculated easily for the case of isolated bit errors. The BER that would cause the same incidence rate of errors is found by dividing by the cell payload size, i.e. BER = CLR/376.

Table D.2 – Average interval between cell losses for a range of CLR and service bitrates

	Average interval time of error			
	5 Mbit/s	10 Mbit/s	50 Mbit/s	100 Mbit/s
10^{-2}	7,52 ms	3,76 ms	0,752 ms	0,376 ms
10^{-3}	75,2 ms	37,6 ms	7,52 ms	3,76 ms
10^{-4}	752 ms	376 ms	75,2 ms	37,6 ms
10^{-5}	7,52 s	3,76 s	752 ms	376 ms
10^{-6}	1,25 m	37,6 s	7,52 s	3,76 s
10^{-7}	12,5 m	6,27 m	1,25 m	37,6 s
10^{-8}	2,09 h	1,04 h	12,5 m	6,27 m

The following techniques of minimising the impact of lost cells and other error/loss effects are provided for reference, and indicate example methods of using the various tools available in this Specification to provide good performance in the presence of those errors. Note that the techniques described may be applicable in the cases of packets of other sizes (e.g. LANs or certain storage media) or video data with uncorrected errors of different characteristics, in addition to cell loss. It may be appropriate to treat a known erasure [uncorrected bit error(s) known to exist somewhere in a data block] as a lost data block, since the impact of bit errors cannot be predicted. However, this should be a decoder option. The discussion that follows refers generally to "transport packets" where appropriate, to emphasise the applicability to a variety of transport and storage systems. However, specific examples will refer to Cell Loss Ratios (CLR) because cell transport is the most completely defined at the time of preparing this Specification.

The error resilience techniques are summarised in three categories, covering methods of concealing the error once it has occurred, and the restriction of the influence of a loss or error in both space (within a picture) and time (from picture to picture).

D.13.1 Concealment possibilities

Concealment techniques hide the effect of losses/errors once they have occurred. Some concealment methods can be implemented using any encoded bitstream, while others are reliant on the encoder to structure the data or provide additional information to enable enhanced performance.

D.13.1.1 Temporal predictive concealment

A decoder can provide concealment of the errors by estimating the lost data from spatio-temporally adjacent data. The decoder uses information which has been successfully received to make an informed estimate of what should be displayed in place of the lost/errored data, under the assumption that the picture characteristics are fairly similar across adjacent blocks (in both the spatial and temporal dimensions). In the temporal case, this means estimation of errored or lost data from nearby fields or frames.

D.13.1.1.1 Substitution from previous frame

The simplest possible approach is to replace a lost macroblock with the macroblock in the same location in the previous picture. This approach is suitable for relatively static picture areas but block displacement is noticeable for moving areas.

The "previous picture" must be interpreted with care due to the use of bi-directional prediction and a difference between picture coded order and picture display order. When a macroblock is lost in a P- or I-picture, it can be concealed by copying the data corresponding to the same macroblock in the previous P-picture or I-picture. This ensures that the picture is complete before it is used for further prediction. Lost macroblocks in B-pictures can be substituted from the last displayed picture, of any type, or from a future I- or P-picture held in memory but not yet displayed.

D.13.1.1.2 Motion compensated concealment

The concealment from neighbouring pictures can be improved by estimating the motion vectors for the lost macroblock, based on the motion vectors of neighbouring macroblocks in the affected picture (provided these are not also lost). This improves the concealment in moving picture areas, but there is an obvious problem with errors in macroblocks whose neighbouring macroblocks are coded intra, because there are ordinarily no motion vectors. Encoder assistance to get around this problem is discussed in D.13.1.1.3.

Sophisticated motion vector estimation might involve storage of adjacent macroblock motion vectors from above and below the lost macroblock, for predictions both forward and backward (for B-pictures) in time. The motion vectors from above and below (if available) could then be averaged.

Less complex decoders could use, for example, only forward prediction and/or only the motion vector from the macroblock above the lost macroblock. This would save on storage and interpolation.

D.13.1.1.3 Use of Intra MVs

The motion compensated concealment technique outlined in D.13.1.1.2 could not ordinarily be applied when the macroblocks above and below the lost/errored macroblock are Intra-coded, since there is no motion vector associated with Intra-coded macroblocks. In particular, in I-pictures, this type of concealment would not be possible with the normal calculation and use of motion vectors.

The encoding process can be extended to include motion vectors for intra macroblocks. Of course, the motion vector and coded information for a particular macroblock must be transmitted separately (e.g. in different packets) so that the motion vector is still available in the event that the image data is lost.

When "concealment_motion_vectors" = 1, motion vectors are transmitted with Intra macroblocks, allowing improved concealment performance of the decoders. The concealment motion vector associated with an Intra-coded macroblock is intended to be used only for concealment (if necessary) of the macroblock located immediately below the Intra-coded macroblock.

For simplicity, concealment motion vectors associated with Intra-coded macroblocks are always forward, and are considered as frame motion-vectors in Frame pictures and field motion-vectors in field pictures.

Therefore, encoders that choose to generate concealment motion vectors should transmit, for a given Intra-coded macroblock, the frame- or field-motion vector that should be used to conceal (i.e. to predict, with forward frame- or field-based prediction respectively) the macroblock located immediately below the Intra-coded macroblock.

Concealment motion vectors are intended primarily for I- and P-pictures, but the syntax allows their use in B-pictures. Concealment in B-pictures is not critical, since B-pictures are not used as predictors and so errors do not propagate to other pictures. Therefore, it may be wasteful to transmit concealment motion vectors in B-pictures.

Concealment motion vectors transmitted with Intra macroblocks located in the bottom row of a picture cannot be used for concealment. However, if "concealment_motion_vectors" = 1, those concealment motion vectors must be transmitted. Encoders can use the (0, 0) motion vector to minimise the coding overhead.

When concealment motion vectors are used, it is a good idea to have one slice contain one row of macroblocks (or smaller), so that concealment can be limited to less than one row of macroblocks when a slice, or part of a slice, is lost. This means that the loss of macroblocks in two successive rows is much less likely, and therefore the chances of achieving effective concealment using concealment motion vectors is improved.

NOTE – When "concealment_motion_vectors" = 1, Predictors for Motion Vectors (PMV) are NOT reset when an Intra macroblock is transmitted. Ordinarily, an Intra macroblock would reset the PMVs.

D.13.1.2 Spatial predictive concealment

The generation of predicted, concealment macroblocks is also possible by interpolation from neighbouring macroblocks within the one picture (see Annex F, Bibliography, reference [17]). This is best suited to areas of high motion, where temporal prediction is not successful, or as an alternative means of concealment for Intra macroblocks when concealment motion vectors (see D.13.1.1.3) are not available. It also could be particularly useful for cell loss after scene changes.

There are several possible approaches to spatial interpolation, and it could be carried out in the spatial or DCT domain, but normally it is only feasible and useful to predict the broad features of a lost macroblock, such as the DC coefficient and perhaps the lowest AC coefficients. Spatial prediction of fine detail (high frequencies) is likely to be unsuccessful and is of little value in fast-moving pictures anyway.

Spatial predictive macroblock concealment may also be useful in combination with layered coding methods (i.e. Data Partitioning or SNR scalability, see D.13.1.3). If in the event of cell loss some DCT coefficients in a macroblock are recovered from the lower layer, it is possible to use all information available (DCT coefficients recovered in the same macroblock from the lower layer and all DCT coefficients received in the adjacent macroblocks) for error concealment. This is especially useful if the lower layer only contains DC coefficients due to bandwidth constraints.

D.13.1.3 Layered coding to facilitate concealment

It is possible to assist the concealment process further by arranging the coded video information such that the most important information is most likely to be received. The loss of the less important information can then be more effectively concealed. This approach can gain from use of a transmission medium or storage device with different priority levels (such as priority-controlled cell-based transmission in the B-ISDN, or where different error protection or correction is provided on different channels). The components produced by the coding process can be placed in a hierarchy of importance according to the effect of loss on the reconstructed image. By indicating the priority of bitstream components and treating the individual components with due importance, superior error concealment performance may be possible.

Strategies available for producing hierarchically ordered bitstreams, or layers, include:

- **Data partitioning** – The coded macroblock data is partitioned into multiple layers such that partition zero contains address and control information and lower order DCT coefficients, while partition one contains high frequency DCT coefficients.
- **SNR scalability** – Two sets of coefficients are dequantised and then added together at the receiver before decoding. One set of coefficients could be a refinement of the quantisation error of the other, but other combinations (including an emulation of data partitioning) are possible.
- **Spatial scalability** – The lower layer may be coded without regard for the enhancement layer, and could use other standard coding methods (ISO/IEC 11172-2, etc.). The enhancement layer contains the coded prediction error from a prediction based on the lower layer.
- **Temporal scalability** – The enhancement layer defines additional pictures which, when re-multiplexed with the base layer, provides a combined picture sequence of greater picture rate.

These strategies produce layers which, when added progressively, produce increasing quality of the reconstructed sequence. While some of these source coding techniques may result in a bitrate increase compared to the system without layering, the performance of the layered systems, when subjected to channel errors, may be greater.

Considering error resilience alone, the hierarchically ordered layers should be handled with due quality, such that some function (such as picture quality for a given total bitrate) is optimised. The bitstream components may be treated differently at one or more of the following locations:

- *Encoder* – Different channel coding might be used.
- *Channel* – The channel may be able to provide different cell/packet loss probabilities or error characteristics to the different bitstream components.
- *Decoder* – Error concealment could be performed differently within each bitstream.

D.13.1.3.1 Use of data partitioning

Data partitioning allows a straightforward division of macroblock data into two layers. The Priority Break Point (PBP) pointer determines the contents of each layer. Ordinarily, data partition 0 contains the address and control information and the low frequency DCT coefficients, while data partition 1 contains the high frequency DCT coefficients.

At the encoder the value of the PBP pointer may be different for each slice such that the distribution of bits between the two layers may be controlled (e.g. maintained constant). The distribution may be different for I-, P-, and B-frames. The management of rate between the layers could mean that, for some macroblocks, data partition 0 contains no DCT coefficients or motion vectors.

Good tolerance to errors can be achieved if channel errors are distributed so that data partition 1 receives most errors.

It is assumed that errors can be detected at the decoder, so that actions can be taken to prevent errored data from being displayed. For data partition 1, errored data is simply not displayed (i.e. only data partition 0 is used). Losses or errors in data partition 0 should be minimised through use of high reliability transport. Decoder concealment actions may also be necessary.

D.13.1.3.2 Use of SNR scalable coding

SNR scalable coding provides two layers with the same spatial resolution but different image quality, depending on whether one or both layers are decoded. This technique is mainly intended to provide a lower-quality layer that is usable even when the enhancement layer is absent. However, it also provides good error resilience if the errors can be mainly confined to the enhancement layer.

In case of errors in the enhancement layer, the lower layer can be used alone for the affected image area. Especially in the case of frequent errors, temporary loss or permanent unavailability of the enhancement layer this concealment is very effective, since the displayed signal can be made relatively free of non-linear distortions like blocking or motion jerkiness.

If the enhancement layer is permanently unavailable and so only the lower layer is decoded, a small drift may occur in the case where only one MC prediction loop is implemented in the encoder. However, this drift is likely to be invisible in most configurations (e.g. M = 3, N = 12 would normally provide correction often enough).

The lower-layer of an SNR Scalable system is well suited to concealment in the case of a very high error rate, temporary or permanent loss of the enhancement-layer signal. However, the enhancement-layer quality in the error-free case does not achieve that of a sub-band like layered scheme (e.g. data partitioning).

D.13.1.3.3 Use of spatial scalable coding

Spatial scalable coding allows the lower layer to be coded without regard for the enhancement layer, and other standard coding methods (ISO/IEC 11172-2, etc.) could be used. The enhancement layer contains the coded prediction error from a prediction based on the lower layer. In case of errors in the enhancement layer, the upconverted lower layer can be used directly as concealment information for the affected image area. Especially in case of frequent errors or temporary loss of the enhancement layer, this concealment data is relatively free of non-linear distortions like blocking (which could arise if high frequency DCT coefficients are completely absent from the lower layer) or motion jerkiness (if the motion information is omitted from the high priority layer).

In the error-free case the upconverted lower layer is used as an additional source of predictions in a macroblock-adaptive way to improve the enhancement-layer coding performance. The enhancement layer bitstream therefore consists of the quantised temporal or lower layer prediction errors.

Spatial scalable coding provides a lower layer that is very suitable for concealment in case of a high error rate or temporary loss of the enhancement layer. However, the quality of the enhanced picture when both layers are available will not, in general, be as good as other layered coding approaches.

D.13.1.3.4 Use of temporal scalable coding

Temporal scalability is a coding technique that allows layering of video frames. The spatial resolution of frames in each layer is the same but the temporal rates of each layer are lower than that of the source; however the combined temporal rate of the two layers results in full temporal rate of the source. In case of errors in the enhancement layer, the base layer of full spatial resolution can be easily used for concealment. Especially in case of frequent errors or temporary loss of the enhancement layer, the base layer offers good concealment properties.

In some telecommunications applications a high degree of error resilience might be achieved with temporal scalability by encoding the base layer using the same spatial resolution but only half the temporal resolution of the source; the remaining frames corresponding to the other half of the temporal resolution are coded in the enhancement layer. Typically, the enhancement layer data may be assigned lower priority and when lost, the base layer decoded frames can be used for concealment by frame repetition. This type of concealment leads to only a temporary loss of full temporal resolution while maintaining full spatial quality and full spatial resolution.

In HDTV applications such as those using high temporal resolution progressive video format as source, high degree of error resilience can be achieved with temporal scalability. Such an application is envisaged to require 2 layers, a base layer and an enhancement layer, each of which process same picture formats (either both progressive or both interlaced) but at half the temporal rates. Temporal re-multiplexing of the base and enhancement layers irrespective of their chosen formats always results in full progressive temporal resolution of the source. In HDTV transmission, if the lower priority enhancement layer is corrupted, the base layer can be used for concealment, either directly, as in case of progressive format base layer or after reversal of parity of fields for interlaced format base layer.

Typically, the enhancement layer data may be assigned lower priority and when lost, the base layer decoded frames can be used for concealment by either frame repetition or frame averaging. This type of concealment leads to only a temporary indistinguishable loss in temporal resolution while maintaining full spatial quality and full spatial resolution.

D.13.2 Spatial localisation

Spatial localisation encompasses those methods aimed at minimising the extent to which errors propagate within a picture, by providing early resynchronisation of the elements in the bitstream that are coded differentially between macroblocks.

Isolated bit errors may be detected through invalid codewords and so a decoder designer may choose to allow an errored sequence to be decoded. However, the effect on the picture is difficult to predict (legal, but incorrect, codewords could be generated) and it may be preferable to control the error through concealment of the entire affected slice(s) even when only one bit is known to be in error somewhere in a block of data.

When long consecutive errors occur (e.g. packet or cell loss), virtually the only option is to discard data until the next resynchronisation point is located (a start code at the next slice or picture header). By providing more resynchronisation points, the area of the screen affected by a loss or error can be reduced, in turn reducing the demands on the concealment techniques and making the errors less visible at the expense of coding efficiency. Spatial localisation of errors is therefore dependent on controlling the slice size since this is the smallest coded unit with resynchronisation points (start codes).

D.13.2.1 Small slices

The most basic method for achieving spatial localisation of errors is to reduce the (fixed) number of macroblocks in a slice. The increased frequency of resynchronisation points will reduce the affected picture area in the event of a loss. It is effective in any transport or storage media, and in any profile since the slice structure is always present in MPEG coded video.

The method results in a small loss of coding efficiency due to the increase of overhead information. The loss is about 3% for 11 Macroblocks per slice and 12% for 4 Macroblocks per slice based on Recommendation ITU-R BT.601 picture format at 4 Mbit/s, (percentages calculated relative to a system using 44 Macroblocks, or one picture width, per slice). The efficiency loss results in degradation of picture quality up to about 1 dB with 4 Macroblocks per slice and 0,2 dB with 11 Macroblocks per slice without errors at 4 Mbit/s. However, the method performs approximately 1 to 5 dB better at CLR = 10^{-2}, depending on the concealment method used (simple macroblock replacement or motion compensated concealment).

From the view point of perceived picture quality, the performance of this method is generally dependent on the relative size of slice size and picture. Therefore, the slice size should be decided by considering the picture size (in macroblocks) and the trade-off between coding efficiency and visual degradation due to errors.

D.13.2.2 Adaptive slice size

There is a significant variation in the number of bits required to code a picture slice, depending on the coding mode, picture activity, etc. If slices contain only a few macroblocks, it will be possible that one transport packet, even a short packet or cell, could contain several slices. Offering multiple resynchronisation points in the same transport packet serves no purpose. Another problem with the simplistic short slice approach is that, because no account is taken of the transport packet structure, the first valid transport packet after a loss could contain most of the information for a slice, but it is unusable because the start code was lost.

An improvement over the small slice method may be to use adaptive slice sizes. As the encoder is producing the bitstream, it keeps track of the data contents within transport packets. The start of a slice is placed at the first opportunity in every transport packet (or in every second, third, …). This approach can achieve about the same spatial localisation of errors as small, fixed size slices, but with a greater efficiency.

However, this method ONLY gives an advantage for cell or packet based transmission, or where error detection occurs over a large block of data. The frequent resynchronisation points of small slice localisation are only wasteful if more than one is lost in the event of an error. If isolated bit errors affect just one slice anyway, then there is no advantage in adapting the slice size.

Furthermore, the adaptive slice size technique requires an intimate connection between encoder and packetiser, to allow a new slice for a new packet or cell. As such, it may not be appropriate for some applications (e.g. stored video intended to be distributed by multiple means) because only one transport packet structure would be assumed during encoding.

D.13.3 Temporal localisation

Temporal localisation encompasses those methods aimed at minimising the extent to which errors propagate from picture to picture in the temporal sequence, by providing early resynchronisation of pictures that are coded differentially. An obvious way to do this is to make use of intra mode coding.

D.13.3.1 Intra pictures

By use of intra pictures a single error will not stay in the decoded picture longer than (N + M –1) pictures if every Nth picture is coded intra and (M-1) B-pictures are displayed before each I-picture.

While the intra pictures, normally used as "anchors" for synchronising the video decoding part way through a sequence, are useful for temporal localisation, care should be taken in adding extra intra pictures (i.e. reducing N) for error resilience. Intra pictures require a large number of bits to code, take up a relatively large proportion of the encoded bitstream and, as a result, are more likely to be affected by losses or errors themselves.

D.13.3.2 Intra slices

To avoid the additional delay caused by intra pictures, some applications requiring low delay may want to update the picture by coding only parts of the picture intra. This may provide the same kind of error resilience as intra pictures. As an example assume that a constant number of slices per picture from top to bottom are intra coded so that the whole picture is updated every P-pictures. Three aspects of this kind of updating should be kept in mind:

- While an errored portion of the scene will ordinarily be erased within P-pictures (with an average duration of about P/2), it is possible that motion compensation will allow the disturbance to bypass the intra refresh and it may persist as long as 2P-pictures.

- To ensure that errors are not propagating into the updated region of the picture, restrictions could be put on motion vectors, limiting the vertical vector components to ensure that predictions are not made from the "oldest" parts of the picture.

- The visual effect of clearing errors can be similar to a windscreen wiper clearing water. This *windscreen wiper* effect can become noticeable in some cases in the error free sequence, unless the rate control mechanism ensures that the quality of the intra slice is close to that of the surrounding non-intra macroblocks.

D.13.4 Summary

Table D.3 summarises the above error resilience techniques, with a guide to their applicability.

Table D.3 – Summary of error concealment techniques

Category	Technique	Profile/Applicability
Concealment	Temporal predictive– Substitution from previous picture	Any profile. Most suited to static pictures.
	Temporal predictive – Motion compensated	Any profile. Choice of sophistication in motion vector estimation.
	Temporal predictive – Using concealment MVs	Any profile, but calculation of Intra MVs is an encoder option.
	Spatial predictive	Any profile. Not suitable for static, complex pictures.
	Data Partitioning	Not currently used in a profile, but may be added as post/pre-processing. Minimal overhead and complexity. Depending on bitrate allocation, lower layer may not provide usable pictures by itself.
	SNR Scalability	SNR SCALABLE, SPATIALLY SCALABLE, HIGH profiles. Suitable for very high error rates or temporary unavailability of the enhancement layer. Relatively simple to implement.
	Spatial Scalability	SPATIALLY SCALABLE and HIGH profiles. Suitable for very high error rates or temporary unavailability of the enhancement layer.
	Temporal Scalability	Not currently used in a profile. Suitable for very high error rates or temporary unavailability of the enhancement layer.
Spatial Localisation	Small Slices	Any profile
	Adaptive slice sizes	Any profile, but requires knowledge of transmission characteristics when packet size is decided.
Temporal Localisation	Intra pictures	Any profile, but has delay implications.
	Intra slices	Any profile, but errors may persist longer than for Intra picture method.

It is not possible to provide a concise indication of error resilience performance, because assessments must necessarily be subjective and application dependent, and so should be taken as nothing more than a guide. It is also true that several different approaches to error resilience are likely to be used in combination. However, the following descriptions are provided as some guidance to performance. They are the results of cell loss experiments, looking only at cell-based transmission of video information.

A simple macroblock substitution from a previous frame combined with the small-slice method (4 macroblocks per slice) will provide adequate picture quality for most sequences in the presence of rather low error rates of around CLR = 10^{-5} (in a reference 4 Mbit/s, Main Profile, Main Level system).

Including sophisticated motion compensated concealment (with full spatial and temporal interpolation of motion vectors for lost macroblocks, and concealing losses in P-pictures that use intra slice updating, i.e. N = infinity, M = 1) provides adequate picture quality at CLR = 10^{-3} (again, in a reference 4 Mbit/s, Main Profile, Main Level system).

Operation in environments with greater loss may require use of one of the layered coding methods. With adequate protection of the high priority information, these schemes can provide adequate performance in the face of CLRs as high as 10^{-2} or even 10^{-1}. Data partitioning, implemented as a post-processing function to a 4 Mbit/s Main Profile, Main Level system, with 50% of the rate allocated to each partition and no loss in the base layer, has been shown in one example to give approximately 0,5 dB loss in SNR at a CLR of 10^{-3}, about 1,5 dB loss at 10^{-2}, and with almost no visible degradation in either case.

Given the range of different layered coding approaches that are possible, some general comments may be useful. In general, it is not expected that inclusion of the most complex layered coding methods could be justified purely on the basis of error resilience. Instead, they could be utilised for error resilience if they were required to satisfy other system requirements. Data partitioning is very simple to implement and is likely to provide error resilience very nearly the same as any of the other methods except in the case of extremely high error rates (> 10% loss) or where the enhancement layer could be lost completely. SNR scalability is slightly more complex, and has slightly lower efficiency than data partitioning, but it is easier to produce lower layers of a usable quality when the enhancement layer is absent. Spatial scalability is more complex again, but provides a good lower layer picture quality at the expense of overall (two layer) efficiency.

D.14 Concatenated sequences

Sequence concatenation occurs when an elementary stream contains a sequence ending with a sequence_end_code that is followed by another sequence starting with a sequence_start_code. Any parameter including but not limited to profile, level, VBV buffer size, frame rate, horizontal size, vertical size, or bitrate, which is not allowed to change within a single sequence may change from sequence to sequence.

The behaviour of the decoding process and display process for concatenated sequences is not within the scope of this Recommendation | International Standard. An application that needs to use concatenated sequences must ensure by private arrangement that the decoder will be able to decode and play concatenated sequences.

Applications should ensure that decoders will have an acceptable behaviour when parameters change. For example changes to the

- frame size;
- frame rate;
- field parity of the first displayed field of the new sequence versus the field parity of the final displayed field of the previous sequence;
- buffer status,

amongst others may cause problems.

Annex E

Profile and level restrictions

(This annex does not form an integral part of this Recommendation | International Standard)

E.1 Syntax element restrictions in profiles

This annex tabulates all of the syntactic elements defined in this Specification. Each is classified to indicate whether it is required to be supported by a decoder compliant to a particular profile and level. Note that normative specifications for compliance are given in ISO/IEC 13818-4.

NOTE – This annex is informative and is simply intended as a summary of the normative restrictions set out in clause 8. If, because of an error in the preparation of this text, a discrepancy exists between clause 8 and Annex E, the normative text in clause 8 shall always take precedence.

In the Tables E.2 to E.19 a number of abbreviations are used as shown in Table E.1.

Table E.1 – Abbreviations used in the Tables of Annex E

Abbreviation	Used in	Meaning
x	Status	Must be supported by the decoder.
o	Status	Need not be supported by the decoder.
D	Type	Item with Level-dependent parameters.
I	Type	Item independent of the Level in the Profile.
P	Type	Item for post-processing after decoding; the decoder must be capable of decoding bitstreams which contain these items, but their use is beyond the scope of this Recommendation | International Standard.
NOTE – "Status" is kept blank if an entry is not a syntactic element.		

Table E.2 – Sequence header

#	Syntactic elements	Status							Type	Comments
		SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view		
01	**horizontal_size_value**	x	x	x	x	x	x	x	D	Table 8-11
02	**vertical_size_value**	x	x	x	x	x	x	x	D	Table 8-11
03	**aspect_ratio_information**	x	x	x	x	x	x	x	P	
04	**frame_rate_code**	x	x	x	x	x	x	x	D	Table 8-11
05	(sample rate) NOTE – This is not a syntactic element								D	Table 8-12. Sample rate is a product of samples/line, lines/frame and frames/sec.
06	**bit_rate_value**	x	x	x	x	x	x	x	D	Table 8-13
07	**vbv_buffer_size_value**	x	x	x	x	x	x	x	D	Table 8-14
08	**constrained_parameters_flag**	x	x	x	x	x	x	x	I	Set to "1" if ISO/IEC 11172-2 constrained, Set to "0" if ITU-T Rec. H.262 | ISO/IEC 13818-2
09	**load_intra_quantiser_matrix**	x	x	x	x	x	x	x	I	
10	**intra_quantiser_matrix[64]**	x	x	x	x	x	x	x	I	
11	**load_non_intra_quantiser_matrix**	x	x	x	x	x	x	x	I	
12	**non_intra_quantiser_matrix[64]**	x	x	x	x	x	x	x	I	
13	sequence_extension()	x	x	x	x	x	x	x	I	Always present if ITU-T Rec. H.262 | ISO/IEC 13818-2
14	sequence_display_extension()	x	x	x	x	x	x	x	P	
15	sequence_scalable_extension()	o	o	x	x	x	o	x	I	Table 8-9 for maximum number of scalable layers
16	user_data()	x	x	x	x	x	x	x	I	Decoder may skip this data

Table E.3 – Sequence extension

#	Syntactic elements	Status							Type	Comments
		SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view		
01	**profile_and_level_indication**	x	x	x	x	x	x	x	D	Profile: one of 8 values Level: one of 16 values Escape bit: one of 2 values
02	**progressive_sequence**	x	x	x	x	x	x	x	I	
03	**chroma_format**	x	x	x	x	x	x	x	I	Table 8-5
04	**horizontal_size_extension**	x	x	x	x	x	x	x	D	Input picture size related
05	**vertical_size_extension**	x	x	x	x	x	x	x	D	Input picture size related
06	**bit_rate_extension**	x	x	x	x	x	x	x	D	Input picture size related
07	**vbv_buffer_size_extension**	x	x	x	x	x	x	x	D	Input picture size related
08	**low_delay**	x	x	x	x	x	x	x	I	
09	**frame_rate_extension_n**	x	x	x	x	x	x	x	I	Set to "0" for all defined profiles
10	**frame_rate_extension_d**	x	x	x	x	x	x	x	I	Set to "0" for all defined profiles

Table E.4 – Sequence display extension elements

#	Syntactic elements	Status							Type	Comments
		SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view		
01	**video_format**	x	x	x	x	x	x	x	P	
02	**colour_description**	x	x	x	x	x	x	x	P	Input format related
03	**colour_primaries**	x	x	x	x	x	x	x	P	
04	**transfer_characteristics**	x	x	x	x	x	x	x	P	
05	**matrix_coefficients**	x	x	x	x	x	x	x	P	
06	**display_horizontal_size**	x	x	x	x	x	x	x	P	Input format related
07	**display_vertical_size**	x	x	x	x	x	x	x	P	Input format related

Table E.5 – Sequence scalable extension

#	Syntactic elements	Status							Type	Comments
		SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view		
01	**scalable_mode**	o	o	x	x	x	o	x	I	SNR Profile: SNR Scalability Spatial and High Profile: SNR and/or Spatial Scalability Multi-view Profile: Temporal Scalability
02	**layer_id**	o	o	x	x	x	o	x	I	
	if (spatial scalable)									
03	**lower_layer_prediction_ horizontal_size**	o	o	o	x	x	o	o	D	Table 8-12 for luminance sampling density
04	**lower_layer_prediction_ vertical_size**	o	o	o	x	x	o	o	D	Table 8-12 for luminance sampling density
05	**horizontal_subsampling_ factor_m**	o	o	o	x	x	o	o	I	
06	**horizontal_subsampling_ factor_n**	o	o	o	x	x	o	o	I	
07	**vertical_subsampling_ factor_m**	o	o	o	x	x	o	o	I	
08	**vertical_subsampling_ factor_n**	o	o	o	x	x	o	o	I	
	if (temporal scalable)									
09	**picture_mux_enable**	o	o	o	o	o	o	x	I	
10	**mux_to_progressive_sequence**	o	o	o	o	o	o	x	I	
11	**picture_mux_order**	o	o	o	o	o	o	x	I	
12	**picture_mux_factor**	o	o	o	o	o	o	x	I	

Table E.6 – Group of pictures header

#	Syntactic elements	Status							Type	Comments
		SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view		
01	**time_code**	x	x	x	x	x	x	x	I	Decoder may skip this data
02	**closed_gop**	x	x	x	x	x	x	x	I	
03	**broken_link**	x	x	x	x	x	x	x	I	

Table E.7 – Picture header

#	Syntactic elements	Status							Type	Comments
		SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view		
01	**temporal_reference**	x	x	x	x	x	x	x	I	
02	**picture_coding_type**	x	x	x	x	x	x	x	I	Simple Profile: I, P at Main level, I, P, B at Low level Main, SNR, Spatial, High and Multi-view Profile: I, P, B
03	**vbv_delay**	x	x	x	x	x	x	x	I	
04	**full_pel_forward_vector**	x	x	x	x	x	x	x	I	Set to "0" for ITU-T Rec. H.262 | ISO/IEC 13818-2
05	**forward_f_code**	x	x	x	x	x	x	x	I	Set to "111" for ITU-T Rec. H.262 | ISO/IEC 13818-2
06	**full_pel_backward_vector**	x	x	x	x	x	x	x	I	Set to "0" for ITU-T Rec. H.262 | ISO/IEC 13818-2
07	**backward_f_code**	x	x	x	x	x	x	x	I	Set to "111" for ITU-T Rec. H.262 | ISO/IEC 13818-2
08	**extra_information_picture**	x	x	x	x	x	x	x	I	
09	picture_coding_extension()	x	x	x	x	x	x	x	I	
10	quant_matrix_extension()	x	x	x	x	x	x	x	I	
11	picture_display_extension()	x	x	x	x	x	x	x	P	
12	picture_spatial_scalable_extension()	o	o	o	x	x	o	o	I	
13	picture_temporal_scalable_extension()	o	o	o	o	o	o	x	I	
14	camera_parameters_extension()	o	o	o	o	o	o	x	P	

Table E.8 – Picture coding extension

#	Syntactic elements	Status							Type	Comments
		SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view		
01	**f_code[0][0] (forward horizontal)**	x	x	x	x	x	x	x	D	Low Level [1:7] Main Level [1:8] High-1440 and High Level [1:9]
02	**f_code[0][1] (forward vertical)**	x	x	x	x	x	x	x	D	Low Level [1:4] Main, High-1440 and High Level [1:5]
03	**f_code[1][0](backward horizontal)**	x	x	x	x	x	x	x	D	Low Level [1:7] Main Level [1:8] High-1440 and High Level [1:9]
04	**f_code[1][1] (backward vertical)**	x	x	x	x	x	x	x	D	Low level [1:4] Main, H-14 and High Level [1:5]
05	**intra_dc_precision**	x	x	x	x	x	x	x	I	Simple, Main, SNR, Spatial and Multi-view Profile: [8:10] High Profile: [8:11] 4:2:2 Profile: [8:11]
06	**picture_structure**	x	x	x	x	x	x	x	I	
07	**top_field_first**	x	x	x	x	x	x	x	I	
08	**frame_pred_frame_dct**	x	x	x	x	x	x	x	I	
09	**concealment_motion_vectors**	x	x	x	x	x	x	x	I	
10	**q_scale_type**	x	x	x	x	x	x	x	I	
11	**intra_vlc_format**	x	x	x	x	x	x	x	I	
12	**alternate_scan**	x	x	x	x	x	x	x	I	
13	**repeat_first_field**	x	x	x	x	x	x	x	I	
14	**chroma_420_type**	x	x	x	x	x	x	x	P	
15	**progressive_frame**	x	x	x	x	x	x	x	P	
16	**composite_display_flag**	x	x	x	x	x	x	x	P	
17	**v_axis**	x	x	x	x	x	x	x	P	
18	**field_sequence**	x	x	x	x	x	x	x	P	
19	**sub_carrier**	x	x	x	x	x	x	x	P	
20	**burst_amplitude**	x	x	x	x	x	x	x	P	
21	**sub_carrier_phase**	x	x	x	x	x	x	x	P	

Table E.9 – Quant matrix extension

#	Syntactic elements	Status							Type	Comments
		SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view		
01	**load_intra_quantiser_matrix**	x	x	x	x	x	x	x	I	
02	**intra_quantiser_matrix[64]**	x	x	x	x	x	x	x	I	
03	**load_non_intra_quantiser_matrix**	x	x	x	x	x	x	x	I	
04	**non_intra_quantiser_ matrix[64]**	x	x	x	x	x	x	x	I	
05	**load_chroma_intra_quantiser_ matrix**	o	o	o	o	x	x	o	I	
06	**chroma_intra_quantiser_ matrix[64]**	o	o	o	o	x	x	o	I	
07	**load_chroma_non_intra_ quantiser_matrix**	o	o	o	o	x	x	o	I	
08	**chroma_non_intra_quantiser_ matrix[64]**	o	o	o	o	x	x	o	I	

Table E.10 – Picture display extension

#	Syntactic elements	Status							Type	Comments
		SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view		
01	**frame_centre_horizontal_offset**	x	x	x	x	x	x	x	P	Input format related
02	**frame_centre_vertical_offset**	x	x	x	x	x	x	x	P	Input format related

Table E.11 – Picture temporal scalable extension

#	Syntactic elements	Status							Type	Comments
		SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view		
01	**reference_select_code**	o	o	o	o	o	o	x	I	
02	**forward_temporal_reference**	o	o	o	o	o	o	x	I	
03	**backward_temporal_reference**	o	o	o	o	o	o	x	I	

Table E.12 – Picture spatial scalable extension

#	Syntactic elements	Status							Type	Comments
		SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view		
01	**lower_layer_temporal_reference**	o	o	o	x	x	o	o	I	
02	**lower_layer_horizontal_offset**	o	o	o	x	x	o	o	D	Input format related
03	**lower_layer_vertical_offset**	o	o	o	x	x	o	o	D	Input format related
04	**spatial_temporal_weight_code_ table_index**	o	o	o	x	x	o	o	I	
05	**lower_layer_progressive_frame**	o	o	o	x	x	o	o	I	
06	**lower_layer_deinterlaced_field_ select**	o	o	o	x	x	o	o	I	

Table E.12-1 – Camera parameters extension

#	Syntactic elements	Status							Type	Comments
								Multi-view		
							4:2:2			
						HIGH				
					SPATIAL					
				SNR						
			MAIN							
		SIMPLE								
01	**reserved**	o	o	o	o	o	o	x	P	
02	**camera_id**	o	o	o	o	o	o	x	P	
03	**marker_bit**	o	o	o	o	o	o	x	P	
04	**height_of_image_device**	o	o	o	o	o	o	x	P	
05	**marker_bit**	o	o	o	o	o	o	x	P	
06	**focal_length**	o	o	o	o	o	o	x	P	
07	**marker_bit**	o	o	o	o	o	o	x	P	
08	**f_number**	o	o	o	o	o	o	x	P	
09	**marker_bit**	o	o	o	o	o	o	x	P	
10	**vertical_angle_of_view**	o	o	o	o	o	o	x	P	
11	**marker_bit**	o	o	o	o	o	o	x	P	
12	**camera_position_x_upper**	o	o	o	o	o	o	x	P	
13	**marker_bit**	o	o	o	o	o	o	x	P	
14	**camera_position_x_lower**	o	o	o	o	o	o	x	P	
15	**marker_bit**	o	o	o	o	o	o	x	P	
16	**camera_position_y_upper**	o	o	o	o	o	o	x	P	
17	**marker_bit**	o	o	o	o	o	o	x	P	
18	**camera_position_y_lower**	o	o	o	o	o	o	x	P	
19	**marker_bit**	o	o	o	o	o	o	x	P	
20	**camera_position_z_upper**	o	o	o	o	o	o	x	P	
21	**marker_bit**	o	o	o	o	o	o	x	P	
22	**camera_position_z_lower**	o	o	o	o	o	o	x	P	
23	**marker_bit**	o	o	o	o	o	o	x	P	
24	**camera_direction_x**	o	o	o	o	o	o	x	P	
25	**marker_bit**	o	o	o	o	o	o	x	P	
26	**camera_direction_y**	o	o	o	o	o	o	x	P	
27	**marker_bit**	o	o	o	o	o	o	x	P	
28	**camera_direction_z**	o	o	o	o	o	o	x	P	
29	**marker_bit**	o	o	o	o	o	o	x	P	
30	**image_plane_vertical_x**	o	o	o	o	o	o	x	P	
31	**marker_bit**	o	o	o	o	o	o	x	P	
32	**image_plane_vertical_y**	o	o	o	o	o	o	x	P	
33	**marker_bit**	o	o	o	o	o	o	x	P	
34	**image_plane_vertical_z**	o	o	o	o	o	o	x	P	
35	**reserved**	o	o	o	o	o	o	x	P	

Table E.13 – Slice layer

#	Syntactic elements	Status							Type	Comments
		SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view		
01	**slice_vertical_position_extension**	x	x	x	x	x	x	x	D	Input format related
02	**priority_breakpoint**	o	o	o	o	o	o	o	I	Only required for data partitioning
03	**quantiser_scale_code**	x	x	x	x	x	x	x	I	
04	**slice_extension_flag**	x	x	x	x	x	x	x	I	
05	**intra_slice**	x	x	x	x	x	x	x	I	Decoder may skip this data
06	**slice_picture_id_enable**	x	x	x	x	x	x	x	I	Decoder may skip this data
07	**slice_picture_id**	x	x	x	x	x	x	x	I	Decoder may skip this data
08	**extra_bit_slice**	x	x	x	x	x	x	x	I	Decoder may skip this data
09	macroblock()	x	x	x	x	x	x	x	I	

Table E.14 – Macroblock layer

#	Syntactic elements	Status							Type	Comments
		SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view		
01	**macroblock_escape**	x	x	x	x	x	x	x	I	
02	**macroblock_address_increment**	x	x	x	x	x	x	x	I	
03	macroblock_modes()	x	x	x	x	x	x	x	I	
04	**quantiser_scale_code**	x	x	x	x	x	x	x	I	
05	motion_vectors(0)	x	x	x	x	x	x	x	I	Forward motion vector
06	motion_vectors(1)	o	x	x	x	x	x	x	I	Backward motion vector
07	coded_block_pattern()	x	x	x	x	x	x	x	I	
08	block(i)	x	x	x	x	x	x	x	I	

Table E.15 – Macroblock modes

#	Syntactic elements	Status							Type	Comments
		SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view		
01	**macroblock_type**	x	x	x	x	x	x	x	I	
02	**spatial_temporal_weight_code**	o	o	o	x	x	o	o	I	
03	**frame_motion_type**	x	x	x	x	x	x	x	I	01: Field-based prediction 10: Frame-based prediction 11: Dual-prime
04	**field_motion_type**	x	x	x	x	x	x	x	I	01: Field-based prediction 10: 16 × 8 MC 11: Dual-prime
05	**dct_type**	x	x	x	x	x	x	x	I	

Table E.16 – Motion vectors

#	Syntactic elements	Status							Type	Comments
		SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view		
01	**motion_vertical_field_select**	x	x	x	x	x	x	x	I	
02	motion_vector()	x	x	x	x	x	x	x	I	

Table E.17 – Motion vector

#	Syntactic elements	SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view	Type	Comments
01	**motion_horizontal_code**	x	x	x	x	x	x	x	I	
02	**motion_horizontal_r**	x	x	x	x	x	x	x	I	
03	**dmv_horizontal**	x	x	x	x	x	x	x	I	
04	**motion_vertical_code**	x	x	x	x	x	x	x	I	
05	**motion_vertical_r**	x	x	x	x	x	x	x	I	
06	**dmv_vertical**	x	x	x	x	x	x	x	I	

Table E.18 – Coded block pattern

#	Syntactic elements	SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view	Type	Comments
01	**coded_block_pattern_420**	x	x	x	x	x	x	x	I	
02	**coded_block_pattern_1**	o	o	o	o	x	x	o	I	4:2:2
03	**coded_block_pattern_2**	o	o	o	o	o	o	o	I	4:4:4

Table E.19 – Block layer

#	Syntactic elements	SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view	Type	Comments
01	DCT coefficients	x	x	x	x	x	x	x	I	
02	End of block	x	x	x	x	x	x	x	I	

E.2 Permissible layer combinations

Tables E.20 to E.46 illustrate the parameter limits that may be applied in each layer of a bitstream, and the corresponding appropriate profile_and_level_indication that should be used. Each table describes the limits of a single compliance point in the profile / level matrix.

The following notation has been adopted:

<profile abbreviation>@<level abbreviation>

The abbreviations are defined in Table E.20.

Table E.20 – Abbreviations for profile and level names

Profile	<profile abbreviation>	Level	<level abbreviation>
Simple	SP	Low	LL
Main	MP	Main	ML
SNR Scalable	SNR	High-1440	H-14
Spatially Scalable	Spt	High	HL
High	HP		
Multi-view	MVP		
ISO/IEC 11172-2 constrained parameters			ISO/IEC 11172-2

Table E.21 – Simple profile @ Main level

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
1	0	Base	720/576/30	10 368 000	15	1 835 008	SP@ML

Table E.22 – Main profile @ Low level

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
1	0	Base	352/288/30	3 041 280	4	475 136	MP@LL

Table E.23 – Main profile @ Main level

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
1	0	Base	720/576/30	10 368 000	15	1 835 008	MP@ML

Table E.24 – Main profile @ High-1440 level

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
1	0	Base	1440/1088/60	47 001 600	60	7 340 032	MP@H-14

Table E.25 – Main profile @ High level

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
1	0	Base	1920/1088/60	62 668 800	80	9 781 248	MP@HL

Table E.26 – SNR profile @ Low level

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
2	0	Base	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	SNR	352/288/30	2 534 400	4	475 136	SNR@LL
2	0	Base	352/288/30	3 041 280	3	360 448	SP@ML
	1	SNR	352/288/30	3 041 280	4	475 136	SNR@LL
2	0	Base	352/288/30	3 041 280	3	360 448	MP@LL
	1	SNR	352/288/30	3 041 280	4	475 136	SNR@LL

Table E.27 – SNR profile @ Main level

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
2	0	Base	720/576/30	2 534 400	1.856	327 680	ISO 11172
	1	SNR	720/576/30	2 534 400	15	1 835 008	SNR@ML
2	0	Base	720/576/30	10 368 000	10	1 212 416	SP@ML
	1	SNR	720/576/30	10 368 000	15	1 835 008	SNR@ML
2	0	Base	352/288/30	3 041 280	4	475 136	MP@LL
	1	SNR	352/288/30	3 041 280	15	1 835 008	SNR@ML
2	0	Base	720/576/30	10 368 000	10	1 212 416	MP@ML
	1	SNR	720/576/30	10 368 000	15	1 835 008	SNR@ML

Table E.28 – Spatial profile @ High-1440 level (Base Layer + SNR)

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
2	0	Base	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	SNR	352/288/30	2 534 400	60	7 340 032	Spt@H-14
2	0	Base	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	SNR	720/576/30	10 368 000	60	7 340 032	Spt@H-14
2	0	Base	352/288/30	3 041 280	4	475 136	MP@LL
	1	SNR	352/288/30	3 041 280	60	7 340 032	Spt@H-14
2	0	Base	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	SNR	720/576/30	10 368 000	60	7 340 032	Spt@H-14
2	0	Base	1440/1088/60	47 001 600	40	4 882 432	MP@H-14
	1	SNR	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14

Table E.29 – Spatial profile @ High-1440 level (Base Layer + Spatial)

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
2	0	Base	768/576/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
2	0	Base	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
2	0	Base	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
2	0	Base	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Spatial	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
2	0	Base	1440/1088/60	47 001 600	40	4 882 432	MP@H-14
	1	Spatial	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14

Table E.30 – Spatial profile @ High-1440 level (Base Layer + SNR + Spatial)

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
3	0	Base	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	SNR	352/288/30	2 534 400	4	475 136	SNR@LL
	2	Spatial	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
3	0	Base	352/288/30	3 041 280	3	360 448	SP@ML
	1	SNR	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
3	0	Base	352/288/30	3 041 280	3	360 448	MP@LL
	1	SNR	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
3	0	Base	720/576/30	2 534 400	1.856	327 680	ISO 11172
	1	SNR	720/576/30	2 534 400	15	1 835 008	SNR@ML
	2	Spatial	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
3	0	Base	720/576/30	10 368 000	10	1 212 416	SP@ML
	1	SNR	720/576/30	10 368 000	15	1 835 008	SNR@ML
	2	Spatial	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
3	0	Base	352/288/30	3 041 280	4	475 136	MP@LL
	1	SNR	352/288/30	3 041 280	15	1 835 008	SNR@ML
	2	Spatial	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
3	0	Base	720/576/30	10 368 000	10	1 212 416	MP@ML
	1	SNR	720/576/30	10 368 000	15	1 835 008	SNR@ML
	2	Spatial	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
3	0	Base	1440/1088/60	10 368 000	15	1 835 008	MP@H-14
	1	SNR	1440/1088/60	10 368 000	40	4 882 432	Spt@H-14
	2	Spatial	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14

Table E.31 – Spatial profile @ High-1440 level (Base Layer + Spatial + SNR)

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
3	0	Base	768/576/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	1440/1088/30	47 001 600	40	4 882 432	Spt@H-14
	2	SNR	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
3	0	Base	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	1440/1088/30	47 001 600	40	4 882 432	Spt@H-14
	2	SNR	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
3	0	Base	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	1440/1088/30	47 001 600	40	4 882 432	Spt@H-14
	2	SNR	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
3	0	Base	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Spatial	1440/1088/30	47 001 600	40	4 882 432	Spt@H-14
	2	SNR	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
3	0	Base	720/576/30	10 368 000	15	1 835 008	MP@H-14
	1	Spatial	1440/1088/60	47 001 600	40	4 882 432	Spt@H-14
	2	SNR	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14

Table E.32 – High profile @ Main level (Base Layer)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
1	0	Base	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
1	0	Base	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML

Table E.33 – High profile @ Main level (Base Layer + SNR)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	SNR	4:2:0	720/576/30	10 368 000	20	2 441 216	HP@ML
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	SNR	4:2:2	720/576/30	10 368 000	20	2 441 216	HP@ML
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	SNR	4:2:0	352/288/30	3 041 280	20	2 441 216	HP@ML
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	SNR	4:2:2	352/288/30	3 041 280	20	2 441 216	HP@ML
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	SNR	4:2:0	720/576/30	10 368 000	20	2 441 216	HP@ML
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	SNR	4:2:2	720/576/30	10 368 000	20	2 441 216	HP@ML
2	0	Base	4:2:0	720/576/30	14 745 600	15	1 835 008	HP@ML
	1	SNR	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
2	0	Base	4:2:2	720/576/30	11 059 200	15	1 835 008	HP@ML
	1	SNR	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML

Table E.34 – High profile @ Main level (Base Layer + Spatial)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
2	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
2	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	SP@ML
	1	Spatial	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	SP@ML
	1	Spatial	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML

Table E.35 – High profile @ Main level (Base Layer + SNR + Spatial)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
3	0	Base	4:2:0	352/288/30	3 041 280	3	360 448	SP@ML
	1	SNR	4:2:0	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
3	0	Base	4:2:0	352/288/30	3 041 280	3	360 448	SP@ML
	1	SNR	4:2:0	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
3	0	Base	4:2:0	352/288/30	3 041 280	3	360 448	MP@LL
	1	SNR	4:2:0	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
3	0	Base	4:2:0	352/288/30	3 041 280	3	360 448	MP@LL
	1	SNR	4:2:0	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML

Table E.36 – High profile @ Main level (Base Layer + Spatial + SNR)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:0	720/576/30	14 745 600	15	1 835 008	HP@ML
	2	SNR	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:0	720/576/30	11 059 200	15	1 835 008	HP@ML
	2	SNR	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:2	720/576/30	11 059 200	15	1 835 008	HP@ML
	2	SNR	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	SP@ML
	1	Spatial	4:2:0	720/576/30	14 745 600	15	1 835 008	HP@ML
	2	SNR	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	SP@ML
	1	Spatial	4:2:0	720/576/30	11 059 200	15	1 835 008	HP@ML
	2	SNR	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	SP@ML
	1	Spatial	4:2:2	720/576/30	11 059 200	15	1 835 008	HP@ML
	2	SNR	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:0	720/576/30	14 745 600	15	1 835 008	HP@ML
	2	SNR	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:0	720/576/30	11 059 200	15	1 835 008	HP@ML
	2	SNR	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:2	720/576/30	11 059 200	15	1 835 008	HP@ML
	2	SNR	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML

Table E.37 – High profile @ High-1440 level (Base Layer)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
1	0	Base	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
1	0	Base	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14

Table E.38 – High profile @ High-1440 level (Base Layer + SNR)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	SNR	4:2:0	720/576/30	10 368 000	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	SNR	4:2:2	720/576/30	10 368 000	80	9 781 248	HP@H-14
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	SNR	4:2:0	352/288/30	3 041 280	80	9 781 248	HP@H-14
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	SNR	4:2:2	352/288/30	3 041 280	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	SNR	4:2:0	720/576/30	10 368 000	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	SNR	4:2:2	720/576/30	10 368 000	80	9 781 248	HP@H-14
2	0	Base	4:2:0	1440/1088/60	47 001 600	60	7 340 032	MP@H-14
	1	SNR	4:2:0	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
2	0	Base	4:2:0	1440/1088/60	47 001 600	60	7 340 032	MP@H-14
	1	SNR	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	14 745 600	20	1 835 008	HP@ML
	1	SNR	4:2:0	720/576/30	14 745 600	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	14 745 600	20	1 835 008	HP@ML
	1	SNR	4:2:2	720/576/30	14 745 600	80	9 781 248	HP@H-14
2	0	Base	4:2:2	720/576/30	11 059 200	20	1 835 008	HP@ML
	1	SNR	4:2:2	720/576/30	11 059 200	80	9 781 248	HP@H-14
2	0	Base	4:2:0	1440/1088/60	62 668 800	60	7 340 032	HP@H-14
	1	SNR	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
2	0	Base	4:2:0	1440/1088/60	47 001 600	60	7 340 032	HP@H-14
	1	SNR	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
2	0	Base	4:2:2	1440/1088/60	47 001 600	60	7 340 032	HP@H-14
	1	SNR	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14

Table E.39 – High profile @ High-1440 level (Base Layer + Spatial)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
2	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
2	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	14 745 600	20	2 441 216	MP@H-14
	1	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	14 745 600	20	2 441 216	MP@H-14
	1	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
	1	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
	1	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
2	0	Base	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
	1	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14

Table E.40 – High profile @ High-1440 level (Base Layer + SNR + Spatial)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
3	0	Base	4:2:0	352/288/30	3 041 280	3	360 448	SP@ML
	1	SNR	4:2:0	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
3	0	Base	4:2:0	352/288/30	3 041 280	3	360 448	SP@ML
	1	SNR	4:2:0	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	10 368 000	10	1 212 416	SP@ML
	1	SNR	4:2:0	720/576/30	10 368 000	15	1 835 008	SNR@ML
	2	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	10 368 000	10	1 212 416	SP@ML
	1	SNR	4:2:0	720/576/30	10 368 000	15	1 835 008	SNR@ML
	2	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	352/288/30	3 041 280	3	360 448	MP@LL
	1	SNR	4:2:0	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
3	0	Base	4:2:0	352/288/30	3 041 280	3	360 448	MP@LL
	1	SNR	4:2:0	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	10 368 000	10	1 212 416	MP@ML
	1	SNR	4:2:0	720/576/30	10 368 000	15	1 835 008	SNR@ML
	2	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	10 368 000	10	1 212 416	MP@ML
	1	SNR	4:2:0	720/576/30	10 368 000	15	1 835 008	SNR@ML
	2	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	SNR	4:2:2	720/576/30	10 368 000	20	2 441 216	HP@ML
	2	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	14 745 600	15	1 835 008	HP@ML
	1	SNR	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
	2	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	11 059 200	15	1 835 008	HP@ML
	1	SNR	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
	2	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:2	720/576/30	11 059 200	15	1 835 008	HP@ML
	1	SNR	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
	2	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14

Table E.41 – High profile @ High-1440 level (Base Layer + Spatial + SNR)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14
	2	SNR	4:2:0	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:0	1440/1088/60	62 668 800	60	7 340 032	HP@H-14
	2	SNR	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:2	1440/1088/60	47 001 600	60	7 340 032	HP@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14
	2	SNR	4:2:0	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	4:2:0	1440/1088/60	62 668 800	60	7 340 032	HP@H-14
	2	SNR	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	4:2:2	1440/1088/60	47 001 600	60	7 340 032	HP@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14
	2	SNR	4:2:0	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:0	1440/1088/60	62 668 800	60	7 340 032	HP@H-14
	2	SNR	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:2	1440/1088/60	47 001 600	60	7 340 032	HP@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14
	2	SNR	4:2:0	1440/1088/60	47 001 600	80	9 781 248	HP@H-14

Table E.41 – High profile @ High-1440 level (Base Layer + Spatial + SNR) *(concluded)*

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Spatial	4:2:0	1440/1088/60	62 668 800	60	7 340 032	HP@H-14
	2	SNR	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Spatial	4:2:2	1440/1088/60	47 001 600	60	7 340 032	HP@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
	1	Spatial	4:2:0	1440/1088/60	62 668 800	60	7 340 032	HP@H-14
	2	SNR	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	HP@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
	1	Spatial	4:2:2	1440/1088/60	47 001 600	60	7 340 032	HP@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
	1	Spatial	4:2:2	1440/1088/60	47 001 600	60	7 340 032	HP@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14

Table E.42 – High profile @ High level (Base Layer)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
1	0	Base	4:2:0	1920/1088/60	83 558 400	100	12 222 464	HP@HL
1	0	Base	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL

Table E.43 – High profile @ High level (Base Layer + SNR)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	SNR	4:2:0	720/576/30	10 368 000	100	12 222 464	HP@HL
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	SNR	4:2:2	720/576/30	10 368 000	100	12 222 464	HP@HL
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	SNR	4:2:0	352/288/30	3 041 280	100	12 222 464	HP@HL
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	SNR	4:2:2	352/288/30	3 041 280	100	12 222 464	HP@HL
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	SNR	4:2:0	720/576/30	10 368 000	100	12 222 464	HP@HL
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	SNR	4:2:2	720/576/30	10 368 000	100	12 222 464	HP@HL
2	0	Base	4:2:0	1440/1088/60	47 001 600	60	7 340 032	MP@H-14
	1	SNR	4:2:0	1440/1088/60	47 001 600	100	12 222 464	HP@HL
2	0	Base	4:2:0	1440/1088/60	47 001 600	60	7 340 032	MP@H-14
	1	SNR	4:2:2	1440/1088/60	47 001 600	100	12 222 464	HP@HL
2	0	Base	4:2:0	1920/1088/60	62 668 800	80	9 781 248	MP@HL
	1	SNR	4:2:0	1920/1088/60	62 668 800	100	12 222 464	HP@HL
2	0	Base	4:2:0	1920/1088/60	62 668 800	80	9 781 248	MP@HL
	1	SNR	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
2	0	Base	4:2:0	720/576/30	14 745 600	20	1 835 008	HP@ML
	1	SNR	4:2:0	720/576/30	14 745 600	100	12 222 464	HP@HL
2	0	Base	4:2:0	720/576/30	14 745 600	20	1 835 008	HP@ML
	1	SNR	4:2:2	720/576/30	14 745 600	100	12 222 464	HP@HL
2	0	Base	4:2:2	720/576/30	11 059 200	20	1 835 008	HP@ML
	1	SNR	4:2:2	720/576/30	11 059 200	100	12 222 464	HP@HL
2	0	Base	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
	1	SNR	4:2:0	1440/1088/60	62 668 800	100	12 222 464	HP@HL
2	0	Base	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
	1	SNR	4:2:2	1440/1088/60	62 668 800	100	12 222 464	HP@HL
2	0	Base	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
	1	SNR	4:2:2	1440/1088/60	47 001 600	100	12 222 464	HP@HL
2	0	Base	4:2:0	1920/1088/60	83 558 400	80	9 781 248	HP@HL
	1	SNR	4:2:0	1920/1088/60	83 558 400	100	12 222 464	HP@HL
2	0	Base	4:2:0	1920/1088/60	62 668 800	80	9 781 248	HP@HL
	1	SNR	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
2	0	Base	4:2:2	1920/1088/60	62 668 800	80	9 781 248	HP@HL
	1	SNR	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL

Table E.44 – High profile @ High level (Base Layer + Spatial)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
2	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:0	1920/1088/60	83 558 400	100	12 222 464	HP@HL
2	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	4:2:0	1920/1088/60	83 558 400	100	12 222 464	HP@HL
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:0	1920/1088/60	83 558 400	100	12 222 464	HP@HL
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Spatial	4:2:0	1920/1088/60	83 558 400	100	12 222 464	HP@HL
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Spatial	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
2	0	Base	4:2:0	960/576/30	19 660 800	25	3 047 424	MP@H-14
	1	Spatial	4:2:0	1920/1088/60	83 558 400	100	12 222 464	HP@HL
2	0	Base	4:2:0	960/576/30	19 660 800	25	3 047 424	MP@H-14
	1	Spatial	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
2	0	Base	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
	1	Spatial	4:2:0	1920/1088/60	83 558 400	100	12 222 464	HP@HL
2	0	Base	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
	1	Spatial	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
2	0	Base	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
	1	Spatial	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
2	0	Base	4:2:0	960/576/30	19 660 800	25	3 047 424	HP@H-14
	1	Spatial	4:2:0	1920/1088/60	83 558 400	100	12 222 464	HP@HL
2	0	Base	4:2:0	960/576/30	19 660 800	25	3 047 424	HP@H-14
	1	Spatial	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
2	0	Base	4:2:2	960/576/30	14 745 600	25	3 047 424	HP@H-14
	1	Spatial	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL

Table E.45 – High profile @ High level (Base Layer + SNR + Spatial)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
3	0	Base	4:2:0	352/288/30	3 041 280	3	360 448	SP@ML
	1	SNR	4:2:0	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	4:2:0	1920/1088/60	83 558 400	100	12 222 464	HP@HL
3	0	Base	4:2:0	352/288/30	3 041 280	3	360 448	SP@ML
	1	SNR	4:2:0	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	4:2:2	1920/1088/60	83 558 400	100	12 222 464	HP@HL
3	0	Base	4:2:0	720/576/30	10 368 000	10	1 212 416	SP@ML
	1	SNR	4:2:0	720/576/30	10 368 000	15	1 835 008	SNR@ML
	2	Spatial	4:2:0	1920/1088/60	83 558 400	100	12 222 464	HP@HL
3	0	Base	4:2:0	720/576/30	10 368 000	10	1 212 416	SP@ML
	1	SNR	4:2:0	720/576/30	10 368 000	15	1 835 008	SNR@ML
	2	Spatial	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	SNR	4:2:2	720/576/30	10 368 000	20	2 441 216	HP@ML
	2	Spatial	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	352/288/30	3 041 280	3	360 448	MP@LL
	1	SNR	4:2:0	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	4:2:0	1920/1088/60	83 558 400	100	12 222 464	HP@HL
3	0	Base	4:2:0	352/288/30	3 041 280	3	360 448	MP@LL
	1	SNR	4:2:0	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	720/576/30	10 368 000	10	1 212 416	MP@ML
	1	SNR	4:2:0	720/576/30	10 368 000	15	1 835 008	SNR@ML
	2	Spatial	4:2:0	1920/1088/60	83 558 400	100	12 222 464	HP@HL
3	0	Base	4:2:0	720/576/30	10 368 000	10	1 212 416	MP@ML
	1	SNR	4:2:0	720/576/30	10 368 000	15	1 835 008	SNR@ML
	2	Spatial	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	SNR	4:2:2	720/576/30	10 368 000	20	2 441 216	HP@ML
	2	Spatial	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	960/576/30	19 660 800	20	2 441 216	MP@H-14
	1	SNR	4:2:0	960/576/30	19 660 800	25	3 047 424	Spt@H-14
	2	Spatial	4:2:0	1920/1088/60	83 558 400	100	12 222 464	HP@HL
3	0	Base	4:2:0	960/576/30	19 660 800	20	2 441 216	MP@H-14
	1	SNR	4:2:0	960/576/30	19 660 800	25	3 047 424	Spt@H-14
	2	Spatial	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	960/576/30	14 745 600	20	2 441 216	MP@H-14
	1	SNR	4:2:2	960/576/30	14 745 600	25	3 047 424	HP@H-14
	2	Spatial	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL

Table E.45 – High profile @ High level (Base Layer + SNR + Spatial) *(concluded)*

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
3	0	Base	4:2:0	720/576/30	14 745 600	15	1 835 008	HP@ML
	1	SNR	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
	2	Spatial	4:2:0	1920/1088/60	83 558 400	100	12 222 464	HP@HL
3	0	Base	4:2:0	720/576/30	14 745 600	15	1 835 008	HP@ML
	1	SNR	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
	2	Spatial	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	720/576/30	11 059 200	15	1 835 008	HP@ML
	1	SNR	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
	2	Spatial	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:2	720/576/30	11 059 200	15	1 835 008	HP@ML
	1	SNR	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
	2	Spatial	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	960/576/30	19 660 800	20	2 441 216	HP@H-14
	1	SNR	4:2:0	960/576/30	19 660 800	25	3 047 424	HP@H-14
	2	Spatial	4:2:0	1920/1088/60	83 558 400	100	12 222 464	HP@HL
3	0	Base	4:2:0	960/576/30	19 660 800	20	2 441 216	HP@H-14
	1	SNR	4:2:0	960/576/30	19 660 800	25	3 047 424	HP@H-14
	2	Spatial	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	960/576/30	14 745 600	20	2 441 216	HP@H-14
	1	SNR	4:2:2	960/576/30	14 745 600	25	3 047 424	HP@H-14
	2	Spatial	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:2	960/576/30	14 745 600	20	2 441 216	HP@H-14
	1	SNR	4:2:2	960/576/30	14 745 600	25	3 047 424	HP@H-14
	2	Spatial	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL

Table E.46 – High profile @ High level (Base Layer + Spatial + SNR)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14
	2	SNR	4:2:0	1440/1088/60	47 001 600	100	12 222 464	HP@HL
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	100	12 222 464	HP@HL
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
	2	SNR	4:2:0	720/576/30	14 745 600	100	12 222 464	HP@HL
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
	2	SNR	4:2:2	720/576/30	14 745 600	100	12 222 464	HP@HL
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
	2	SNR	4:2:2	720/576/30	11 059 200	100	12 222 464	HP@HL
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
	2	SNR	4:2:0	1440/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
	2	SNR	4:2:2	1440/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	100	12 222 464	HP@HL
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:0	1920/1088/60	83 558 400	80	9 781 248	HP@HL
	2	SNR	4:2:0	1920/1088/60	83 558 400	100	12 222 464	HP@HL
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:0	1920/1088/60	62 668 800	80	9 781 248	HP@HL
	2	SNR	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:2	1920/1088/60	62 668 800	80	9 781 248	HP@HL
	2	SNR	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14
	2	SNR	4:2:0	1440/1088/60	47 001 600	100	12 222 464	HP@HL
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	100	12 222 464	HP@HL

Table E.46 – High profile @ High level (Base Layer + Spatial + SNR) *(continued)*

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
	2	SNR	4:2:0	1440/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
	2	SNR	4:2:2	1440/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	100	12 222 464	HP@HL
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	4:2:0	1920/1088/60	83 558 400	80	9 781 248	HP@HL
	2	SNR	4:2:0	1920/1088/60	83 558 400	100	12 222 464	HP@HL
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	4:2:0	1920/1088/60	62 668 800	80	9 781 248	HP@HL
	2	SNR	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	4:2:2	1920/1088/60	62 668 800	80	9 781 248	HP@HL
	2	SNR	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14
	2	SNR	4:2:0	1440/1088/60	47 001 600	100	12 222 464	HP@HL
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	100	12 222 464	HP@HL
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
	2	SNR	4:2:0	720/576/30	14 745 600	100	12 222 464	HP@HL
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
	2	SNR	4:2:2	720/576/30	14 745 600	100	12 222 464	HP@HL
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
	2	SNR	4:2:2	720/576/30	11 059 200	100	12 222 464	HP@HL
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
	2	SNR	4:2:0	1440/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
	2	SNR	4:2:2	1440/1088/60	62 668 800	100	12 222 464	HP@HL

Table E.46 – High profile @ High level (Base Layer + Spatial + SNR) *(continued)*

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
	2	SNR	4:2:2	1440/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:0	1920/1088/60	83 558 400	80	9 781 248	HP@HL
	2	SNR	4:2:0	1920/1088/60	83 558 400	100	12 222 464	HP@HL
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:0	1920/1088/60	62 668 800	80	9 781 248	HP@HL
	2	SNR	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:2	1920/1088/60	62 668 800	80	9 781 248	HP@HL
	2	SNR	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14
	2	SNR	4:2:0	1440/1088/60	47 001 600	100	12 222 464	HP@HL
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	100	12 222 464	HP@HL
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
	2	SNR	4:2:0	1440/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
	2	SNR	4:2:2	1440/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	100	12 222 464	HP@HL
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Spatial	4:2:0	1920/1088/60	83 558 400	80	9 781 248	HP@HL
	2	SNR	4:2:0	1920/1088/60	83 558 400	100	12 222 464	HP@HL
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Spatial	4:2:0	1920/1088/60	62 668 800	80	9 781 248	HP@HL
	2	SNR	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Spatial	4:2:2	1920/1088/60	62 668 800	80	9 781 248	HP@HL
	2	SNR	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	960/576/30	19 660 800	25	3 047 424	HP@H-14
	1	Spatial	4:2:0	1920/1088/60	83 558 400	80	9 781 248	HP@HL
	2	SNR	4:2:0	1920/1088/60	83 558 400	100	12 222 464	HP@HL

Table E.46 – High profile @ High level (Base Layer + Spatial + SNR) *(concluded)*

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
3	0	Base	4:2:0	960/576/30	19 660 800	25	3 047 424	HP@H-14
	1	Spatial	4:2:0	1920/1088/60	62 668 800	80	9 781 248	HP@HL
	2	SNR	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:0	960/576/30	19 660 800	25	3 047 424	HP@H-14
	1	Spatial	4:2:2	1920/1088/60	62 668 800	80	9 781 248	HP@HL
	2	SNR	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL
3	0	Base	4:2:2	960/576/30	14 745 600	25	3 047 424	HP@H-14
	1	Spatial	4:2:2	1920/1088/60	62 668 800	80	9 781 248	HP@HL
	2	SNR	4:2:2	1920/1088/60	62 668 800	100	12 222 464	HP@HL

Table E.47 – Multi-view profile @ Low level

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
2	0	Base	352/288/30	3 041 280	4	475 136	MP@LL
	1	Temporal	352/288/30	3 041 280	8	950 272	MVP@LL

Table E.48 – Multi-view profile @ Main level

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
2	0	Base	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Temporal	720/576/30	10 368 000	25	3 047 424	MVP@ML
2	0	Base	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Temporal	720/576/30	10 368 000	25	3 047 424	MVP@ML

Table E.49 – Multi-view profile @ High-1440 level

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
2	0	Base	1440/1088/60	47 001 600	60	7 340 032	MP@H-14
	1	Temporal	1440/1088/60	47 001 600	100	12 222 464	MVP@H-14

Table E.50 – Multi-view profile @ High level

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
2	0	Base	1920/1088/60	62 668 800	80	9 781 248	MP@HL
	1	Temporal	1920/1088/60	62 668 800	130	15 898 480	MVP@HL

Annex F

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(This annex does not form an integral part of this Recommendation | International Standard)

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Annex G

Registration Procedure

(This annex does not form an integral part of this Recommendation | International Standard)

G.1 Procedure for the request of a Registered Identifier (RID)

Requesters of an RID shall apply to the Registration Authority. Registration forms shall be available from the Registration Authority. Information which the requester shall provide is given in G.3. Companies and organizations are eligible to apply.

G.2 Responsibilities of the Registration Authority

The primary responsibilities of the Registration Authority administrating the registration of copyright_identifiers is outlined in this subclause; certain other responsibilities may be found in the JTC 1 Directives. The Registration Authority shall:

a) implement a registration procedure for application for a unique RID in accordance with Annex H of the JTC 1 Directives;

b) receive and process the applications for allocation of the work type code identifier from Copyright Registration Authority;

c) ascertain which applications received are in accordance with this registration procedure, and to inform the requester within 30 days of receipt of the application of their assigned RID;

d) inform application providers whose request is denied in writing within 30 days of receipt of the application, and also inform the requesting party of the appeals process;

e) maintain an accurate register of the allocated RID. Revisions to the contact information and technical specifications shall be accepted and maintained by the Registration Authority;

f) make the contents of this register available upon request to any interested party;

g) maintain a database of RID request forms, granted and denied. Parties seeking technical information on the format of private data which has a copyright_identifier shall have access to such information which is part of the database maintained by the Registration Authority;

h) report its activities to JTC 1, the ITTF, and the JTC 1/SC 29 Secretariat, or their respective assignees, annually on a schedule mutually agreed upon.

G.2.1 Contact information of the Registration Authority

Organization Name:

Address:

Telephone:

Fax:

G.3 Responsibilities of parties requesting an RID

The party requesting an RID for the purpose of copyright identification shall:

a) apply using the form and procedures supplied by the Registration Authority;

b) provide contact information describing how a complete description of the copyright organization can be obtained on a non-discriminatory basis;

c) include technical details of the syntax and semantics of the data format used to describe the audiovisual works or other copyrighted works within the additional_copyright_info field. Once registered, the syntax used for the additional copyright information shall not change;

d) agree to institute the intended use of the granted copyright_identifier within a reasonable time-frame;

e) maintain a permanent record of the application form and the notification received from the Registration Authority of each granted copyright_identifier.

G.4 Appeal procedure for denied applications

The Registration Management Group is formed to have jurisdiction over appeals relating to a denied request for an RID. The RMG shall have a membership who are nominated by P and L members of the ISO technical body responsible for this Recommendation | International Standard. It shall have a convenor and secretariat nominated from its members. The Registration Authority is entitled to nominate one non-voting observing member.

The responsibilities of the RMG shall be:

a) to review and act on all appeals within a reasonable time-frame;

b) to inform, in writing, organizations which make an appeal for reconsideration of its petition of the RMG's disposition of the matter;

c) to review the annual report of the Registration Authority summary of activities;

d) to supply ISO member bodies with information concerning the scope of operation of the Registration Authority.

Annex H

Registration Application Form

(This annex does not form an integral part of this Recommendation | International Standard)

H.1 Contact information of organization requesting a Registered Identifier (RID)

Organization Name:

Address:

Telephone:

Fax:

E-mail:

H.2 Statement of an intention to apply the assigned RID

RID application domain: using guidelines to be provided by the Registration Authority.

H.3 Date of intended implementation of the RID

H.4 Authorized representative

Name:

Title:

Address:

Signature _____

H.5 For official use only of the Registration Authority

Registration Rejected _____

Reason for rejection of the application:

Registration Granted _____ Registration Value _____

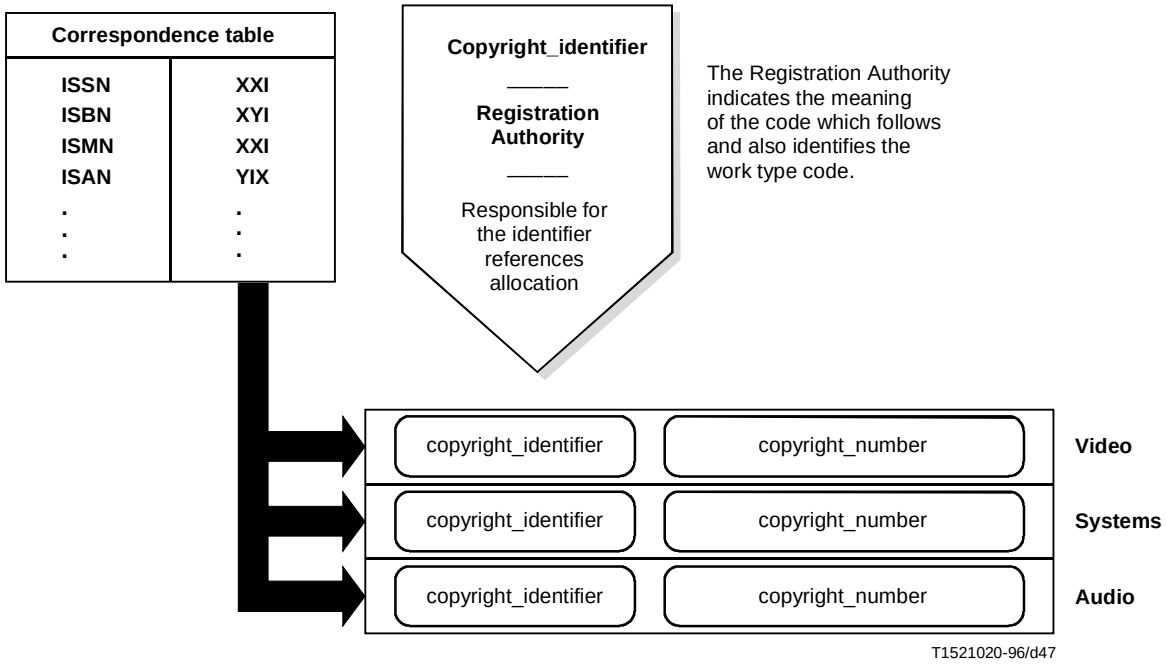
Attachment 1 – Attachment of technical details of the registered data format.

Attachment 2 – Attachment of notification of appeal procedure for rejected applications.

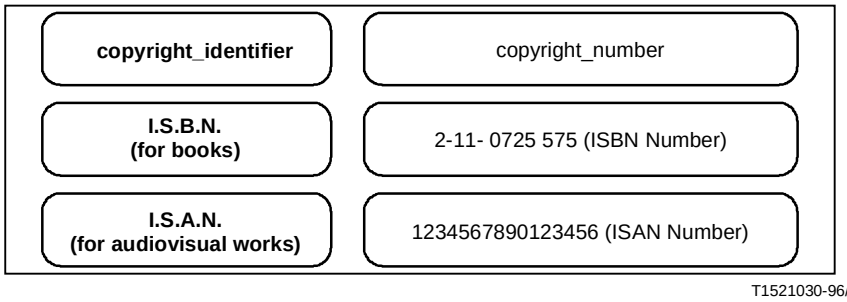
Annex I

(This annex does not form an integral part of this Recommendation | International Standard)

Registration Authority
Diagram of administration structure



Examples



All the copyright_identifiers are registered by the Registration Authority, uniquely for copyright_numbers standardized by ISO. Each organization which allocates copyright_numbers, requests a specific copyright_identifier from the Registration Authority, e.g. Staatsbibliothek Preussischer Kulturbesitz, designated by ISO to manage I.S.B.N., asks for a specific copyright_identifier from the R.A. for book numbering.

Annex J

4:2:2 Profile test results

(This annex does not form an integral part of this Recommendation | International Standard)

J.1 Introduction

This annex provides guidance to users regarding the applicability of the 4:2:2 Profile at Main Level to applications which may require:

- higher quality than Main Profile at Main Level;
- better chroma resolution than Main Profile at Main Level;
- post processing after compression and decompression;
- multiple generations of compression and decompression;
- short Group of Pictures (GOP) for editability;
- capability to pass all active video;
- capability to pass vertical blanking interval information.

It should be noted that application of this Profile is an area of ongoing progress. Results presented here reflect varying degrees of algorithm refinement, so further improvement can be expected.

J.1.1 Test sequences

The test sequences were generated using computer simulation of the ITU-T Rec. H.262 | ISO/IEC 13818-2 compression and decompression. For 525/60, the test material included:

- Gwen;
- Trailblazers;
- Mobile and Calendar;
- Dissolve.

For 625/50, the test material included:

- Balls of Wool;
- Cactus and Comb;
- Basketball;
- Wall;
- Renata and Butterfly;
- Mobile and Calendar.

"Gwen" is a chroma key test sequence with a woman in the foreground keyed over a forest scene in the background. "Gwen" is a difficult sequence to chroma key but an easy sequence to compress. Both "Cactus and Comb" and "Balls of Wool" are chroma key sequences which were used with a coloured background. "Trailblazers" is a rapid motion basketball sequence shot with an unshuttered CCD camera. "Basketball" is also a rapid motion sports sequence. Both are typical program material and moderately difficult to compress. "Wall" consists of a woman standing in front of a wall made of many small stones. "Renata" consists of a woman in front of a complex background with a dissolve to a complex image of butterflies. "Mobile and Calendar" is a particularly difficult compression test sequence with saturated colours and complex motion. "Dissolve" consists of two segments of "Mobile and Calendar" with a one second fade between the two segments and is also difficult to compress.

Test sequences were supplied by:

- ITU-R;
- Portland Trailblazers;
- SMPTE;
- Tektronix.

J.1.2 Test procedures

MPEG has conducted experiments to verify the performance of the 4:2:2 Profile. The results of those experiments are presented here. There are separate tests for 525/60 and 625/50. The 525/60 tests explore a broad range of data rates and GOP structures, while the 625/50 tests include more variety of test material but less combinations of data rate, GOP structure, and number of generations. The parameters chosen for the experiments are for example only, and do not cover the entire range of allowed parameter values. The examples are not intended as specific recommendations. Each application should use the combination of parameters that is most appropriate, depending on its requirements for quality, editability, and cost.

The tests include both a single generation and eight generations of cascaded compression and decompression. For the eight generation tests, separate tests were done with no shifts, with two spatial shifts, and with two temporal shifts. Spatial shifting means that the picture was shifted horizontally and vertically by two pixels and two spatial lines between the first and second generations and then back between the fifth and sixth generations. Spatial shifting represents the effects of picture repositioning which might occur in a DVE. Temporal shifting means that the GOP structure was shifted one frame between the first and second generations and again between the fifth and sixth generations. Temporal shifting represents the effect of multiple generations which have different GOP alignment.

Chroma key experiments were done by processing the foreground with blue screen through compression and decompression. After decompression the component digital signal was chroma keyed to add the background. The background image was not compressed.

Mixed environment tests for 525/60 used ITU-T Rec. H.262 | ISO/IEC 13818-2 4:2:2 compression and decompression cascaded with a compressed digital VTR using 2:1 intra-field compression. The tests used a total of eight generations of compression. The four odd number generations were MPEG and the four even number generations were compressed digital VTR. There were no shifts between generations.

Mixed environment tests for 625/50 used only MPEG compression. The tests used a total of three generations of compression. The first and third generations were ITU-T Rec. H.262 | ISO/IEC 13818-2 4:2:2 compression with IBBP-GOP structure at 20 Mbits/s, while the second generation was ITU-T Rec. H.262 | ISO/IEC 13818-2 4:2:2 compression with I-only GOP structure at 50 Mbits/s. A temporal shift of one frame was included between the second and third generations.

Compression and decompression processing were contributed by:

- CCETT;
- FTZ;
- IRT;
- JVC;
- Sony;
- Technical University of Braunschweig/BTS;
- Tektronix.

Editing and duplication of test tapes were contributed by:

- RAI;
- Tektronix.

J.1.3 Subjective assessment

The subjective assessment used the DSCQS method described in ITU-R Rec. BT.500-6. Both expert and non-expert viewing sessions were conducted at a number of sites around the world. All of the expert viewing results were combined, and all of the non-expert viewing results were combined. Both expert and non-expert results are presented here. Only subjective test results are presented, as signal to noise ratio is not regarded as a reliable measure of picture quality in these cases.

Expert subjective assessment viewing sessions were conducted by:

- NHK;
- SMPTE.

Non-expert subjective assessment viewing sessions were conducted by:

- CCETT;
- JVC/MPT/NHK/NTV;
- RAI;
- Technical University of Braunschweig/BTS.

J.1.4 Test results

Test results are presented in the following order (see Tables J.1 and J.2):

- 525/60 Homogeneous Environment;
- 525/60 Non-Homogeneous Environment;
- 625/50 Homogeneous Environment;
- 625/50 Non-Homogeneous Environment.

The tables of test results are organized with higher data rates presented first and lower data rates presented last. Within a given bit rate, results are organized by GOP structure, number of generations, and type of shifting. The mean and confidence interval are given for each test sequence.

These tests used the continuous quality scale specified in ITU-R Rec. BT.500-6. The subjective assessments were done on a continuous 0 to 100 scale. The mean differences between original and compressed sequence ratings were calculated, on a 0 to 100 scale, with differences inferior or equal to 0 representing no degradation through compression and 100 being the worst possible rating.

Hereinafter the average of the differences between original and compressed sequence ratings, calculated over the subjects, will be referred to as diff-grade.

The results presented here are based on the following quality definitions:

- **transparency**: diff-grade for all test sequences does not exceed 12% of the scale;
- **near transparency**: the diff-grade of the 25% of the test sequences is between 12% and 18%, while all the other diff-grades do not exceed 12% of the scale;
- **good quality in most of the material**: the mean diff-grades calculated over the test sequences do not exceed 18%, while the diff-grades of 25% of the test sequences exceed 18% of the scale;
- **difficulties in some materials**: all other cases.

Table J.1 – Subjective test results for the 525/60 system

Compression parameters		Viewer ratings	
525/60 50 Mbits/s		**Expert viewers**	**Non-expert viewers**
GOP = I	1 generation	Transparency	Transparency
	8 generations, No shifts	Good quality in most test materials	Transparency
	8 generations, 2 spatial shifts	Good quality in most test materials	Near-transparency
GOP = IB	1 generation	Transparency	Transparency
	8 generations, No shifts	Transparency	Transparency
	8 generations, 2 spatial shifts	Good quality in most test materials	Transparency
	8 generations, 2 temporal shifts	Transparency	Transparency
525/60 30 Mbits/s		**Expert viewers**	**Non-expert viewers**
GOP = I	1 generation	Difficulties in some materials	Good quality in most test materials
	8 generations, No shifts	Difficulties in some materials	Transparency
	8 generations, 2 spatial shifts	Difficulties in some materials	Difficulties in some materials
GOP = IB	1 generation	Good quality in most test materials	Transparency
	8 generations, No shifts	Good quality in most test materials	Transparency
	8 generations, 2 spatial shifts	Difficulties in some materials	Near-transparency
	8 generations, 2 temporal shifts	Difficulties in some materials	Good quality in most test materials
525/60 20 Mbits/s		**Expert viewers**	**Non-expert viewers**
GOP = IB	1 generation	Difficulties in some materials	Difficulties in some materials
	8 generations, No shifts	Difficulties in some materials	Transparency
	8 generations, 2 spatial shifts	Difficulties in some materials	Difficulties in some materials
	8 generations, 2 temporal shifts	Difficulties in some materials	Difficulties in some materials
GOP = IBBP	1 generation	Transparency	Transparency
	8 generations, No shifts	Difficulties in some materials	Good quality in most test materials
	8 generations, 2 spatial shifts	Difficulties in some materials	Difficulties in some materials
	8 generations, 2 temporal shifts	Difficulties in some materials	Difficulties in some materials
525/60 mixed environment		**Expert viewers**	**Non-expert viewers**
30 Mbits/s GOP = I	8 generations, No shifts	Difficulties in some materials	Good quality in most test materials
20 Mbits/s GOP = IB	8 generations, No shifts	Difficulties in some materials	Good quality in most test materials

Table J.2 – Subjective test results for the 625/50 system

Compression parameters		Viewers	
625/50 50 Mbits/s		**Expert viewers**	**Non-expert viewers**
GOP = I	1 generation	Transparency	Transparency
	8 generations, 2 spatial shifts	Transparency	Transparency
625/50 30 Mbits/s		**Expert viewers**	**Non-expert viewers**
GOP = I	1 generation	Transparency	Transparency
	8 generations, 2 spatial shifts	Good quality in most test materials	Difficulties in some materials
GOP = IB	8 generations, 2 spatial shifts	Good quality in most test materials	Near-transparency
	8 generations, 2 temporal shifts	Good quality in most test materials	Near-transparency
625/50 20 Mbits/s		**Expert viewers**	**Non-expert viewers**
GOP = IB	1 generation	Transparency	Transparency
	8 generations, 2 spatial shifts	Difficulties in some materials	Difficulties in some materials
	8 generations, 2 temporal shifts	Difficulties in some materials	Difficulties in some materials
GOP = IBBP	8 generations, 2 spatial shifts	Difficulties in some materials	Difficulties in some materials
	8 generations, 2 temporal shifts	Good quality in most test materials	Good quality in most test materials
625/50 mixed environment Cascaded 20 Mbits/s + 50 Mbits/s + 20 Mbits/s		**Expert viewers**	**Non-expert viewers**
GOP = IBBP + I + IBBP	3 generations, 1 temporal shift	Good quality in most test materials	Good quality in most test materials

ITU-T RECOMMENDATIONS SERIES

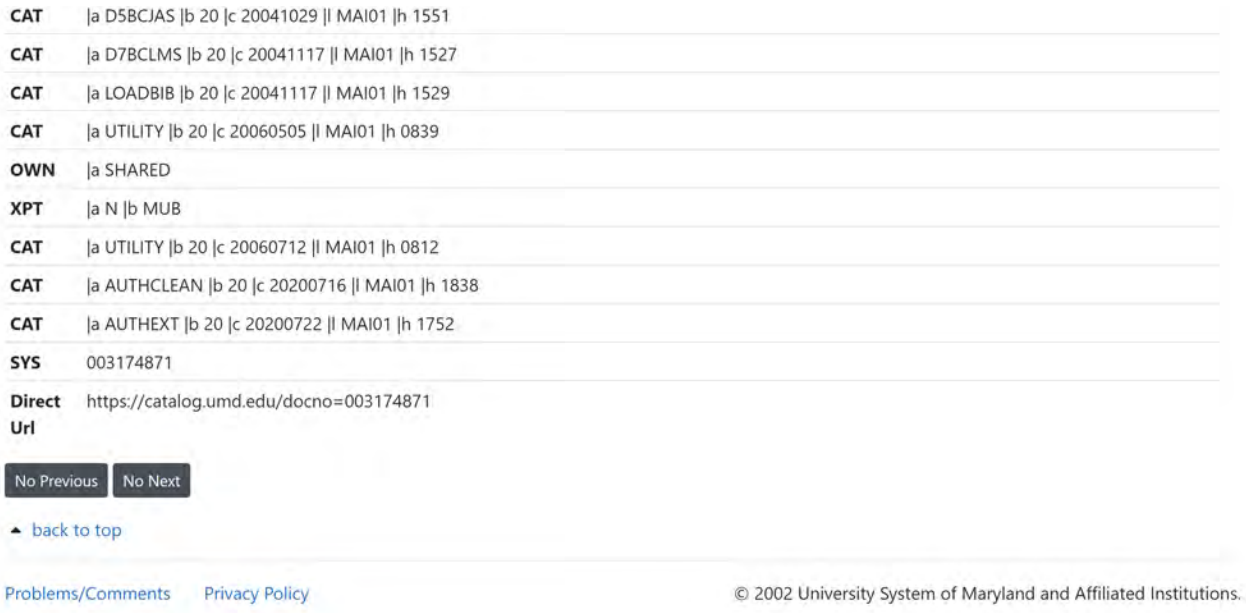
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Series B	Means of expression: definitions, symbols, classification
Series C	General telecommunication statistics
Series D	General tariff principles
Series E	Overall network operation, telephone service, service operation and human factors
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Series G	Transmission systems and media, digital systems and networks
Series H	**Audiovisual and multimedia systems**
Series I	Integrated services digital network
Series J	Transmission of television, sound programme and other multimedia signals
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APPENDIX ITU02

screenshot-catalog.umd.edu-2023.11.28-15_55_46
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28.11.2023

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260	|a [Geneva] : |b International Telecommunication Union,
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310	|a Quarterly
3621	|a Began in 2004.
500	|a Description based on: Sept. 2004; title from disc label.
520	|a International telecommunications standards on technical, operating and tariff questions, developed by the Telecommunication Standardization Sector of the ITU. Includes Recommendations in force and provisional pre-published Recommendations.
530	|a Also issued in print and online.
538	|a System requirements: Intel Pentium processor or compatible; 64 MB of RAM; Microsoft Windows 95 OSR 2.0, 98 SE, Millennium Edition, NT 4.0 with Service Pack 5, 2000, or XP; Adobe Acrobat Reader (included); DVD drive.
61020	|a International Telecommunication Union |v Periodicals.
650 0	|a Telecommunication |x Standards |v Periodicals.
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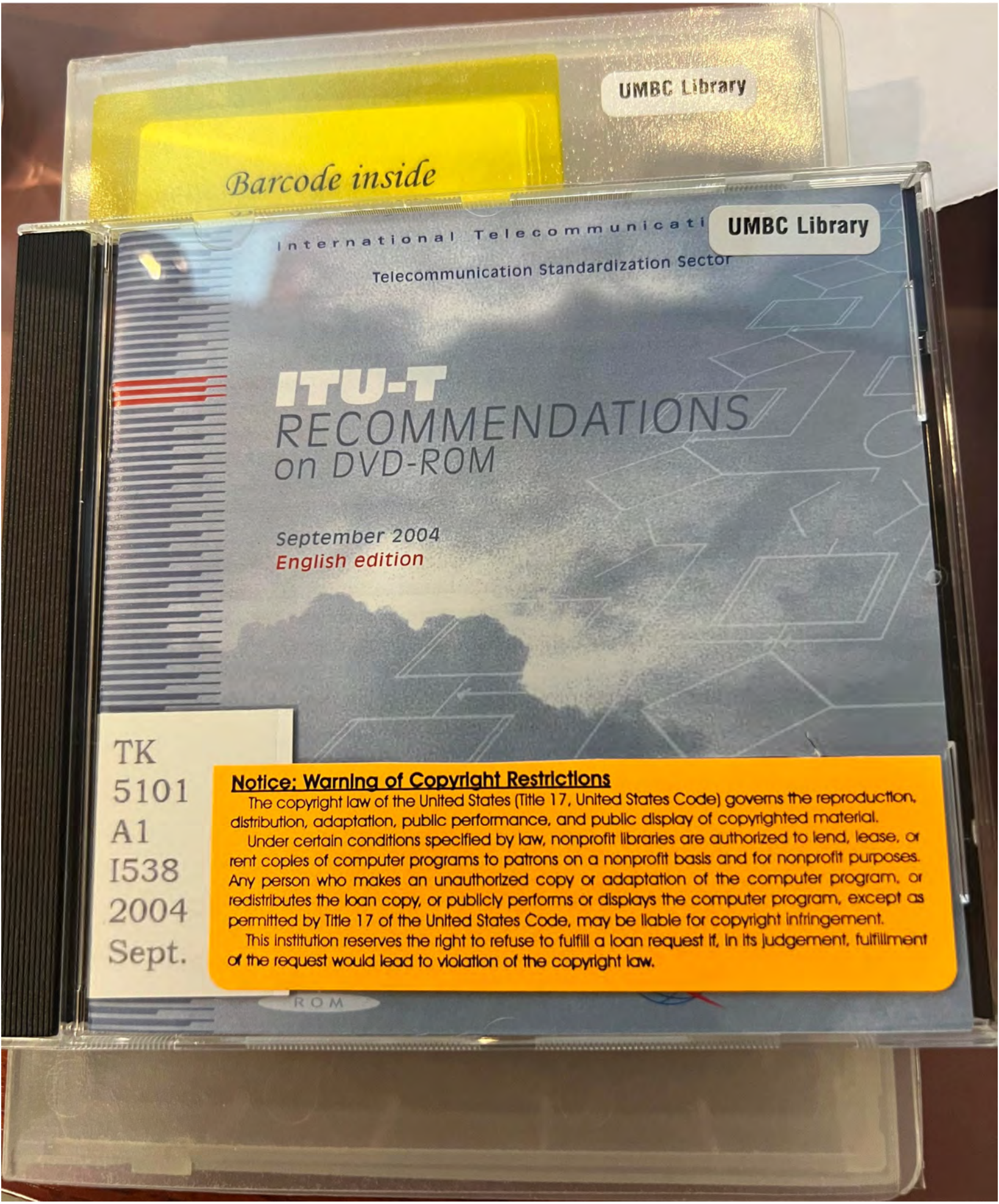
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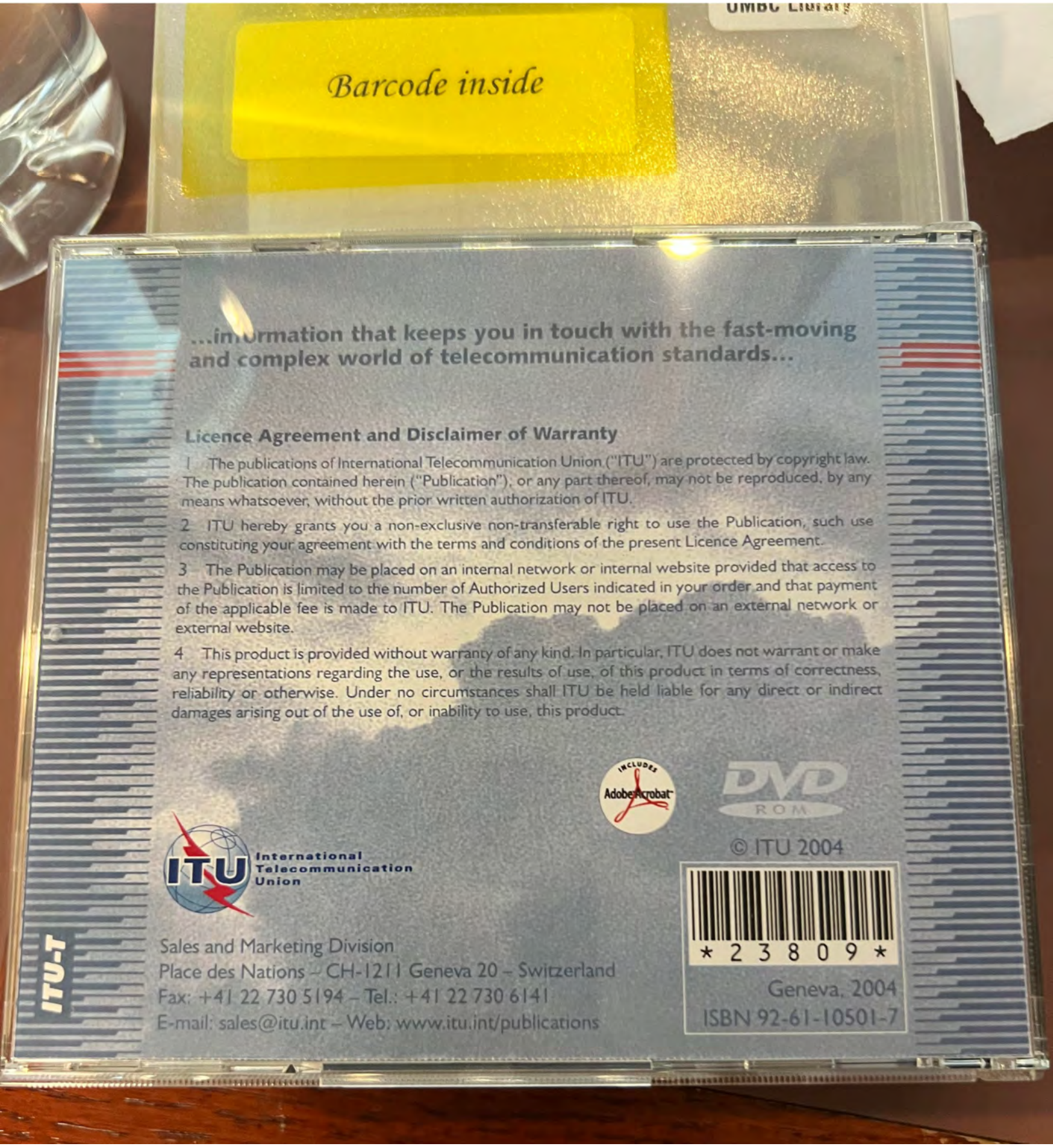
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APPENDIX ITU04

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Series A : Organization of the work of ITU-T

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A.1	10-2000	Work Methods for Study Groups of the ITU Telecommunication Standardization Sector (ITU-T)
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		Means of expression: definitions, symbols, classification

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		General telecommunication statistics

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E.600	03-1993	Terms and definitions of traffic engineering
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E.770	03-1993	Land mobile and fixed network interconnection traffic grade of service concept
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E.801	10-1996	Framework for Service Quality Agreement
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E.820	10-1992	Call models for serveability and service integrity performance
E.830	10-1992	Models for the specification, evaluation and allocation of serveability and service integrity
E.845	11-1988	Connection accessibility objective for the international telephone service
E.846	03-1993	Accessibility for 64 kbit/s circuit-switched international end-to-end ISDN connection types
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E.862	06-1992	Dependability planning of telecommunication networks
E.880	11-1988	Field data collection and evaluation on the performance of equipment, networks and services
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E.300 Series Supplement 3	11-1988	North american precise audible tone plan

E.300 Series Supplement 4	11-1988	Treatment of calls considered as terminating abnormally
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E.300 Series Supplement 6	11-1988	Preparation of information to customers travelling abroad
E.300 Series Supplement 7	11-1988	Description of INMARSAT existing and planned systems
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F.723	07-1996	Videophone service in the Public Switched Telephone Network (PSTN)
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		Transmission systems and media, digital systems and networks
G.100	02-2001	Definitions used in Recommendations on general characteristics of international telephone connections and circuits
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G.115	02-1996	Mean active speech level for announcement and speech synthesis systems
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G.174	06-1994	Transmission performance objectives for terrestrial digital wireless systems using portable terminals to access the PSTN
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G.177	09-1999	Transmission planning for voiceband services over hybrid Internet/PSTN connections
G.180	03-1993	Characteristics of N + M type direct transmission restoration systems for use on digital and analogue sections, links or equipment
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G.191 STL-2000 Manual	12-2000	Software tools for speech and audio coding standardization
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G.322	11-1988	General characteristics recommended for systems on symmetric pair cables
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G.352	11-1988	Interconnection of coaxial carrier systems of different designs
G.411	11-1988	Use of radio-relay systems for international telephone circuits
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G.602	11-1988	Reliability and availability of analogue cable transmission systems and associated equipments
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G.651	02-1998	Characteristics of a 50/125 µm multimode graded index optical fibre cable
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G.653	12-2003	Characteristics of a dispersion-shifted single-mode optical fibre and cable
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G.661	10-1998	Definition and test methods for the relevant generic parameters of optical amplifier devices and subsystems
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G.663	04-2000	Application related aspects of optical amplifier devices and subsystems
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G.671	06-2002	Transmission characteristics of optical components and subsystems
G.691	12-2003	Optical interfaces for single channel STM-64 and other SDH systems with optical amplifiers
G.692	10-1998	Optical interfaces for multichannel systems with optical amplifiers
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G.701	03-1993	Vocabulary of digital transmission and multiplexing, and pulse code modulation (PCM) terms
G.702	11-1988	Digital hierarchy bit rates
G.703	11-2001	Physical/electrical characteristics of hierarchical digital interfaces
G.704	10-1998	Synchronous frame structures used at 1544, 6312, 2048, 8448 and 44 736 kbit/s hierarchical levels
G.705	10-2000	Characteristics of plesiochronous digital hierarchy (PDH) equipment functional blocks
G.706	04-1991	Frame alignment and cyclic redundancy check (CRC) procedures relating to basic frame structures defined in Recommendation G.704
G.707/Y.1322	12-2003	Network node interface for the synchronous digital hierarchy (SDH)
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G.708	07-1999	Sub STM-0 network node interface for the synchronous digital hierarchy (SDH)
G.709/Y.1331	03-2003	Interfaces for the Optical Transport Network (OTN)
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G.711	11-1988	Pulse code modulation (PCM) of voice frequencies
G.711 Appendix I	09-1999	A high quality low-complexity algorithm for packet loss concealment with G.711
G.711 Appendix II	02-2000	A comfort noise payload definition for ITU-T G.711 use in packet-based multimedia communication systems
G.712	11-2001	Transmission performance characteristics of pulse code modulation channels
G.720	07-1995	Characterization of low-rate digital voice coder performance with non-voice signals
G.722	11-1988	7 kHz audio-coding within 64 kbit/s
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G.722 Annex A	03-1993	Testing signal-to-total distortion ratio for 7 kHz audio-codecs at 64 kbit/s Recommendation G.722 connected back-to-back
G.722 Appendix II	03-1987	Digital test sequences for the verification of the G.722 64 kbit/s SB-ADPCM 7 kHz codec
G.722.1	09-1999	Coding at 24 and 32 kbit/s for hands-free operation in systems with low frame loss
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G Suppl. 7	12-1972	Loss-frequency response of channel-translating equipment used in some countries for international circuits
G Suppl. 8	12-1972	Method proposed by the Belgian telephone administration for interconnection between coaxial and symmetric pair systems
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G Suppl. 19	10-1984	Digital crosstalk measurement (method used by the Administrations of France, the Netherlands and Spain)
G Suppl. 22	10-1984	Mathematical models of multiplex signals
G Suppl. 26	10-1984	Estimating the signal load margin of FDM wideband amplifier equipment and transmission systems
G Suppl. 27	10-1984	Interference from external sources

G Suppl. 28	10-1984	Application of transmultiplexers, FDM codecs, data-in-voice (DIV) systems and data-over-voice (DOV) systems during the transition from an analogue to a digital network
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G Suppl. 35	11-1988	Guidelines concerning the measurement of wander
G Suppl. 36	11-1988	Jitter and wander accumulation in digital networks
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G.Sup38	10-1998	Variable bit rate calculations for the ITU-T Recommendation G.767 Digital Circuit Multiplication Equipment (DCME)
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H.100	11-1988	Visual telephone systems
H.110	11-1988	Hypothetical reference connections for videoconferencing using primary digital group transmission
H.120	03-1993	Codecs for videoconferencing using primary digital group transmission
H.130	11-1988	Frame structures for use in the international interconnection of digital codecs for videoconferencing or visual telephony
H.140	11-1988	A multipoint international videoconference system
H.200	03-1993	Framework for Recommendations for audiovisual services
H.221	03-2004	Frame structure for a 64 to 1920 kbit/s channel in audiovisual teleservices
H.222.0	02-2000	Information technology – Generic coding of moving pictures and associated audio information: Systems
H.222.0 (2000) Technical Cor.1	03-2001	
H.222.0 (2000) Technical Cor.2	03-2002	
H.222.0 (2000) Amendment 1	12-2002	Carriage of metadata over ITU-T Rec. H.222.0 | ISO/IEC 13818-1 streams
H.222.0 (2000) Amend.1/Cor.1	06-2003	
H.222.0 Amendment 2	06-2003	Support of IPMP on MPEG-2 systems
H.222.0 (2000) Amendment 2 Erratum 1	02-2004	
H.222.0 (2000) Amendment 3	03-2004	Transport of AVC video data over ITU-T Rec. H.222.0 | ISO/IEC 13818-1 streams
H.222.1	03-1996	Multimedia multiplex and synchronization for audiovisual communication in ATM environments

H.223	07-2001	Multiplexing protocol for low bit rate multimedia communication
H.224	02-2000	A real time control protocol for simplex applications using the H.221 LSD/HSD/MLP channels
H.225.0	07-2003	Call signalling protocols and media stream packetization for packet-based multimedia communication systems
H.226	09-1998	Channel aggregation protocol for multilink operation on circuit-switched networks
H.230	03-2004	Frame-synchronous control and indication signals for audiovisual systems
H.231	07-1997	Multipoint control units for audiovisual systems using digital channels up to 1920 kbit/s
H.233	11-2002	Confidentiality system for audiovisual services
H.234	11-2002	Encryption key management and authentication system for audiovisual services
H.235	08-2003	Security and encryption for H-series (H.323 and other H.245-based) multimedia terminals
H.235 (2003) Amendment 1	04-2004	
H.239	07-2003	Role management and additional media channels for H.300-series terminals
H.241	07-2003	Extended video procedures and control signals for H.300-series terminals
H.241 (2003) Corrigendum 1	03-2004	
H.242	03-2004	System for establishing communication between audiovisual terminals using digital channels up to 2 Mbit/s
H.243	02-2000	Procedures for establishing communication between three or more audiovisual terminals using digital channels up to 1920 kbit/s
H.243 (2000) Corrigendum 1	11-2000	
H.244	07-1995	Synchronized aggregation of multiple 64 or 56 kbit/s channels
H.245	07-2003	Control protocol for multimedia communication
H.246	02-1998	Interworking of H-series multimedia terminals with H-series multimedia terminals and voice/voiceband terminals on GSTN and ISDN
H.246 Annex C	07-2003	Annex C: ISDN User Part function – H.225.0 interworking
H.246 Annex E1	11-2000	Mobile Application Part and H.225.0 interworking
H.246 Annex E2	11-2000	ANSI-41 (Americas) Mobile Application Part and H.225.0 interworking
H.246 Annex F	07-2001	H.323-H.324 Interworking
H.247	09-1998	Multipoint extension for broadband audiovisual communication systems and terminals
H.248.1	05-2002	Gateway control protocol: Version 2
H.248.1 V2 (2002) Corrigendum 1	03-2004	
H.248.2	11-2000	Gateway control protocol: Facsimile, text conversation and call discrimination packages
H.248.3	11-2000	Gateway control protocol: User interface elements and actions packages
H.248.3 (2000) Corrigendum 1	03-2004	

H.248.4	11-2000	Gateway control protocol: Transport over Stream Control Transmission Protocol (SCTP)
H.248.4 (2000) Corrigendum 1	03-2004	
H.248.5	11-2000	Gateway control protocol: Transport over ATM
H.248.6	11-2000	Gateway control protocol: Dynamic Tone Definition package
H.248.7	03-2004	Gateway control protocol: Generic Announcement package
H.248.8	03-2002	Gateway control protocol: Error code and service change reason description
H.248.8 (2002) Amendment 1	03-2004	New error code 458 (Unexpected Event/RequestID)
H.248.9	03-2002	Gateway control protocol: Advanced media server packages
H.248.10	07-2001	Gateway control protocol: Media gateway resource congestion handling package
H.248.11	11-2002	Gateway control protocol: Media gateway overload control package
H.248.12	07-2001	Gateway control protocol: H.248.1 packages for H.323 and H.324 interworking
H.248.12 (2001) Amendment 1	11-2002	New Annex A: Extended H.324, H.245 command and H.245 indication packages
H.248.13	03-2002	Gateway control protocol: Quality Alert Ceasing package
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H.248.17	11-2002	Gateway control protocol: Line test packages
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H.248.18	11-2002	Gateway control protocol: Package for support of multiple profiles
H.248.19	03-2004	Gateway control protocol: Decomposed multipoint control unit, audio, video and data conferencing packages
H.248.20	11-2002	Gateway control protocol: The use of local and remote descriptors with H.221 and H.223 multiplexing
H.248.21	03-2004	Gateway control protocol: Semi-permanent connection handling package
H.248.22	07-2003	Gateway control protocol: Shared Risk Group package
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H.248.23	07-2003	Gateway control protocol: Enhanced Alerting packages
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H.248.24	07-2003	Gateway control protocol: Multi-frequency tone generation and detection packages
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H.248.26	07-2003	Gateway control protocol: Enhanced analog lines packages
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H.248.27	07-2003	Gateway control protocol: Supplemental tones packages
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H.248.30	03-2004	Gateway control protocol: RTCP extended performance metrics packages
H.248.31	04-2004	Gateway control protocol: Adaptive jitter buffer package
H.261	03-1993	Video codec for audiovisual services at p x 64 kbit/s
H.262	02-2000	Information technology – Generic coding of moving pictures and associated audio information: Video
H.262 (2000) Technical Cor. 1	11-2000	
H.262 (2000) Amendment 1	11-2000	Content description data
H.262 (2000) Amendment 1 Erratum 1	04-2002	
H.263	02-1998	Video coding for low bit rate communication
H.263 Annex U	11-2000	Enhanced reference picture selection mode
H.263 Annex V	11-2000	Data-partitioned slice mode
H.263 Annex W	11-2000	Additional supplemental enhancement information specification
H.263 Annex X	03-2004	Profiles and levels definition
H.263 Appendix II	06-2001	Recommended optional enhancement
H.263 Appendix III	06-2001	Examples for H.263 encoder/decoder implementations
H.264	05-2003	Advanced video coding for generic audiovisual services
H.264 (2003) Cor.1	05-2004	
H.281	11-1994	A far end camera control protocol for videoconferences using H.224
H.282	05-1999	Remote device control protocol for multimedia applications
H.283	05-1999	Remote device control logical channel transport
H.310	09-1998	Broadband audiovisual communication systems and terminals
H.320	03-2004	Narrow-band visual telephone systems and terminal equipment
H.321	02-1998	Adaptation of H.320 visual telephone terminals to B-ISDN environments
H.322	03-1996	Visual telephone systems and terminal equipment for local area networks which provide a guaranteed quality of service
H.323	07-2003	Packet-based multimedia communications systems
H.324	03-2002	Terminal for low bit-rate multimedia communication
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H.331	03-1993	Broadcasting type audiovisual multipoint systems and terminal equipment
H.332	09-1998	H.323 extended for loosely coupled conferences
H.341	05-1999	Multimedia management information base
H.350	08-2003	Directory services architecture for multimedia conferencing
H.350.1	08-2003	Directory services architecture for H.323
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H.350.6	03-2004	Directory services architecture for call forwarding and preferences
H.360	03-2004	An architecture for end-to-end QoS control and signalling
H.450.1	02-1998	Generic functional protocol for the support of supplementary services in H.323
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H.450.3	02-1998	Call diversion supplementary service for H.323
H.450.4	05-1999	Call hold supplementary service for H.323
H.450.5	05-1999	Call park and call pickup supplementary services for H.323
H.450.5 Erratum 1	05-2000	
H.450.5 Erratum 2	04-2002	
H.450.6	05-1999	Call waiting supplementary service for H.323
H.450.7	05-1999	Message waiting indication supplementary service for H.323
H.450.8	02-2000	Name identification supplementary service for H.323
H.450.9	11-2000	Call completion supplementary services for H.323
H.450.10	03-2001	Call offering supplementary services for H.323
H.450.11	03-2001	Call intrusion supplementary service for H.323
H.450.12	07-2001	Common Information Addtional Network Feature for H.323
H.460.1	03-2002	Guidelines for the Use of the Generic Extensible Framework
H.460.2	07-2001	Number Portability interworking between H.323 and SCN networks
H.460.3	11-2002	Circuit maps within H.323 systems
H.460.4	11-2002	Call priority designation for H.323 calls
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H.460.6	11-2002	Extended Fast Connect feature
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H.460.9	11-2002	Support for online QoS-monitoring reporting within H.323 systems
H.460.9 (2002) Amendment 1	03-2004	New Annex B – Extended performance metrics
H.460.10	03-2004	Call party category within H.323 systems
H.460.11	03-2004	Delayed call establishment within H.323 systems
H.460.12	03-2004	Glare control indicator within H.323 systems
H.460.13	03-2004	Called user release control within H.323 systems
H.460.14	03-2004	Support for Multi-Level Precedence and Preemption (MLPP) within H.323 systems
H.460.15	03-2004	Call signalling transport channel suspension and redirection within H.323 systems
H.501	03-2002	Protocol for mobility management and intra/inter-domain communication in multimedia systems
H.510	03-2002	Mobility for H.323 multimedia systems and services
H.530	03-2002	Symmetric security procedures for H.323 mobility in H.510
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H.610	07-2003	Full service VDSL – System architecture and customer premises equipment
H.611	07-2003	Full-Service VDSL – Operations, Administration Maintenance & Provision aspects
H.Sup1	05-1999	Application profile – Sign language and lip-reading real-time conversation using low bit rate video communication
H.Sup2	01-2004	H.248.x sub-series packages guide – Release 5
H.Sup3	05-2003	Operator requirements for full-service VDSL in ITU-T Recommendations H.610 and H.611
H.Sup4	01-2004	Repository of generic parameters for the ITU-T Recommendations H.460.x sub-series

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		Integrated services digital network
I.112	03-1993	Vocabulary of terms for ISDNs
I.112 Appendix I	02-2002	General telecommunication terminology and definitions
I.113	06-1997	Vocabulary of terms for broadband aspects of ISDN
I.114	03-1993	Vocabulary of terms for universal personal telecommunication
I.120	03-1993	Integrated services digital networks (ISDNs)
I.121	04-1991	Broadband aspects of ISDN
I.122	03-1993	Framework for frame mode bearer services
I.130	11-1988	Method for the characterization of telecommunication services supported by an ISDN and network capabilities of an ISDN
I.140	03-1993	Attribute technique for the characterization of telecommunication services supported by an ISDN and network capabilities of an ISDN

I.141	11-1988	ISDN network charging capabilities attributes
I.150	02-1999	B-ISDN asynchronous transfer mode functional characteristics
I.200	11-1988	Guidance to the I.200-series of Recommendations
I.210	03-1993	Principles of telecommunication services supported by an ISDN and the means to describe them
I.211	03-1993	B-ISDN service aspects
I.220	11-1988	Common dynamic description of basic telecommunication services
I.221	03-1993	Common specific characteristics of services
I.230	11-1988	Definition of bearer service categories
		Circuit-mode bearer service categories
I.231.1	11-1988	Circuit-mode 64 kbit/s unrestricted, 8 kHz structured bearer service
I.231.2	11-1988	Circuit-mode 64 kbit/s, 8 kHz structured bearer service usable for speech information transfer
I.231.3	11-1988	Circuit-mode 64 kbit/s, 8 kHz structured bearer service usable for 3.1 kHz audio information transfer
I.231.4	11-1988	Circuit-mode, alternate speech / 64 kbit/s unrestricted, 8 kHz structured bearer service
I.231.5	11-1988	Circuit-mode 2 x 64 kbit/s unrestricted, 8 kHz structured bearer service
I.231.6	07-1996	Circuit-mode 384 kbit/s unrestricted, 8 kHz structured bearer service
I.231.7	07-1996	Circuit-mode 1536 kbit/s unrestricted, 8 kHz structured bearer service
I.231.8	07-1996	Circuit-mode 1920 kbit/s unrestricted, 8 kHz structured bearer service
I.231.9	03-1993	Circuit-mode 64 kbit/s 8 kHz structured multi-use bearer service
I.231.10	08-1992	Circuit-mode multiple-rate unrestricted 8 kHz structured bearer service
		Packet-mode bearer services categories
I.232.1	11-1988	Virtual call and permanent virtual circuit bearer service category
I.232.2	11-1988	Connectionless bearer service category
I.232.3	03-1993	User signalling bearer service category (USBS)
		Frame mode bearer services
I.233.1	10-1991	ISDN frame relaying bearer service
I.233.1 Annex F	07-1996	Frame relay multicast
I.233.2	10-1991	ISDN frame switching bearer service
I.240	11-1988	Definition of teleservices
		Teleservices supported by an ISDN
I.241.1	11-1988	Telephony
I.241.2	11-1988	Teletex
I.241.3	11-1988	Telefax 4
I.241.4	11-1988	Mixed mode

I.241.5	11-1988	Videotex
I.241.6	11-1988	Telex
I.241.7	03-1993	Telephony 7 kHz teleservice
I.241.8	10-1995	Teleaction stage one service description
I.250	11-1988	Definition of supplementary services
		Number identification supplementary services
I.251.1	08-1992	Direct-dialling-In
I.251.2	08-1992	Multiple Subscriber Number
I.251.3	08-1992	Calling Line Identification Presentation
I.251.4	08-1992	Calling Line Identification Restriction
I.251.5	02-1995	Connected Line Identification Presentation (COLP)
I.251.6	02-1995	Connected Line Identification Restriction (COLR)
I.251.7	08-1992	Malicious call Identification
I.251.8	08-1992	Sub-addressing supplementary service
I.251.9	07-1996	Calling name identification presentation
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		Call offering supplementary services
I.252.1	11-1988	Call Transfer
I.252.2	08-1992	Call Forwarding Busy
I.252.3	08-1992	Call Forwarding No Reply
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I.252.5	08-1992	Call Deflection
I.252.6	11-1988	Line Hunting (LH)
I.252.7	05-1997	Explicit call transfer
		Call completion supplementary services
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I.253.3	07-1996	Completion of calls to busy subscribers
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		Multiparty supplementary services
I.254.1	11-1988	Conference calling (CONF)
I.254.2	08-1992	Three-Party Supplementary Service
I.254.5	05-1997	Meet-me conference
		Community of interest supplementary services

I.255.1	08-1992	Closed User Group
I.255.2	07-1996	Support of Private Numbering Plans
I.255.3	07-1990	Multi-level precedence and preemption service (MLPP)
I.255.4	07-1990	Priority service
I.255.5	08-1992	Outgoing call barring
		Charging supplementary services
I.256.1	11-1988	Credit card calling (CRED)
I.256.2a	03-1993	Advice of charge: charging information at call set-up time (AOC-S)
I.256.2b	03-1993	Advice of charge: charging information during the call (AOC-D)
I.256.2c	03-1993	Advice of charge: charging information at the end of the call (AOC-E)
I.256.3	08-1992	Reverse charging
		Additional information transfer supplementary services
I.257.1	10-1995	User-to-User Signalling (UUS)
		Mobility and modification supplementary services
I.258.1	10-1995	Terminal portability (TP)
I.258.2	02-1995	In-call modification (IM)
		Screening supplementary services
I.259.1	07-1996	Address screening (ADS)
I.310	03-1993	ISDN – Network functional principles
I.311	08-1996	B-ISDN general network aspects
I.311 (1996) Amendment 1	03-2000	
I.312/Q.1201	10-1992	Principles of intelligent network architecture
I.313	09-1997	B-ISDN network requirements
I.320	11-1993	ISDN protocol reference model
I.321	04-1991	B-ISDN protocol reference model and its application
I.322	02-1999	Generic protocol reference model for telecommunication networks
I.324	10-1991	ISDN network architecture
I.325	03-1993	Reference configurations for ISDN connection types
I.326	03-2003	Functional architecture of transport networks based on ATM
I.327	03-1993	B-ISDN functional architecture
I.328/Q.1202	09-1997	Intelligent network – Service plane architecture
I.329/Q.1203	09-1997	Intelligent network – Global functional plane architecture
I.330	11-1988	ISDN numbering and addressing principles
E.164	05-1997	The international public telecommunication numbering plan

E.164 Supplement 1	03-1998	Alternatives for carrier selection and network identification
E.164 Supplement 2	11-1998	Number Portability
I.333	03-1993	Terminal selection in ISDN
I.334	11-1988	Principles relating ISDN numbers/sub-addresses to the OSI reference model network layer addresses
I.340	11-1988	ISDN connection types
I.350	03-1993	General aspects of quality of service and network performance in digital networks, including ISDNs
G.820/I.351/Y.1501	07-2004	Relationships among ISDN, IP-based network, and physical layer performance Recommendations
I.352	03-1993	Network performance objectives for connection processing delays in an ISDN
I.353	08-1996	Reference events for defining ISDN and B-ISDN performance parameters
I.354	03-1993	Network performance objectives for packet-mode communication in an ISDN
I.355	10-2000	ISDN 64 kbit/s connection type availability performance
I.356	03-2000	B-ISDN ATM layer cell transfer performance
I.356 (2000) Amendment 1	02-2004	New Appendix V – Support of Y.1541 QoS classes 0 and 2 in ATM-based networks
I.357	11-2000	B-ISDN semi-permanent connection availability
I.358	09-2003	Call processing performance for switched virtual channel connections (VCCs) in a B-ISDN
I.359	02-1999	Accuracy and dependability of ISDN 64 kbit/s circuit-mode connection types
I.361	02-1999	B-ISDN ATM layer specification
		B-ISDN ATM Adaptation Layer specification
I.363.1	08-1996	Type 1 AAL
I.363.2	11-2000	Type 2 AAL
I.363.3	08-1996	Type 3/4 AAL
I.363.5	08-1996	Type 5 AAL
I.364	02-1999	Support of the broadband connectionless data bearer service by the B-ISDN
		B-ISDN ATM adaptation layer sublayers
I.365.1	11-1993	Frame relaying service specific convergence sublayer (FR-SSCS)
I.365.2	11-1995	Service-specific coordination function to provide the connection-oriented network service
I.365.3	11-1995	Service-specific coordination function to provide the connection-oriented transport service
I.365.4	08-1996	Service-specific convergence sublayer for HDLC applications
I.366.1	06-1998	Segmentation and Reassembly Service Specific Convergence Sublayer for the AAL type 2
I.366.2	11-2000	AAL type 2 service specific convergence sublayer for narrow-band services

I.366.2 (2000) Corrigendum 1	03-2002	
I.370	10-1991	Congestion management for the ISDN frame relaying bearer service
I.371	03-2004	Traffic control and congestion control in B-ISDN
I.372	03-1993	Frame relaying bearer service network-to-network interface requirements
I.373	03-1993	Network capabilities to support universal personal telecommunication (UPT)
		Network capabilities to support multimedia services
I.375.1	06-1998	General aspects
I.375.2	06-1998	Example of multimedia retrieval service class – Video-on-demand service using an ATM-based network
I.375.3	03-2000	Example of multimedia distribution service class – Switched digital broadcasting
I.376	03-1995	ISDN network capabilities for the support of the teleaction service
I.377	10-2000	Network requirements to support charging and accounting in B-ISDN
I.378	12-2002	Traffic control and congestion control at the ATM Adaptation Layer type 2
I.378 (2002) Amendment 1	08-2003	New Appendix IV: Deriving AAL 2 traffic parameters from AAL 2 link characteristics
I.381	03-2001	ATM adaptation layer (AAL) Performance
I.410	11-1988	General aspects and principles relating to Recommendations on ISDN user-network interfaces
I.411	03-1993	ISDN user-network interfaces – Reference configurations
I.412	11-1988	ISDN user-network interfaces – Interface structures and access capabilities
I.413	03-1993	B-ISDN user-network interface
I.414	09-1997	Overview of Recommendations on layer 1 for ISDN and B-ISDN customer accesses
I.420	11-1988	Basic user-network interface
I.421	11-1988	Primary rate user-network interface
I.430	11-1995	Basic user-network interface – Layer 1 specification
I.431	03-1993	Primary rate user-network interface – Layer 1 specification
I.431 (1993) Amendment 1	06-1997	
		B-ISDN user-network interface – Physical layer specification
I.432.1	02-1999	General characteristics
I.432.2	02-1999	155 520 kbit/s and 622 080 kbit/s operation
I.432.3	02-1999	1544 kbit/s and 2048 kbit/s operation
I.432.4	02-1999	51 840 kbit/s operation
I.432.5	06-1997	25 600 kbit/s operation
Q.920	03-1993	ISDN user-network interface data link layer – General aspects
Q.920 (1993) Amendment 1	06-2000	

Q.921	09-1997	ISDN user-network interface – Data link layer specification
Q.921 (1997) Amendment 1	06-2000	
Q.930	03-1993	ISDN user-network interface layer 3 – General aspects
Q.931	05-1998	ISDN user-network interface layer 3 specification for basic call control
Q.931 (1998) Amendment 1	12-2002	Extensions for the support of digital multiplexing equipment
Q.931 (1998) Erratum 1	02-2003	
I.460	02-1999	Multiplexing, rate adaption and support of existing interfaces
X.30	03-1993	Support of X.21, X.21 bis and X.20 bis based Data Terminal Equipments (DTEs) by an Integrated Services Digital Network (ISDN)
X.31	11-1995	Support of packet mode terminal equipment by an ISDN
V.110	02-2000	Support by an ISDN of data terminal equipments with V-series type interfaces
I.464	02-1999	Multiplexing, rate adaption and support of existing interfaces for restricted 64 kbit/s transfer capability
V.120	10-1996	Support by an ISDN of data terminal equipment with V-series type interfaces with provision for statistical multiplexing
V.120 (1996) Corrigendum 1	05-1999	
I.470	11-1988	Relationship of terminal functions to ISDN
I.480	03-2000	1+1 protection switching for cell-based physical layer
I.500	03-1993	General structure of the ISDN interworking Recommendations
I.501	03-1993	Service interworking
I.510	03-1993	Definitions and general principles for ISDN interworking
I.511	11-1988	ISDN-to-ISDN layer 1 internetwork interface
I.515	03-1993	Parameter exchange for ISDN interworking
I.520	03-1993	General arrangements for network interworking between ISDNs
I.525	08-1996	Interworking between networks operating at bit rates less than 64 kbit/s with 64 kbit/s-based ISDN and B-ISDN
I.530	03-1993	Network interworking between an ISDN and a public switched telephone network (PSTN)
X.321	10-1996	General arrangements for interworking between Circuit-Switched Public Data Networks (CSPDNs) and Integrated Services Digital Networks (ISDNs) for the provision of data transmission services
X.325	10-1996	General arrangements for interworking between Packet-Switched Public Data Networks (PSPDNs) and Integrated Services Digital Networks (ISDNs) for the provision of data transmission services
I.555	09-1997	Frame Relaying Bearer Service interworking
U.202	03-1993	Technical requirements to be met in providing the international telex service within an integrated services digital network
I.570	03-1993	Public/private ISDN interworking
I.571	08-1996	Connection of VSAT based private networks to the public ISDN

I.572	03-2000	VSAT interconnection with the PSTN
I.580	11-1995	General arrangements for interworking between B-ISDN and 64 kbit/s based ISDN
I.581	09-1997	General arrangements for B-ISDN interworking
I.601	11-1988	General maintenance principles of ISDN subscriber access and subscriber installation
I.610	02-1999	B-ISDN operation and maintenance principles and functions
I.610 (1999) Corrigendum 1	03-2000	
I.610 (1999) Amendment 1	03-2000	
I.630	02-1999	ATM protection switching
I.630 (1999) Corrigendum 1	03-2000	
I.630 (1999) Amendment 1	03-2000	
I.731	10-2000	Types and general characteristics of ATM equipment
I.732	10-2000	Functional characteristics of ATM equipment
I.741	07-1999	Interworking and interconnection between ATM and switched telephone networks for the transmission of speech, voiceband data and audio signals
I.751	03-1996	Asynchronous transfer mode management of the network element view
I.761	03-2000	Inverse multiplexing for ATM (IMA)
I.762	03-2000	ATM over fractional physical links
I.Sup1	03-1998	Generic service descriptions for ten supplementary services defined in I.250-Series Recommendations

Series J : Cable networks and transmission of television, sound programme and other multimedia signals

Number	*Approval Date*	*Recommendation Title*
		Cable networks and transmission of television, sound programme and other multimedia signals
J.2	09-1999	Guidelines on the use of some ITU-T Recommendations in the J series
J.11	11-1988	Hypothetical reference circuits for sound-programme transmissions
J.12	11-1988	Types of sound-programme circuits established over the international telephone network
J.13	11-1988	Definitions for international sound-programme circuits
J.14	11-1988	Relative levels and impedances on an international sound-programme connection
J.15	11-1988	Lining-up and monitoring an international sound-programme connection
J.16	11-1988	Measurement of weighted noise in sound-programme circuits
J.17	11-1988	Pre-emphasis used on sound-programme circuits
J.18	11-1988	Crosstalk in sound-programme circuits set up on carrier systems

J.19	11-1988	A conventional test signal simulating sound-programme signals for measuring interference in other channels
J.21	08-1994	Performance characteristics of 15 kHz-type sound-programme circuits – Circuits for high quality monophonic and stereophonic transmissions
J.23	11-1988	Performance characteristics of 7 kHz type (narrow bandwidth) sound-programme circuits
J.24	02-1982	Modulation of signals carried by sound-programme circuits by interfering signals from power supply sources
J.25	05-1986	Estimation of transmission performance of sound-programme circuits shorter or longer than the hypothetical reference circuit
J.26	06-1990	Test signals to be used on international sound-programme connections
J.27	06-1990	Signals for the alignment of international sound-programme connections
J.41	11-1988	Characteristics of equipment for the coding of analogue high quality sound programme signals for transmission on 384 kbit/s channels
J.42	11-1988	Characteristics of equipment for the coding of analogue medium quality sound-programme signals for transmission on 384-kbit/s channels
J.51	08-1994	General principles and user requirements for the digital transmission of high quality sound programmes
J.52	07-1996	Digital transmission of high-quality sound-programme signals using one, two or three 64 kbit/s channels per mono signal (and up to six per stereo signal)
J.52 (1996) Amendment 1	09-1999	New Appendix II – Extracts from EBU specification of an ISDN Codec capable of delivering high-quality audio
J.53	05-2000	Sampling frequencies to be used for the digital transmission of studio-quality and high-quality sound-programme signals
J.54	05-1986	Transmission of analogue high-quality sound-programme signals on mixed analogue-and-digital circuits using 384 kbit/s channels
J.55	06-1990	Digital transmission of high-quality sound-programme signals on distribution circuits using 480 kbit/s (496 kbit/s) per audio channel
J.57	06-1990	Transmission of digital studio quality sound signals over H1 channels
J.61	06-1990	Transmission performance of television circuits designed for use in international connections
J.62	02-1978	Single value of the signal-to-noise ratio for all television systems
J.63	06-1990	Insertion of test signals in the field-blanking interval of monochrome and colour television signals
J.64	02-1986	Definitions of parameters for simplified automatic measurement of television insertion test signals
J.65	02-1978	Standard test signal for conventional loading of a television channel
J.66	02-1978	Transmission of one sound programme associated with analogue television signal by means of time division multiplex in the line synchronizing pulse
J.67	03-2001	Test signals and measurement techniques for transmission circuits carrying MAC/packet signals
J.68	02-1982	Hypothetical reference chain for television transmissions over very long distances
J.80	09-1993	Transmission of component-coded digital television signals for contribution-quality applications at bit rates near 140 Mbit/s
J.81	09-1993	Transmission of component-coded digital television signals for contribution-quality applications at the third hierarchical level of ITU-T Recommendation G.702
J.81 (1993) Amendment 1	10-1995	Appendix II to Annex A to Recommendation J.81 – Guidelines for implementation of a complete television codec

J.81 (1993) Corrigendum 1	10-1996	
J.81 (1993) Amendment 2	03-1998	Appendix IV to Annex A – Results of 34 Mbit/s codec interworking tests (February 1996)
J.82	07-1996	Transport of MPEG-2 constant bit rate television signals in B-ISDN
J.83	04-1997	Digital multi-programme systems for television, sound and data services for cable distribution
J.83 (1997) Erratum 1	07-1998	
J.84	03-2001	Distribution of digital multi-programme signals for television, sound and data services through SMATV networks
J.85	06-1990	Digital television transmission over long distances – General principles
J.86	06-1990	Mixed analogue-and-digital transmission of analogue composite television signals over long distances
J.87	03-2001	Use of hybrid cable television links for the secondary distribution of television into the user's premises
J.88	09-1999	Transmission of enhanced definition television signals over digital links
J.89	09-1999	Transport Mechanism for component-coded digital television signals using MPEG-2 4:2:2 P@ML including all service elements for contribution and primary distribution
J.90	05-2000	Electronic programme guides for delivery by digital cable television and similar methods – Reference operating scenario and requirements
J.91	08-1994	Technical methods for ensuring privacy in long-distance international television transmission
J.92	04-1997	Recommended operating guidelines for point-to-point transmission of television programmes
J.93	03-1998	Requirements for conditional access in the secondary distribution of digital television on cable television systems
J.94	11-1998	Service information for digital broadcasting in cable television systems
J.94 (1998) Amendment 1	10-2000	Annex B – Service information delivered out of band for digital cable television systems
J.94 (1998) Amendment 2	03-2001	Revised Annex C – Service information for digital multi-programme System C
J.95	09-1999	Copy protection of intellectual property for content delivered on cable television systems
J.96	07-2002	Technical method for ensuring privacy in long-distance international MPEG-2 television transmission conforming to ITU-T Recommendation J.89
J.97	07-2002	Metadata on cable networks
J.98	05-2003	Metadata requirements for video-on-demand in cable networks
J.100	06-1990	Tolerances for transmission time differences between the vision and sound components of a television signal
J.101	06-1990	Measurement methods and test procedures for teletext signals
J.110	04-1997	Basic principles for a worldwide common family of systems for the provision of interactive television services
J.111	03-1998	Network independent protocols for interactive systems
J.112	03-1998	Transmission systems for interactive cable television services

J.112 Annex A	03-2001	Digital Video Broadcasting: DVB interaction channel for Cable TV (CATV) distribution systems
J.112 Annex B	03-2004	Data-over-cable service interface specifications: Radio-frequency interface specification
J.112 Annex C	02-2002	Data-over-cable service interface specifications: Radio-frequency interface specification using QAM technique
J.113	03-1998	Digital video broadcasting interaction channel through the PSTN/ISDN
J.114	09-1999	Interaction channel using digital enhanced cordless telecommunications
J.115	09-1999	Interaction channel using the global system for mobile communications
J.116	05-2000	Interaction channel for local multipoint distribution systems
J.117	09-1999	Home digital network interface specification
J.118	05-2000	Access systems for interactive services on SMATV/MATV networks
J.120	05-2000	Distribution of sound and television programs over the IP network
J.121	02-2002	Quality control protocol for webcasting
J.122	12-2002	Second-generation transmission systems for interactive cable television services – IP cable modems
J.123	07-2002	Multiplexing format for webcasting on the TCP/IP network
J.124	03-2004	Multiplexing format for multimedia webcasting over TCP/IP networks
J.125	04-2004	Link privacy for cable modem implementations
J.126	04-2004	Embedded CableModem device specification
J.131	03-1998	Transport of MPEG-2 signals in PDH networks
J.132	03-1998	Transport of MPEG-2 signals in SDH networks
J.133	07-2002	Measurement of MPEG-2 transport streams in networks
J.140	03-1998	Subjective picture quality assessment for digital cable television systems
J.141	09-1999	Performance indicators for data services delivered over digital cable television systems
J.142	05-2000	Methods for the measurement of parameters in the transmission of digital cable television signals
J.143	05-2000	User requirements for objective perceptual video quality measurements in digital cable television
J.144	03-2004	Objective perceptual video quality measurement techniques for digital cable television in the presence of a full reference
J.145	03-2001	Measurement and control of the quality of service for sound transmission over contribution and distribution networks
J.146	07-2002	Loop latency issues in contribution circuits for conversational TV programmes
J.147	07-2002	Objective picture quality measurement method by use of in-service test signals
J.148	05-2003	Requirements for an objective perceptual multimedia quality model
J.149	03-2004	Method for specifying accuracy and cross-calibration of Video Quality Metrics (VQM)
J.150	03-1998	Operational functionalities for the delivery of digital multiprogramme television, sound and data services through multichannel, multipoint distribution systems (MMDS)

J.150 (1998) Amendment 1	09-1999	Additions to Recommendation J.150 to also encompass local multipoint distribution systems (LMDS)
J.150 (1998) Amendment 2	03-2001	
J.151	10-2000	RF remodulator interface for digital television
J.160	02-2002	Architectural framework for the delivery of time-critical services over cable television networks using cable modems
J.161	03-2001	Audio codec requirements for the provision of bidirectional audio service over cable television networks using cable modems
J.162	03-2004	Network call signalling protocol for the delivery of time-critical services over cable television networks using cable modems
J.163	03-2004	Dynamic quality of service for the provision of real-time services over cable television networks using cable modems
J.164	03-2001	Event message requirements for the support of real-time services over cable television networks using cable modems
J.165	05-2003	IPCablecom Internet signalling transport protocol (ISTP)
J.166	03-2001	IPCablecom Management Information Base (MIB) framework
J.167	03-2001	Media terminal adapter (MTA) device provisioning requirements for the delivery of real-time services over cable television networks using cable modems
J.168	03-2001	IPCablecom Media Terminal Adapter (MTA) MIB requirements
J.169	03-2001	IPCablecom network call signalling (NCS) MIB requirements
J.170	02-2002	IPCablecom security specification
J.171	02-2002	IPCablecom Trunking Gateway Control Protocol (TGCP)
J.171 (2002) Amendment 1	05-2003	TGCP Profile 2
J.172	02-2002	IPCablecom management event mechanism
J.173	02-2002	IPCablecom embedded MTA primary line support
J.174	02-2002	IPCablecom interdomain quality of service
J.175	07-2002	Audio server protocol
J.176	07-2002	IPCablecom management event mechanism MIB
J.177	05-2003	IPCablecom CMS subscriber provisioning specification
J.178	05-2003	IPCablecom CMS to CMS signalling
J.179	04-2004	IPCablecom support for multimedia
J.180	05-2000	User requirements for statistical multiplexing of several programmes on a transmission channel
J.182	03-2001	Parameter sets for analogue interface specifications for the interconnection of set-top boxes and presentation devices in the home
J.183	03-2001	Time-division multiplexing of multiple MPEG-2 transport streams over cable television systems
J.184	03-2001	Digital broadband delivery system: Out-of-band transport
J.185	02-2002	Transmission equipment for transferring multi-channel television signals over optical access networks by FM conversion

J.186	02-2002	Transmission equipment for multi-channel television signals over optical access networks by sub-carrier multiplexing (SCM)
J.187	07-2002	Transport mechanism for component-coded digital high-definition television signals using MPEG-2 video coding including all service elements for contribution and primary distribution
J.187 (2002) Corrigendum 1	04-2003	
J.188	07-2002	A framework for an efficient parallel video transmission system including codecs with functions of failure detection and picture quality evaluation
J.189	07-2002	Seamless splicing for MPEG-2 bit streams
J.189 (2002) Corrigendum 1	04-2003	
J.190	07-2002	Architecture of MediaHomeNet that supports cable-based services
J.191	03-2004	IP feature package to enhance cable modems
J.192	03-2004	A residential gateway to support the delivery of cable data services
J.200	03-2001	Worldwide common core – Application environment for digital interactive television services
J.200 (2001) Corrigendum 1	05-2004	
J.202	05-2003	Harmonization of procedural content formats for interactive TV applications
J.240	06-2004	Framework for remote monitoring of transmitted picture signal-to-noise ratio using spread-spectrum and orthogonal transform
J.280	03-2004	Digital Program Insertion: Splicing application programming interface
J.Sup1	11-1998	Example of linking options between annexes of ITU-T Recommendation J.112 and annexes of ITU-T Recommendation J.83
J.Sup2	11-1998	Guidelines for the implementation of annex A of Recommendation J.112, "Transmission systems for interactive cable television services" – Example of digital video broadcasting (DVB) interaction channel for cable television distribution
J.Sup3	11-1998	Guidelines for the implementation of Recommendation J.111 "Network independent protocols" – Example of digital video broadcasting (DVB) systems for interactive services
J.Sup5	09-1999	Guidelines on the use of some ITU-T Recommendations in the J series

Series K : Protection against interference

Number	*Approval Date*	*Recommendation Title*
		Protection against interference
K.5	11-1988	Joint use of poles for electricity distribution and for telecommunications
K.6	11-1988	Precautions at crossings
K.7	11-1988	Protection against acoustic shock
K.8	11-1988	Separation in the soil between telecommunication cables and earthing system of power facilities
K.9	11-1988	Protection of telecommunication staff and plant against a large earth potential due to a neighbouring electric traction line
K.10	10-1996	Low frequency interference due to unbalance about earth of telecommunication equipment

K.11	10-1993	Principles of protection against overvoltages and overcurrents
K.12	02-2000	Characteristics of gas discharge tubes for the protection of telecommunications installations
K.13	11-1988	Induced voltages in cables with plastic-insulated conductors
K.14	11-1988	Provision of a metallic screen in plastic-sheathed cables
K.18	11-1988	Calculation of voltage induced into telecommunication lines from radio station broadcasts and methods of reducing interference
K.19	11-1988	Joint use of trenches and tunnels for telecommunication and power cables
K.20	07-2003	Resistibility of telecommunication equipment installed in a telecommunications centre to overvoltages and overcurrents
K.20 (2003) Erratum 1	01-2004	Correction to table 7/K.20
K.21	07-2003	Resistibility of telecommunication equipment installed in customer premises to overvoltages and overcurrents
K.21 (2003) Erratum 1	01-2004	Correction to table 7/K.21
K.23	11-1988	Types of induced noise and description of noise voltage parameters for ISDN basic user networks
K.24	11-1988	Method for measuring radio-frequency induced noise on telecommunications pairs
K.25	02-2000	Protection of optical fibre cables
K.26	11-1988	Protection of telecommunication lines against harmful effects from electric power and electrified railway lines
K.27	05-1996	Bonding configurations and earthing inside a telecommunication building
K.28	03-1993	Characteristics of semi-conductor arrester assemblies for the protection of telecommunications installations
K.29	01-1992	Coordinated protection schemes for telecommunication cables below ground
K.30	03-1993	Positive temperature coefficient (PTC) thermistors
K.31	03-1993	Bonding configurations and earthing of telecommunication installations inside a subscriber's building
K.33	10-1996	Limits for people safety related to coupling into telecommunications system from a.c. electric power and a.c. electrified railway installations in fault conditions
K.34	07-2003	Classification of electromagnetic environmental conditions for telecommunication equipment – Basic EMC Recommendation
K.35	05-1996	Bonding configurations and earthing at remote electronic sites
K.36	05-1996	Selection of protective devices
K.37	02-1999	Low and high frequency EMC mitigation techniques for telecommunication installations and systems – Basic EMC Recommendation
K.38	10-1996	Radiated emission test procedure for physically large systems
K.39	10-1996	Risk assessment of damages to telecommunication sites due to lightning discharges
K.40	10-1996	Protection against LEMP in telecommunications centres
K.42	05-1998	Preparation of emission and immunity requirements for telecommunication equipment – General principles
K.43	07-2003	Immunity requirements for telecommunication equipment

K.44	07-2003	Resistibility tests for telecommunication equipment exposed to overvoltages and overcurrents – Basic Recommendation
K.45	07-2003	Resistibility of telecommunication equipment installed in the access and trunk networks to overvoltages and overcurrents
K.46	07-2003	Protection of telecommunication lines using metallic symmetric conductors against lightning-induced surges
K.47	12-2000	Protection of telecommunication lines using metallic conductors against direct lightning discharges
K.48	07-2003	EMC requirements for each telecommunication equipment – Product family Recommendation
K.49	02-2000	Test condition and performance criteria for voice terminal subject to disturbance from digital mobile phone
K.50	02-2000	Safe limits of operating voltages and currents for telecommunication systems powered over the network
K.51	02-2000	Safety criteria for telecommunication equipment
K.52	02-2000	Guidance on complying with limits for human exposure to electromagnetic fields
K.53	02-2000	Values of induced voltages on telecommunication installations to establish telecom and a.c. power and railway operators responsibilities
K.54	10-2000	Conducted immunity test method and level at fundamental power frequencies
K.54 (2000) Erratum 1	08-2002	
K.55	08-2002	Overvoltage and overcurrent requirements for insulation displacement connectors (IDC) terminations
K.56	07-2003	Protection of radio base stations against lightning discharges
K.57	09-2003	Protection measures for radio base stations sited on power line towers
K.58	07-2003	EMC, resistibility and safety requirements and procedures for co-located telecommunication installations
K.59	07-2003	EMC, resistibility and safety requirements and procedures for connection to unbundled cables
K.60	07-2003	Emission limits and test methods for telecommunication networks
K.61	09-2003	Guidance to measurement and numerical prediction of electromagnetic fields for compliance with human exposure limits for telecommunication installations
K.62	02-2004	System level radiated emissions compliance using mathematical modelling
K.63	02-2004	Maintaining the suitability of production telecommunications equipment to its intended electromagnetic environment
K.64	02-2004	Safe working practices for outside equipment installed in particular environments

Series L : Construction, installation and protection of cables and other elements of outside plant

Number	*Approval Date*	*Recommendation Title*
		Construction, installation and protection of cables and other elements of outside plant
L.1	11-1988	Construction, installation and protection of telecommunication cables in public networks
L.2	11-1988	Impregnation of wooden poles

L.3	11-1988	Armouring of cables
L.4	11-1988	Aluminium cable sheaths
L.5	11-1988	Cable sheaths made of metals other than lead or aluminium
L.6	11-1988	Methods of keeping cables under gas pressure
L.7	11-1988	Application of joint cathodic protection
L.8	11-1988	Corrosion caused by alternating current
L.9	11-1988	Methods of terminating metallic cable conductors
L.10	12-2002	Optical fibre cables for duct and tunnel application
L.11	11-1988	Joint use of tunnels by pipelines and telecommunication cables, and the standardization of underground duct plans
L.12	05-2000	Optical fibre joints
L.13	04-2003	Performance requirements for passive optical nodes: Sealed closures for outdoor environments
L.14	07-1992	Measurement method to determine the tensile performance of optical fibre cables under load
L.15	03-1993	Optical local distribution networks – Factors to be considered for their construction
L.16	03-1993	Conductive plastic material (CPM) as protective covering for metal cable sheaths
L.17	06-1995	Implementation of connecting customers into the public switched telephone network (PSTN) via optical fibres
L.17 Appendix I	02-1997	Examples of possible applications
L.18	10-1996	Sheath closures for terrestrial copper telecommunication cables
L.19	11-2003	Multi-pair copper network cable supporting shared multiple services such as POTS, ISDN and xDSL
L.20	10-1996	Creation of a fire security code for telecommunication facilities
L.21	10-1996	Fire detection and alarm systems, detector and sounder devices
L.22	10-1996	Fire protection
L.23	10-1996	Fire extinction – Classification and location of fire extinguishing installations and equipment on premises
L.24	10-1996	Classification of outside plant waste
L.25	10-1996	Optical fibre cable network maintenance
L.26	12-2002	Optical fibre cables for aerial application
L.27	10-1996	Method for estimating the concentration of hydrogen in optical fibre cables
L.28	10-2002	External additional protection for marinized terrestrial cables
L.29	01-2002	As-laid report and maintenance/repair log for marinized terrestrial cable installation
L.30	10-1996	Markers on marinized terrestrial cables
L.31	10-1996	Optical fibre attenuators
L.32	10-1998	Protection devices for through-cable penetrations of fire-sector partitions
L.33	10-1998	Periodic control of fire extinction devices in telecommunication buildings

L.34	10-1998	Installation of Optical Fibre Ground Wire (OPGW) cable
L.35	10-1998	Installation of optical fibre cables in the access network
L.36	10-1998	Single mode fibre optic connectors
L.37	10-1998	Fibre optic (non-wavelength selective) branching devices
L.38	09-1999	Use of trenchless techniques for the construction of underground infrastructures for telecommunication cable installation
L.39	05-2000	Investigation of the soil before using trenchless techniques
L.40	10-2000	Optical fibre outside plant maintenance support, monitoring and testing system
L.41	05-2000	Maintenance wavelength on fibres carrying signals
L.42	05-2003	Extending optical fibre solutions into the access network
L.43	12-2002	Optical fibre cables for buried application
L.44	10-2000	Electric power supply for equipment installed as outside plant
L.45	10-2000	Minimizing the effect on the environment from the outside plant in telecommunication networks
L.46	10-2000	Protection of telecommunication cables and plant from biological attack
L.47	10-2000	Access facilities using hybrid fibre/copper networks
L.48	03-2003	Mini-trench installation technique
L.49	03-2003	Micro-trench installation technique
L.50	11-2003	Requirements for passive optical nodes: Optical distribution frames for central office environments
L.51	04-2003	Passive node elements for fibre optic networks – General principles and definitions for characterization and performance evaluation
L.52	05-2003	Deployment of Passive Optical Networks (PON)
L.53	05-2003	Optical fibre maintenance criteria for access networks
L.54	02-2004	Splice closure for marinized terrestrial cables (MTC)
L.55	11-2003	Digital database for marine cables and pipelines
L.56	05-2003	Installation of optical fibre cables along railways
L.57	05-2003	Air-assisted installation of optical fibre cables
L.58	03-2004	Optical fibre cables: Special needs for access network

Series M : TMN and network maintenance: international transmission systems, telephone circuits, telegraphy, facsimile and leased circuits

Number	*Approval Date*	*Recommendation Title*
		TMN and network maintenance: international transmission systems, telephone circuits, telegraphy, facsimile and leased circuits
M.10	10-1992	Scope and application of Recommendations for maintenance of telecommunication networks and services
M.15	11-1988	Maintenance considerations for new systems

M.20	10-1992	Maintenance philosophy for telecommunication networks
M.21	10-1992	Maintenance philosophy for telecommunication services
M.32	11-1988	Principles for using alarm information for maintenance of international transmission systems and equipment
M.34	11-1988	Performance monitoring on international transmission systems and equipment
M.35	11-1988	Principles concerning line-up and maintenance limits
M.50	11-1988	Use of telecommunication terms for maintenance
M.60	03-1993	Maintenance terminology and definitions
M.70	11-1988	Guiding principles on the general maintenance organization for telephone-type international circuits
M.75	10-1992	Technical service
M.80	11-1988	Control stations
M.85	10-1992	Fault report points
M.90	11-1988	Sub-control stations
M.100	11-1988	Service circuits
M.110	11-1988	Circuit testing
M.120	11-1988	Access points for maintenance
M.125	11-1988	Digital loopback mechanisms
M.160	11-1988	Stability of transmission
M.320	11-1988	Numbering of the channels in a group
M.330	11-1988	Numbering of groups within a supergroup
M.340	11-1988	Numbering of supergroups within a mastergroup
M.350	11-1988	Numbering of mastergroups within a supermastergroup
M.380	11-1988	Numbering in coaxial systems
M.390	11-1988	Numbering in systems on symmetric pair cable
M.400	11-1988	Numbering in radio-relay links or open-wire line systems
M.410	11-1988	Numbering of digital blocks in transmission systems
M.450	11-1988	Bringing a new international transmission system into service
M.460	11-1988	Bringing international group, supergroup, etc., links into service
M.470	11-1988	Setting up and lining up analogue channels for international telecommunication services
M.475	11-1988	Setting up and lining up mixed analogue/digital channels for international telecommunication services
M.495	11-1988	Transmission restoration and transmission route diversity: Terminology and general principles
M.496	11-1988	Functional organization for automatic transmission restoration
M.500	11-1988	Routine maintenance measurements to be made on regulated line sections

M.510	11-1988	Readjustment to the nominal value of a regulated line section (on a symmetric pair line, a coaxial line or a radio-relay link)
M.520	11-1988	Routine maintenance on international group, supergroup, etc., links
M.525	11-1988	Automatic maintenance procedures for international group, supergroup, etc., links
M.530	11-1988	Readjustment to the nominal value of an international group, supergroup, etc., link
M.535	11-1988	Special maintenance procedures for multiple destination, unidirectional (MU) group and supergroup links
M.540	11-1988	Routine maintenance of carrier and pilot generating equipment
M.556	11-1988	Setting up and initial testing of digital channels on an international digital path or block
M.560	11-1988	International telephone circuits – Principles, definitions and relative transmission levels
M.562	11-1988	Types of circuit and circuit section
M.565	11-1988	Access points for international telephone circuits
M.570	11-1988	Constitution of the circuit; preliminary exchange of information
M.580	11-1988	Setting up and lining up an international circuit for public telephony
M.585	11-1988	Bringing an international digital circuit into service
M.590	11-1988	Setting up and lining up a circuit fitted with a compandor
M.600	11-1988	Organization of routine maintenance measurements on circuits
M.605	11-1988	Routine maintenance schedule for international public telephony circuits
M.610	11-1988	Periodicity of maintenance measurements on circuits
M.620	11-1988	Methods for carrying out routine measurements on circuits
M.630	11-1988	Maintenance of circuits using control chart methods
M.650	11-1988	Routine line measurements to be made on the line repeaters of audio-frequency sections or circuits
M.660	11-1988	Periodical in-station tests of echo suppressors complying with Recommendations G.161 and G.164
M.665	11-1988	Testing of echo cancellers
M.670	11-1988	Maintenance of a circuit fitted with a compandor
M.675	11-1988	Lining up and maintaining international demand assignment circuits (SPADE)
M.710	11-1988	General maintenance organization for the international automatic and semi-automatic telephone service
M.715	11-1988	Fault report point (circuit)
M.716	11-1988	Fault report point (network)
M.717	11-1988	Testing point (transmission)
M.718	11-1988	Testing point (line signalling)
M.719	11-1988	Testing point (switching and interregister signalling)
M.720	11-1988	Network analysis point
M.721	11-1988	System availability information point

M.722	11-1980	Network management point
M.723	11-1988	Circuit control station
M.724	11-1988	Circuit sub-control station
M.725	11-1988	Restoration control point
M.726	11-1988	Maintenance organization for the wholly digital international automatic and semi-automatic telephone service
M.729	11-1988	Organization of the maintenance of international public switched telephone circuits used for data transmission
M.730	11-1988	Maintenance methods
M.731	11-1988	Subjective testing
M.732	11-1988	Signalling and switching routine maintenance tests and measurements
M.733	11-1988	Transmission routine maintenance measurements on automatic and semi-automatic telephone circuits
M.734	11-1988	Exchange of information on incoming test facilities at international switching centres
M.760	11-1988	Transfer link for common channel Signalling System No. 6
M.762	11-1988	Maintenance of common channel Signalling System No. 6
M.800	11-1988	Use of circuits for voice-frequency telegraphy
M.810	11-1988	Setting up and lining up an international voice-frequency telegraph link for public telegraph circuits (for 50, 100 and 200 baud modulation rates)
M.820	11-1988	Periodicity of routine tests on international voice-frequency telegraph links
M.830	11-1988	Routine measurements to be made on international voice-frequency telegraph links
M.850	11-1988	International time division multiplex (TDM) telegraph systems
M.880	11-1988	International phototelegraph transmission
M.900	11-1988	Use of leased group and supergroup links for wide-spectrum signal transmission (data, facsimile, etc.)
M.910	11-1988	Setting up and lining up an international leased group link for wide-spectrum signal transmission
M.1010	11-1988	Constitution and nomenclature of international leased circuits
M.1012	11-1988	Circuit control station for leased and special circuits
M.1013	11-1988	Sub-control station for leased and special circuits
M.1014	11-1988	Transmission maintenance point (international line) (TMP-IL)
M.1015	11-1988	Types of transmission on leased circuits
M.1016	11-1988	Assessment of the service availability performance of international leased circuits
M.1020	03-1993	Characteristics of special quality international leased circuits with special bandwidth conditioning
M.1025	03-1993	Characteristics of special quality international leased circuits with basic bandwidth conditioning
M.1030	11-1988	Characteristics of ordinary quality international leased circuits forming part of private switched telephone networks
M.1040	11-1988	Characteristics of ordinary quality international leased circuits

M.1045	05-1996	Preliminary exchange of information for the provision of international leased circuits and international data transmission systems
M.1050	06-1998	Lining up an international point-to-point leased circuit with analogue presentation to the user
M.1055	11-1988	Lining up an international multiterminal leased circuit
M.1060	11-1988	Maintenance of international leased circuits
M.1130	10-1992	General definitions and general principles of operation/maintenance procedures to be used in satellite mobile systems
M.1140	10-1992	Maritime mobile telecommunication services via satellite
M.1150	04-1997	Maintenance aspects of maritime/land mobile telecommunication store-and-forward services (packet mode) via satellite
M.1160	04-1997	Maintenance aspects of aeronautical mobile telecommunication service via satellite
M.1170	04-1997	Maintenance aspects of mobile digital telecommunication service via satellite
M.1230	05-1996	Method to improve the management of operations and maintenance processes in the international telephone network
M.1235	11-1988	Use of automatically generated test calls for assessment of network performance
M.1300	10-1997	Maintenance of international data transmission systems operating in the range 2.4 kbit/s to 140 Mbit/s
M.1301	01-2001	General description and operational procedures for international SDH leased circuits
M.1320	11-1988	Numbering of channels in data transmission systems
M.1340	02-2000	Performance objectives, allocations and limits for international PDH leased circuits and supporting data transmission links and systems
M.1340 (2000) Cor.1	08-2001	
M.1350	11-1988	Setting up, lining up and characteristics of international data transmission systems operating in the range 2.4 kbit/s to 14.4 kbit/s
M.1355	11-1988	Maintenance of international data transmission systems operating in the range 2.4 to 14.4 kbit/s
M.1370	06-1998	Bringing-into-service of international data transmission systems
M.1375	06-1998	Maintenance of international data transmission systems
M.1380	02-2000	Bringing-into-service of international leased circuits that are supported by international data transmission systems
M.1385	02-2000	Maintenance of international leased circuits that are supported by international data transmission systems
M.1400	01-2004	Designations for interconnections among operators' networks
M.1401	02-2004	Formalization of interconnection designations among operators' networks
M.1510	10-1992	Exchange of contact point information for the maintenance of international services and the international network
M.1520	10-1992	Standardized information exchange between Administrations
M.1530	03-1999	Network maintenance information
M.1532	02-2000	Network maintenance service performance agreement (MSPA)
M.1535	05-1996	Principles for maintenance information to be exchanged at customer contact point (MICC)

M.1537	10-1997	Definition of maintenance information to be exchanged at customer contact point (MICC)
M.1539	03-1999	Management of the grade of network maintenance services at the Maintenance Service Customer Contact Point (MSCC)
M.1540	10-1994	Exchange of information for planned outages of transmission systems
M.1550	10-1992	Escalation procedure
M.1560	10-1992	Escalation procedure for international leased circuits
M.2100	04-2003	Performance limits for bringing-into-service and maintenance of international multi-operator PDH paths and connections
M.2101	06-2003	Performance limits for bringing-into-service and maintenance of international multi-operator SDH paths and multiplex sections
M.2102	02-2000	Maintenance thresholds and procedures for recovery mechanisms (protection and restoration) of international SDH VC trails (paths) and multiplex sections
M.2110	07-2002	Bringing into service international multi-operator paths, sections and transmission systems
M.2120	07-2002	International multi-operator paths, sections and transmission systems fault detection and localization procedures
M.2130	02-2000	Operational procedures for the maintenance of the transport network
M.2140	02-2000	Transport network event correlation
M.2201	03-2001	Performance objectives, allocations and limits for bringing-into-service and maintenance of international ATM virtual path and virtual channel connections
M.2301	07-2002	Performance objectives and procedures for provisioning and maintenance of IP-based networks
M.2401	12-2003	Error performance limits and procedures for bringing-into-service and maintenance of multi-operator international paths and sections within an optical transport network
M.3000	02-2000	Overview of TMN Recommendations
M.3010	02-2000	Principles for a telecommunications management network
M.3010 (2000) Amendment 1	12-2003	TMN conformance and TMN compliance
M.3013	02-2000	Considerations for a telecommunications management network
M.3016	06-1998	TMN Security Overview
M.3017	06-2003	Framework for the integrated management of hybrid circuit/packet networks
M.3020	02-2000	TMN Interface Specification Methodology
M.3030	08-2002	Telecommunications Markup Language (tML) framework
M.3100	07-1995	Generic network information model
M.3100 (1995) Corrigendum 1	06-1998	
M.3100 (1995) Amendment 1	03-1999	
M.3100 (1995) Amendment 2	02-2000	
M.3100 (1995) Corrigendum 2	01-2001	

M.3100 (1995) Amendment 3	01-2001	Definition of the management interface for a generic alarm reporting control (ARC) feature
M.3100 (1995) Corrigendum 3	08-2001	
M.3100 (1995) Amendment 4	08-2001	Definition of the management interface for a bridge-and-roll cross-connect feature
M.3100 (1995) Amendment 5	08-2001	Enhanced cross-connect model
M.3100 (1995) Amendment 6	03-2003	
M.3100 (1995) Amendment 7	12-2003	
M.3101	07-1995	Managed object conformance statements for the generic network information model
		TMN management services for dedicated and reconfigurable circuits network
M.3108.1	03-1999	Information model for management of leased circuit and reconfigurable services
M.3108.1 (1999) Corrigendum 1	01-2001	
M.3108.2	02-2000	Information model for connection management of preprovisioned service link connections to form a reconfigurable leased service
M.3108.3	01-2001	Information model for management of virtual private network service
M.3120	10-2001	CORBA generic network and network element level information model
M.3120 (2001) Amendment 1	05-2002	Protection switching
M.3120 (2001) Amendment 2	03-2003	
M.3180	10-1992	Catalogue of TMN management information
M.3200	04-1997	TMN management services and telecommunications managed areas: overview
M.3207.1	05-1996	TMN management service: Maintenance aspects of B-ISDN management
		TMN management services for dedicated and reconfigurable circuits network
M.3208.1	10-1997	Leased circuit services
M.3208.1 (1997) Corrigendum 1	02-2000	
M.3208.2	03-1999	Connection management of pre-provisioned service link connections to form a leased circuit service
M.3208.2 (1999) Corrigendum 1	01-2001	
M.3208.3	02-2000	Virtual private network service
M.3210.1	01-2001	TMN management services for IMT-2000 security management
M.3211.1	05-1996	TMN management service: Fault and performance management of the ISDN access
M.3300	06-1998	TMN F interface requirements
M.3320	04-1997	Management requirements framework for the TMN X-Interface
M.3341	12-2003	Requirements for QoS/SLA management over the TMN X-interface for IP-based services

M.3350	05-2004	TMN service management requirements for information interchange across the TMN X-interface to support provisioning of telecommunication capabilities for disaster relief operations and mitigation
M.3400	02-2000	TMN management functions
M.3600	10-1992	Principles for the management of ISDNs
M.3602	10-1992	Application of maintenance principles to ISDN subscriber installations
M.3603	10-1992	Application of maintenance principles to ISDN basic rate access
M.3604	10-1992	Application of maintenance principles to ISDN primary rate access
M.3605	10-1992	Application of maintenance principles to static multiplexed ISDN basic rate access
M.3610	05-1996	Principles for applying the TMN concept to the management of B-ISDN
M.3611	04-1997	Test management of the B-ISDN ATM layer using the TMN
M.3620	10-1992	Principles for the use of ISDN test calls, systems and responders
M.3621	07-1995	Integrated management of the ISDN customer access
M.3640	10-1992	Management of the D-channel – Data link layer and network layer
M.3641	10-1994	Management information model for the management of the data link and network layer of the ISDN D-channel
M.3650	04-1997	Network performance measurements of ISDN calls
M.3660	10-1992	ISDN interface management services
M.4010	10-1992	Inter-Administration agreements on common channel Signalling System No. 6
M.4030	10-1992	Transmission characteristics for setting up and lining up a transfer link for common channel Signalling System N° 6 (analogue version)
M.4100	05-1996	Maintenance of common channel Signalling System No. 7
M.4110	05-1996	Inter-Administration agreements on common channel Signalling System No. 7

Series N : Maintenance: international sound programme and television transmission circuits

Number	*Approval Date*	*Recommendation Title*
		Maintenance: international sound programme and television transmission circuits
N.1	03-1993	Definitions for application to international sound-programme and television-sound transmission
N.2	11-1988	Different types of sound-programme circuit
N.3	11-1988	Control circuits
N.4	11-1988	Definition and duration of the line-up period and the preparatory period
N.5	11-1988	Sound-programme control, sub-control and send reference stations
N.10	03-1993	Limits for the lining-up of international sound-programme links and connections
N.11	11-1988	Essential transmission performance objectives for international sound-programme centres (ISPC)
N.12	11-1988	Measurements to be made during the line-up period that precedes a sound-programme transmission

N.13	11-1988	Measurements to be made by the broadcasting organizations during the preparatory period
N.15	11-1988	Maximum permissible power during an international sound-programme transmission
N.16	11-1988	Identification signal
N.17	11-1988	Monitoring the transmission
N.18	11-1988	Monitoring for charging purposes, releasing
N.21	11-1988	Limits and procedures for the lining-up of a sound-programme circuit
N.23	11-1988	Maintenance measurements to be made on international sound-programme circuits
N.51	11-1988	Definitions for application to international television transmissions
N.52	11-1988	Multiple destination television transmissions and coordination centres
N.54	11-1988	Definition and duration of the line-up period and the preparatory period
N.55	03-1993	Organization, responsibilities and functions of control and sub-control international television centres and control and sub-control stations for international television connections, links, circuits and circuit sections
N.60	03-1993	Nominal amplitude of video signals at video interconnection points
N.61	11-1988	Measurements to be made before the line-up period that precedes a television transmission
N.62	03-1993	Tests to be made during the line-up period that precedes a television transmission
N.63	11-1988	Test signals to be used by the broadcasting organizations during the preparatory period
N.64	11-1988	Quality and impairment assessment
N.67	03-1993	Monitoring television transmissions – Use of the field blanking interval
N.73	11-1988	Maintenance of permanent international television circuits, links and connections

Series O : Specifications of measuring equipment

Number	*Approval Date*	*Recommendation Title*
		Specifications of measuring equipment
O.1	02-2000	Scope and application of measurement equipment specifications covered in the O-series Recommendations
O.3	10-1992	Climatic conditions and relevant tests for measuring equipment
O.6	11-1988	1020 Hz reference test frequency
O.9	03-1999	Measuring arrangements to assess the degree of unbalance about earth
O.11	10-1992	Maintenance access lines
O.22	10-1992	CCITT automatic transmission measuring and signalling testing equipment ATME No. 2
O.27	11-1988	In-station echo canceller test equipment
O.33	07-1995	Automatic equipment for rapidly measuring stereophonic pairs and monophonic sound-programme circuits, links and connections
O.41	10-1994	Psophometer for use on telephone-type circuits

O.42	11-1988	Equipment to measure non-linear distortion using the 4-tone intermodulation method
O.61	11-1988	Simple equipment to measure interruptions on telephone-type circuits
O.62	11-1988	Sophisticated equipment to measure interruptions on telephone-type circuits
O.71	11-1988	Impulsive noise measuring equipment for telephone-type circuits
O.81	11-1988	Group-delay measuring equipment for telephone-type circuits
O.81 Appendix I	06-1998	A measuring signal (multitone test signal) for fast measurement of amplitude and phase for telephone type circuits
O.81 Appendix I Erratum1	06-2000	
O.82	11-1988	Group-delay measuring equipment for the range 5 to 600 kHz
O.91	11-1988	Phase jitter measuring equipment for telephone-type circuits
O.95	11-1988	Phase and amplitude hit counters for telephone-type circuits
O.111	11-1988	Frequency shift measuring equipment for use on carrier channels
O.131	11-1988	Quantizing distortion measuring equipment using a pseudo-random noise test signal
O.132	11-1988	Quantizing distortion measuring equipment using a sinusoidal test signal
O.133	03-1993	Equipment for measuring the performance of PCM encoders and decoders
O.150	05-1996	General requirements for instrumentation for performance measurements on digital transmission equipment
O.150 (1996) Corrigendum 1	05-2002	
O.151	10-1992	Error performance measuring equipment operating at the primary rate and above
O.151 (1992) Corrigendum 1	05-2002	
O.152	10-1992	Error performance measuring equipment for bit rates of 64 kbit/s and N x 64 kbit/s
O.153	10-1992	Basic parameters for the measurement of error performance at bit rates below the primary rate
O.161	11-1988	In-service code violation monitors for digital systems
O.162	10-1992	Equipment to perform in-service monitoring on 2048, 8448, 34 368 and 139 264 kbit/s signals
O.163	11-1988	Equipment to perform in-service monitoring on 1544 kbit/s signals
O.171	04-1997	Timing jitter and wander measuring equipment for digital systems which are based on the plesiochronous digital hierarchy (PDH)
O.172	03-2001	Jitter and wander measuring equipment for digital systems which are based on the synchronous digital hierarchy (SDH)
O.172 (2001) Amendment 1	03-2003	
O.173	03-2003	Jitter measuring equipment for digital systems which are based on the Optical Transport Network (ONT)
O.181	05-2002	Equipment to assess error performance on STM-N interfaces
O.191	02-2000	Equipment to measure the cell transfer performance of ATM connections
O.201	07-2003	Q-factor test equipment to estimate the transmission performance of optical channels

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		Telephone transmission quality, telephone installations, local line networks
P.10	12-1998	Vocabulary of terms on telephone transmission quality and telephone sets
P.10 (1998) Amendment 1	11-2003	New Annex A – List of psychoacoustic parameters
P.11	03-1993	Effect of transmission impairments
P.16	11-1988	Subjective effects of direct crosstalk; thresholds of audibility and intelligibility
P.32	11-1988	Evaluation of the efficiency of telephone booths and acoustic hoods
P.48	11-1988	Specification for an intermediate reference system
P.50	09-1999	Artificial voices
P.50 Erratum 1	05-2000	
P.50 Appendix I	02-1998	Test signals
P.51	08-1996	Artificial mouth
P.52	03-1993	Volume meters
O.41	10-1994	Psophometer for use on telephone-type circuits
P.54	11-1988	Sound level meters (apparatus for the objective measurement of room noise)
P.55	11-1988	Apparatus for the measurement of impulsive noise
P.56	03-1993	Objective measurement of active speech level
P.57	07-2002	Artificial ears
P.58	08-1996	Head and torso simulator for telephonometry
P.58 Erratum 1	01-2003	
P.59	03-1993	Artificial conversational speech
P.61	11-1988	Methods for the calibration of condenser microphones
P.64	09-1999	Determination of sensitivity/frequency characteristics of local telephone systems
P.64 Erratum 1	05-2000	
P.75	11-1988	Standard conditioning method for handsets with carbon microphones
P.76	11-1988	Determination of loudness ratings; fundamental principles
P.78	02-1996	Subjective testing method for determination of loudness ratings in accordance with Recommendation P.76
P.79	09-1999	Calculation of loudness ratings for telephone sets
P.79 Erratum 1	05-2000	
P.79 (1999) Corrigendum 1	10-2000	
P.79 Corrigendum 2	02-2001	

P.79 Annex G	11-2001	Wideband loudness rating algorithm
P.82	11-1988	Method for evaluation of service from the standpoint of speech transmission quality
P.85	06-1994	A method for subjective performance assessment of the quality of speech voice output devices
P.300	11-2001	Transmission performance of group audio terminals (GATs)
P.310	03-2003	Transmission characteristics for telephone band (300-3400 Hz) digital telephones
P.311	02-1998	Transmission characteristics for wideband (150-7000 Hz) digital handset telephones
P.313	05-2004	Transmission characteristics for cordless and mobile digital terminals
P.330	03-2003	Speech processing devices for acoustic enhancement
P.330 (2003) Amendment 1	09-2003	
P.340	05-2000	Transmission characteristics and speech quality parameters of hands-free terminals
P.340 (2000) Corrigendum 1	03-2004	
P.341	02-1998	Transmission characteristics for wideband (150-7000 Hz) digital hands-free telephony terminals
P.341 (1998) Corrigendum 1	09-1999	
P.342	05-2000	Transmission characteristics for telephone band (300-3400 Hz) digital loudspeaking and hands-free telephony terminals
P.350	03-2001	Handset dimensions
P.360	12-1998	Efficiency of devices for preventing the occurrence of excessive acoustic pressure by telephone receivers
P.370	08-1996	Coupling hearing aids to telephone sets
P.380	11-2003	Electro-acoustic measurements on headsets
P.501	05-2000	Test signals for use in telephonometry
P.501 Erratum 1	09-2001	
P.501 Annex A	05-2004	Test signals for TCL tests
P.501 Annex B	05-2004	Speech files and noise sequences
P.502	05-2000	Objective test methods for speech communication systems using complex test signals
P.502 Erratum 1	07-2001	
P.561	07-2002	In-service non-intrusive measurement device – Voice service measurements
P.561 App. III	02-1998	Digital speech recordings
P.562	05-2004	Analysis and interpretation of INMD voice-service measurements
P.563	05-2004	Single-ended method for objective speech quality assessment in narrow-band telephony applications
P.581	05-2000	Use of head and torso simulator (HATS) for hands-free terminal testing
P.800	08-1996	Methods for subjective determination of transmission quality
P.800.1	03-2003	Mean Opinion Score (MOS) terminology

P.810	02-1996	Modulated noise reference unit (MNRU)
P.830	02-1996	Subjective performance assessment of telephone-band and wideband digital codecs
P.831	12-1998	Subjective performance evaluation of network echo cancellers
P.832	05-2000	Subjective performance evaluation of hands-free terminals
P.833	02-2001	Methodology for derivation of equipment impairment factors from subjective listening-only tests
P.834	07-2002	Methodology for the derivation of equipment impairment factors from instrumental models
P.835	11-2003	Subjective test methodology for evaluating speech communication systems that include noise suppression algorithm
P.840	11-2003	Subjective listening test method for evaluating circuit multiplication equipment
P.851	11-2003	Subjective quality evaluation of telephone services based on spoken dialogue systems
P.862	02-2001	Perceptual evaluation of speech quality (PESQ): An objective method for end-to-end speech quality assessment of narrow-band telephone networks and speech codecs
P.862 (2001) Amd.1	03-2003	Revised Annex A: Source code for reference implementation and conformance tests
P.862.1	11-2003	Mapping function for transforming P.862 raw result scores to MOS-LQO
P.880	05-2004	Continuous evaluation of time-varying speech quality
P.910	09-1999	Subjective video quality assessment methods for multimedia applications
P.911	12-1998	Subjective audiovisual quality assessment methods for multimedia applications
P.911 (1998) Corrigendum 1	09-1999	
P.920	05-2000	Interactive test methods for audiovisual communications
P.930	08-1996	Principles of a reference impairment system for video
P.931	12-1998	Multimedia communications delay, synchronization and frame rate measurement
P.1010	07-2004	Fundamental voice transmission objectives for VoIP terminals and gateways
P.supp10	11-1988	Considerations relating to transmission characteristics for analogue handset telephones
P.supp16	11-1988	Guidelines for placement of microphones and loudspeakers in telephone conference rooms and for group audio terminals (GATs)
P.supp20	03-1993	Examples of measurements of handset receive-frequency responses: dependence on earcap leakage losses
P.Sup23	02-1998	ITU-T coded-speech database

Series Q : Switching and signalling

Number	*Approval Date*	*Recommendation Title*
		Switching and signalling
Q.1	11-1988	Signal receivers for manual working
Q.2	11-1988	Signal receivers for automatic and semi-automatic working, used for manual working
Q.4	11-1988	Automatic switching functions for use in national networks

Q.5	11-1988	Advantages of semi-automatic service in the international telephone service
Q.6	11-1988	Advantages of international automatic working
Q.7	11-1988	Signalling systems to be used for international automatic and semi-automatic telephone working
Q.8	11-1988	Signalling systems to be used for international manual and automatic working on analogue leased circuits
Q.9	11-1988	Vocabulary of switching and signalling terms
E.164	05-1997	The international public telecommunication numbering plan
E.164 Supplement 1	03-1998	Alternatives for carrier selection and network identification
E.164 Supplement 2	11-1998	Number Portability
Q.12	11-1988	Overflow – alternative routing – rerouting – automatic repeat attempt
Q.14	11-1988	Means to control the number of satellite links in an international telephone connection
Q.20	11-1988	Comparative advantages of "in-band" and "out-band" systems
Q.21	11-1988	Systems recommended for out-band signalling
Q.22	11-1988	Frequencies to be used for in-band signalling
Q.23	11-1988	Technical features of push-button telephone sets
Q.24	11-1988	Multifrequency push-button signal reception
Q.25	11-1988	Splitting arrangements and signal recognition times in "in-band" signalling systems
Q.26	11-1988	Direct access to the international network from the national network
Q.27	11-1988	Transmission of the answer signal
Q.28	11-1988	Determination of the moment of the called subscriber's answer in the automatic service
Q.29	11-1988	Causes of noise and ways of reducing noise in telephone exchanges
Q.30	11-1988	Improving the reliability of contacts in speech circuits
Q.31	11-1988	Noise in a national 4-wire automatic exchange
Q.32	11-1988	Reduction of the risk of instability by switching means
Q.33	11-1988	Protection against the effects of faulty transmission on groups of circuits
E.180/Q.35	03-1998	Technical characteristics of tones for the telephone service
Q.44	11-1988	Attenuation distortion
Q.45	10-1984	Transmission characteristics of an analogue international exchange
Q.45bis	11-1988	Transmission characteristics of an analogue international exchange
Q.48	11-1988	Demand assignment signalling systems
Q.50	07-2001	Signalling between Circuit Multiplication Equipment (CME) and International Switching Centres (ISC)
Q.50.1	07-2001	Signalling between International Switching Centres (ISC) and Digital Circuit Multiplication Equipment (DCME) including the control of compression/decompression

Q.50.2	12-2002	Signalling between International Switching Centres (ISC) and Digital Circuit Multiplication Equipment (DCME) including the control of compression/decompression over an IP network
Q.52	03-2001	Signaling between international switching centers and stand-alone echo control devices
Q.55	12-1999	Signalling between signal processing network equipments (SPNE) and international switching centres (ISC)
Q.56	05-2001	Signalling between signal processing network equipment (SPNE) and international switching centres (ISC) over an IP network
Q.65	06-2000	The unified functional methodology for the characterization of services and network capabilities including alternative object oriented techniques
Q.68	03-1993	Overview of methodology for developing management services
Q.71	03-1993	ISDN circuit mode switched bearer services
Q.72	03-1993	Stage 2 description for packet mode services
Q.76	02-1995	Service procedures for Universal Personal Telecommunication – Functional modelling and information flows
Q.80	11-1988	Introduction to stage 2 service descriptions for supplementary services
		Stage 2 description for number identification supplementary services
Q.81.1	11-1988	Direct dialling-in
Q.81.2	02-1992	Multiple subscriber number
Q.81.3	09-1991	Calling line identification presentation (CLIP) and calling line identification restriction (CLIR)
Q.81.5	09-1991	Connected line identification, presentation and restriction (COLP) and (COLR)
Q.81.7	06-1997	Malicious call identification (MCID)
Q.81.8	02-1992	Sub-addressing (SUB)
		Stage 2 description for call offering supplementary services
Q.82.1	11-1988	Call transfer
Q.82.2	03-1993	call forwarding
Q.82.3	03-1993	Call deflection
Q.82.4	11-1988	Line hunting
Q.82.7	07-1996	Explicit call transfer
		Stage 2 description for call completion supplementary services
Q.83.1	09-1991	Call waiting (CW)
Q.83.2	02-1992	Call hold
Q.83.3	11-1988	Completion of call to busy subscriber
Q.83.4	09-1991	Terminal portability
		Stage 2 description for multiparty supplementary services
Q.84.1	03-1993	Conference calling (CONF)
Q.84.2	10-1995	Three-party service

		Stage 2 description for community of interest supplementary services
Q.85.1	02-1992	Closed user group
Q.85.3	02-1992	Multi-level precedence and preemption (MLPP)
Q.85.6	02-1995	Global Virtual Network Service (GVNS)
Q.85.6 Annex A	07-1996	Service procedures and information flows based on intelligent network CS-1 capabilities
		Stage 2 description for charging supplementary services
Q.86.1	11-1988	Credit card call
Q.86.2	10-1995	Advice of charge (AOC)
Q.86.3	03-1993	Reverse charging (REV)
Q.86.4	06-1997	International Freephone Service (IFS)
Q.86.7	10-1995	International Telecommunication Charge Card (ITCC)
		Stage 2 description for additional information transfer supplementary services
Q.87.1	03-1993	User-to-user signalling (UUS)
Q.87.2	11-1988	User signalling bearer services
Q.101	11-1988	Facilities provided in international semi-automatic working
Q.102	11-1988	Facilities provided in international automatic working
Q.103	11-1988	Numbering used
Q.104	11-1988	Language digit or discriminating digit
Q.105	11-1988	National (significant) number
Q.106	11-1988	The sending-finished signal
Q.107	11-1988	Standard sending sequence of forward address information
Q.107bis	03-1993	Analysis of forward address information for routing
Q.108	11-1988	One-way or both-way operation of international circuits
Q.109	11-1988	Transmission of the answer signal in international exchanges
Q.110	11-1988	General aspects of the utilization of standardized CCITT signalling systems on PCM links
Q.112	11-1988	Signal levels and signal receiver sensitivity
Q.113	11-1988	Connection of signal receivers in the circuit
Q.114	11-1988	Typical transmission requirements for signal senders and receivers
Q.115.0	12-2002	Protocols for the control of signal processing network elements and functions
Q.115.0 Erratum 1	09-2003	
Q.115.1	12-2002	Logic for the control of echo control devices and functions
Q.116	11-1988	Indication given to the outgoing operator or calling subscriber in case of an abnormal condition
Q.117	11-1988	Alarms for technical staff and arrangements in case of faults

Q.118	09-1997	Abnormal conditions – Special release arrangements
Q.118bis	11-1988	Indication of congestion conditions at transit exchanges
Q.120-Q.139	11-1988	Specifications of Signalling system No. 4
Q.140-Q.180	11-1988	Specifications of Signalling System No. 5
Q.251-Q.300	11-1988	Specifications of Signalling System No. 6
Q.310-Q.332	11-1988	Specifications of Signalling System R1
Q.400-Q.490	11-1988	Specifications of Signalling System R2
Q.500	11-1988	Digital local, combined, transit and international exchanges – Introduction and field of application
Q.511	11-1988	Exchange interfaces towards other exchanges
Q.512	02-1995	Digital exchange interfaces for subscriber access
Q.513	03-1993	Digital exchange interfaces for operations, administration and maintenance
Q.521	03-1993	Digital exchange functions
Q.522	11-1988	Digital exchange connections, signalling and ancillary functions
Q.541	03-1993	Digital exchange design objectives – General
Q.542	03-1993	Digital exchange design objectives – Operations and maintenance
Q.543	03-1993	Digital exchange performance design objectives
Q.544	11-1988	Digital exchange measurements
Q.551	01-2002	Transmission characteristics of digital exchanges
Q.552	11-2001	Transmission characteristics at 2-wire analogue interfaces of digital exchanges
Q.553	11-2001	Transmission characteristics at 4-wire analogue interfaces of digital exchanges
Q.554	11-1996	Transmission characteristics at digital interfaces of digital exchanges
Q.601	03-1993	Interworking of signalling systems – General
Q.602	03-1993	Interworking of signalling systems – Introduction
Q.603	11-1988	Events
Q.604	03-1993	Interworking of signalling systems – Information analysis tables
Q.605	11-1988	Drawing conventions
Q.606	11-1988	Logic procedures
Q.607	11-1988	Interworking requirements for new signalling systems
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R.79	11-1988	Automatic tests of transmission quality on telegraph circuits between switching centres
R.80	11-1988	Causes of disturbances to signals in VFT channels and their effect on telegraph distortion
R.81	11-1988	Maximum acceptable limit for the duration of interruption of telegraph channels arising from failure of the normal power supplies
R.82	11-1988	Appearance of false calling and clearing signals in circuits operated by switched teleprinter services
R.83	11-1988	Changes of level and interruptions in VFT channels
R.90	11-1988	Organization for locating and clearing faults in international telegraph switched networks
R.91	11-1988	General maintenance aspects for the maritime satellite telex service
R.100	03-1993	Transmission characteristics of international TDM links
R.101	03-1993	Code and speed dependent TDM system for anisochronous telegraph and data transmission using bit interleaving
R.102	03-1993	4800 bit/s code and speed dependent and hybrid TDM systems for anisochronous telegraph and data transmission using bit interleaving
R.103	11-1988	Code and speed-dependent TDM 600 bit/s system for use in point-to-point or branch-line muldex configurations

R.105	03-1993	Duplex muldex concentrator, connecting a group of gentex and telex subscribers to a telegraph exchange by assigning virtual channels to time slots of a bit-interleaved TDM system
R.106	08-1995	Muldex unit for telegraph and low speed data transmission using TDM bit interleaving with an aggregate bit rate higher than 4800 bit/s
R.111	03-1993	Code and speed independent TDM system for anisochronous telegraph and data transmission
R.112	03-1993	TDM hybrid system for anisochronous telegraph and data transmission using bit interleaving
R.113	03-1993	Combined muldex for telegraphy and synchronous data transmission
R.114	03-1993	Numbering of international TDM channels
R.115	03-1993	Maintenance loops for TDM-systems
R.116	11-1988	Maintenance tests to be carried out on international TDM systems
R.117	03-1993	End-to-end error performance for telegraph, telex and gentex connections involving regenerative equipment
R.118	03-1993	Performance and availability monitoring in regenerative TDM
R.120	11-1988	Tolerable limits for the degree of isochronous distortion of code-independent telegraph circuits operating at modulation rates of 75, 100 and 200 bauds
R.121	11-1988	Standard limits of transmission quality for start-stop user classes of service 1 and 2 on anisochronous data networks
R.122	11-1988	Summary of transmission plans for rates up to 300 bauds
R.140	11-1988	Definitions of essential technical terms in the field of telegraph transmission
R.150	11-1988	Automatic protection switching of dual diversity bearers

Series S : Telegraph services terminal equipment

Number	*Approval Date*	*Recommendation Title*
		Telegraph services terminal equipment
S.1	03-1993	International Telegraph Alphabet No. 2
S.2	11-1988	Coding scheme using International Telegraph Alphabet No. 2 (ITA2) to allow the transmission of capital and small letters
S.3	11-1988	Transmission characteristics of the local end with its termination (ITA2)
S.4	03-1993	Special use of certain characters of the International Telegraph Alphabet No. 2
S.5	11-1988	Standardization of page-printing start-stop equipment and cooperation between page-printing and tape-printing start-stop equipment (ITA2)
S.6	11-1988	Characteristics of answerback units (ITA2)
S.7	11-1988	Control of teleprinter motors
S.8	03-1993	Intercontinental standardization of the modulation rate of start-stop apparatus and of the use of combination No. 4 in figure-shift
S.9	11-1988	Switching equipment of start-stop apparatus
S.10	11-1988	Transmission at reduced character transfer rate over a standardized 50-baud telegraph channel
S.11	11-1988	Use of start-stop reperforating equipment for perforated tape retransmission

S.12	11-1988	Conditions that must be satisfied by synchronous systems operating in connection with standard 50-baud teleprinter circuits
S.13	11-1988	Use on radio circuits of 7-unit synchronous systems giving error correction by automatic repetition
S.14	11-1988	Suppression of unwanted reception in radiotelegraph multi-destination teleprinter systems
S.15	11-1988	Use of the telex network for data transmission at 50 bauds
S.16	03-1993	Connection to the telex network of an automatic terminal using a V.24 DCE/DTE interface
S.17	11-1988	Answer-back unit simulators
S.18	11-1988	Conversion between International Telegraph Alphabet No. 2 and International Alphabet No. 5
S.19	11-1988	Calling and answering in the telex network with automatic terminal equipment
S.20	03-1993	Automatic clearing procedure for a telex terminal
S.21	03-1993	Use of display screens in telex machines
S.22	03-1993	"Conversation impossible" and or pre-recorded message in response to J/BELL signals from a telex terminal
S.23	03-1993	Automatic request of the answerback of the terminal of the calling party, by the telex terminal of the called party or by the international network
S.30	11-1988	Standardization of basic model page-printing machine using International Alphabet No. 5
S.31	11-1988	Transmission characteristics for start-stop data terminal equipment using International Alphabet No. 5
S.32	11-1988	Answer-back units for 200- and 300-baud start-stop machines in accordance with Recommendation S.30
S.33	03-1993	Alphabets and presentation characteristics for the intex service
S.34	03-1993	Intex terminals – Requirements to effect interworking with the international telex service
S.35	03-1993	Answerback coding for the Intex service
S.36	07-1996	Intex and similar services – Terminal requirements to effect interworking between terminals operating at different speeds
S.140	11-1988	Definitions of essential technical terms relating to apparatus for alphabetic telegraphy
S.supp1	11-1988	Minimal specifications for the bilingual (arabic/latin) teleprinter

Series T : Terminals for telematic services

Number	*Approval Date*	*Recommendation Title*
		Terminals for telematic services
T.0	07-1996	Classification of facsimile terminals for document transmission over the public networks
T.1	11-1988	Standardization of phototelegraph apparatus
T.4	07-2003	Standardization of Group 3 facsimile terminals for document transmission
G.511	02-1998	Test methodology for Group 3 facsimile processing equipment in the Public Switched Telephone Network

T.6	11-1988	Facsimile coding schemes and coding control functions for Group 4 facsimile apparatus
T.10	11-1988	Document facsimile transmissions on leased telephone-type circuits
T.10bis	11-1988	Document facsimile transmissions in the general switched telephone network
T.22	03-1993	Standardized test charts for document facsimile transmissions
T.23	04-1994	Standardized colour test chart for document facsimile transmissions
T.24	06-1998	Standardized digitized image set
T.24 (1998) Amend.1	02-2000	
T.30	07-2003	Procedures for document facsimile transmission in the general switched telephone network
T.30 (2003) Erratum 1	04-2004	
T.31	08-1995	Asynchronous facsimile DCE control – Service Class 1
T.31 (1995) Amendment 1	07-1996	Annex B: Procedure for Service Class 1 support of V.34 modems
T.32	08-1995	Asynchronous facsimile DCE control – Service Class 2
T.32 (1995) Amendment 1	07-1996	
T.33	07-1996	Facsimile routing utilizing the subaddress
T.35	02-2000	Procedure for the allocation of ITU-T defined codes for non-standard facilities
T.36	07-1997	Security capabilities for use with Group 3 facsimile terminals
T.36 (1997) Amendment 1	04-1999	
T.37	06-1998	Procedures for the transfer of facsimile data via store-and-forward on the Internet
T.37 (1998) Amendment 1	09-1999	Full Mode
T.37 (1998) Amendment 2	03-2001	Replacement of reference RFC 2531 by RFC 2879
T.37 (1998) Amendment 3	11-2002	Support of image/tiff and image/tiff-fx MIME content-types
T.38	04-2004	Procedures for real-time Group 3 facsimile communication over IP networks
T.39	10-1997	Application profiles for simultaneous voice and facsimile terminals
T.42	07-2003	Continuous-tone colour representation method for facsimile
T.42 (2003) Corrigendum 1	03-2004	
T.43	07-1997	Colour and gray-scale image representations using lossless coding scheme for facsimile
T.43 (1997) Amendment 1	02-2000	Accommodation of new and future Resolutions
T.44	04-1999	Mixed Raster Content (MRC)
T.44 (1999) Amendment 1	02-2000	Accommodation of new Annex B

T.45	02-2000	Run-length Colour Encoding
T.50	09-1992	International Reference Alphabet (IRA) (Formerly International Alphabet No. 5 or IA5) – Information technology – 7-bit coded character set for information interchange
T.51	09-1992	Latin based coded character sets for telematic services
T.51 (1992) Amendment 1	08-1995	
T.52	03-1993	Non-latin coded character sets for telematic services
T.52 (1993) Amendment 1	10-1996	
T.53	04-1994	Character coded control functions for telematic services
T.62	03-1993	Control procedures for teletex and Group 4 facsimile services
T.62bis	03-1993	Control procedures for teletex and G4 facsimile services based on Recommendations X.215 and X.225
T.66	03-2002	Facsimile code points for use with Recommendations V.8 and V.8 bis
T.70	03-1993	Network-independent basic transport service for the telematic services
T.71	11-1988	Link access protocol balanced (LAPB) extended for half-duplex physical level facility
T.80	09-1992	Common components for image compression and communication – Basic principles
T.81	09-1992	Information technology – Digital compression and coding of continuous-tone still images – Requirements and guidelines
T.81 (2002) Amendment 1	01-2004	Patent information update
T.82	03-1993	Information technology – Coded representation of picture and audio information – Progressive bi-level image compression
T.82 (1993) Technical Cor.1	03-1995	
T.82 (1993) Technical Cor.2	03-2001	
T.83	11-1994	Information technology – Digital compression and coding of continuous-tone still images: Compliance testing
T.84	07-1996	Information technology – Digital compression and coding of continuous-tone still images: Extensions
T.84 (1996) Amendment 1	04-1999	Provisions to allow registration of new compression types and versions in the SPIFF header
T.85	08-1995	Application profile for Recommendation T.82 – Progressive bi-level image compression (JBIG coding scheme) for facsimile apparatus
T.85 (1995) Amendment 1	10-1996	
T.85 (1995) Corrigendum 1	02-1997	
T.85 (1995) Amendment 2	10-1997	
T.86	06-1998	Information technology – Digital compression and coding of continuous-tone still images: Registration of JPEG Profiles, SPIFF Profiles, SPIFF Tags, SPIFF colour Spaces, APPn Markers, SPIFF Compression types and Registration authorities (REGAUT)
T.87	06-1998	Information technology – Lossless and near-lossless compression of continuous-tone still images – Baseline

T.88	02-2000	Information technology – Lossy/lossless coding of bi-level images
T.88 (2000) Amendment 1	06-2003	Encoder
T.88 (2000) Amendment 2	06-2003	Extension of adaptive templates for halftone coding
T.89	09-2001	Application profiles for Recommendation T.88 – Lossy/lossless coding of bi-level images (JBIG2) for facsimile
T.90	02-1992	Characteristics and protocols for terminals for telematic services in ISDN
T.90 (1992) Amendment 1	11-1994	
T.90 (1992) Amendment 2	07-1996	
T.90 (1992) Amendment 3	06-1998	Cause value for a G4 fax fallback
T.100	11-1988	International information exchange for interactive Videotex
T.101	11-1994	International interworking for Videotex services
T.102	03-1993	Syntax-based Videotex end-to-end protocols for the circuit mode ISDN
T.103	03-1993	Syntax-based Videotex end-to-end protocols for the packet mode ISDN
T.104	03-1993	Packet mode access for syntax-based Videotex via PSTN
T.105	11-1994	Syntax-based Videotex application layer protocol
T.106	03-1993	Framework of videotex terminal protocols
T.107	08-1995	Enhanced man machine interface for videotex and other retrieval services (VEMMI)
T.120	07-1996	Data protocols for multimedia conferencing
T.120 Annex C	02-1998	Lightweight profiles for the T.120 architecture
T.121	07-1996	Generic application template
T.122	02-1998	Multipoint communication service – Service definition
T.123	05-1999	Network-specific data protocol stacks for multimedia conferencing
T.124	02-1998	Generic Conference Control
T.125	02-1998	Multipoint communication service protocol specification
T.126	07-1997	Multipoint still image and annotation protocol
T.127	08-1995	Multipoint binary file transfer protocol
T.128	02-1998	Multipoint application sharing
T.134	02-1998	Text chat application entity
T.135	02-1998	User-to-reservation system transactions within T.120 conferences
T.136	05-1999	Remote device control application protocol
T.137	02-2000	Virtual meeting room management for multimedia conferencing audio-visual control
T.140	02-1998	Protocol for multimedia application text conversation

T.140 Addendum 1	02-2000	
T.150	11-1988	Telewriting terminal equipment
T.170	02-1998	Framework of the T.170-Series of Recommendations
T.171	10-1996	Protocols for interactive audiovisual services: Coded representation of multimedia and hypermedia objects
T.172	02-1998	MHEG-5 – Support for base-level interactive applications
T.173	07-1997	MHEG-3 script interchange representation
T.174	10-1996	Application programming interface (API) for MHEG-1
T.175	02-1998	Application programming interface (API) for MHEG-5
T.176	02-1998	Application programming interface (API) for digital storage media command and control (DSM-CC)
T.180	06-1998	Homogeneous access mechanism to communication services
T.190	08-1995	Cooperative Document Handling (CDH) – Framework and basic services
T.191	07-1996	Cooperative document handling (CDH) – Joint synchronous editing (point-to-point)
T.192	06-1998	Cooperative document handling – Complex services: Joint synchronous editing and joint document presentation/viewing
T.300	11-1988	General principles of telematic interworking
T.330	11-1988	Telematic access to interpersonal messaging system
T.351	11-1988	Imaging process of character information on facsimile apparatus
T.390	11-1988	Teletex requirements for interworking with the telex service
T.411	03-1993	Information technology – Open Document Architecture (ODA) and interchange format: Introduction and general principles
T.411 (1993) Technical Cor. 1	10-1997	
T.412	03-1993	Information technology – Open Document Architecture (ODA) and interchange format: Document structures
T.412 (1993) Technical Cor. 1	10-1997	
T.412 (1993) Technical Cor. 2	10-1997	
T.413	11-1994	Information technology – Open Document Architecture (ODA) and interchange format: Abstract interface for the manipulation of ODA documents
T.414	03-1993	Information technology – Open Document Architecture (ODA) and interchange format: Document profile
T.414 (1993) Technical Cor. 1	10-1997	
T.414 (1993) Technical Cor. 2	10-1997	
T.415	03-1993	Information technology – Open Document Architecture (ODA) and interchange format: Open document interchange format (ODIF)
T.415 (1993) Technical Cor. 1	10-1997	

T.415 (1993) Technical Cor. 2	10-1997	
T.416	03-1993	Information technology – Open Document Architecture (ODA) and interchange format: Character content architectures
T.416 (1993) Technical Cor. 1	10-1997	
T.417	03-1993	Information technology – Open Document Architecture (ODA) and interchange format: Raster graphics content architectures
T.417 (1993) Technical Cor. 1	10-1997	
T.417 (1993) Amendment 1	10-1997	
T.417 (1993) Amendment 2	02-2000	
T.418	03-1993	Information technology – Open Document Architecture (ODA) and interchange format: Geometric graphics content architecture
T.419	08-1995	Information technology – Open Document Architecture (ODA) and interchange format: Audio content architectures
T.421	11-1994	Information technology – Open Document Architecture (ODA) and interchange format: Tabular structures and tabular layout
T.422	08-1995	Information technology – Open Document Architecture (ODA) and interchange format: Identification of document fragments
T.424	07-1996	Information technology – Open Document Architecture (ODA) and interchange format: Temporal relationships and non-linear structures
T.431	09-1992	Document Transfer And Manipulation (DTAM) – Services and protocols – Introduction and general principles
T.432	09-1992	Document Transfer And Manipulation (DTAM) – Services and protocols – Service definition
T.432 (1992) Amendment 1	08-1995	Revisions of T.432 to support G4 colour and file transfer
T.433	09-1992	Document Transfer And Manipulation (DTAM) – Services and protocols – Protocol specification
T.433 (1992) Amendment 1	08-1995	Revisions of T.433 to support G4 colour and file transfer
T.434	04-1999	Binary file transfer format for the telematic services
T.435	08-1995	Document Transfer And Manipulation (DTAM) – Services and protocols – Abstract service definition and procedures for confirmed document manipulation
T.436	08-1995	Document Transfer and Manipulation (DTAM) – Services and protocols – Protocol specifications for confirmed document manipulation
T.441	11-1988	Document Transfer And Manipulation (DTAM) – Operational structure
T.501	03-1993	Document application profile MM for the interchange of formatted mixed mode documents
T.502	11-1994	Document application profile PM-11 for the interchange of simple structure, character content documents in processable and formatted forms
T.503	02-2000	Document application profile for the interchange of Group 4 facsimile documents
T.504	03-1993	Document application profile for videotex interworking
T.505	11-1994	Document application profile PM-26 for the interchange of enhanced structure, mixed content documents in processable and formatted forms

T.506	08-1993	Document application profile PM-36 for the interchange of extended document structures and mixed content documents in processable and formatted forms
T.510	03-1993	General overview of the T.510-Series Recommendations
T.521	11-1994	Communication application profile BT0 for document bulk transfer based on the session service
T.521 (1994) Amendment 1	08-1995	
T.522	09-1992	Communication application profile BT1 for document bulk transfer
T.523	03-1993	Communication application profile DM-1 for videotex interworking
T.541	03-1993	Operational application profile for videotex interworking
T.561	11-1988	Terminal characteristics for mixed mode of operation MM
T.562	11-1988	Terminal characteristics for teletex processable mode PM.1
T.563	10-1996	Terminal characteristics for Group 4 facsimile apparatus
T.563 (1996) Amendment 1	07-1997	
T.563 (1996) Amendment 2	10-1997	Annex C – T.30 frames for G4 facsimile
T.563 (1996) Corrigendum 1	06-1998	
T.563 (1996) Amendment 3	04-1999	
T.564	03-1993	Gateway characteristics for videotex interworking
T.571	09-1992	Terminal characteristics for the telematic file transfer within the teletex service
T.611	11-1994	Programming Communication Interface (PCI) APPLI/COM for facsimile Group 3, facsimile Group 4, teletex, telex, E-mail and file transfer services
T.800	08-2002	Information technology – JPEG 2000 image coding system: Core coding system
T.801	08-2002	Information technology – JPEG 2000 image coding system: Extensions
T.803	11-2002	Information technology – JPEG 2000 image coding system: Conformance testing
T.804	08-2002	Information technology – JPEG 2000 image coding system: Reference software
T.870	03-2002	Information technology – Lossless and near-lossless compression of continuous-tone still images: Extensions

Series U : Telegraph switching

Number	*Approval Date*	*Recommendation Title*
		Telegraph switching
U.1	03-1993	Signalling conditions to be applied in the international telex service
U.2	11-1988	Standardization of dials and dial pulse generators for the international telex service
U.3	11-1988	Arrangements in switching equipment to minimize the effects of false calling signals
U.4	11-1988	Exchange of information regarding signals destined to be used over international circuits concerned with switched teleprinter networks

U.5	11-1988	Requirements to be met by regenerative repeaters in international connections
U.6	11-1988	Prevention of fraudulent transit traffic in the fully automatic international telex service
U.7	03-1993	Numbering schemes for automatic switching networks
U.8	11-1988	Hypothetical reference connections for telex and gentex networks
U.10	03-1993	Equipment of an international telex position
U.11	03-1993	Telex and gentex signalling on intercontinental circuits used for intercontinental automatic transit traffic (type C signalling)
U.12	03-1993	Terminal and transit control signalling system for telex and similar services on international circuits (type D signalling)
U.15	03-1993	Interworking rules for international signalling systems according to Recommendations U.1, U.11 and U.12
U.20	11-1988	Telex and gentex signalling on radio channels (synchronous 7-unit systems affording error correction by automatic repetition)
U.21	11-1988	Operator recall on a telex call set up on a radiotelegraph circuit
U.22	11-1988	Signals indicating delay in transmission on calls set up by means of synchronous systems with automatic error correction by repetition
U.23	11-1988	Use of radiotelegraph circuits with ARQ equipment for fully automatic telex calls charged on the basis of elapsed time
U.24	11-1988	Requirements for telex and gentex operation to be met by synchronous multiplex equipment described in Recommendation R.44
U.25	11-1988	Requirements for telex and gentex operation to be met by code- and speed-dependent TDM systems conforming to Recommendation R.101
U.30	11-1988	Signalling conditions for use in the international gentex network
U.31	11-1988	Prevention of connection to faulty stations and/or station lines in the gentex service
U.40	03-1993	Reactions by automatic terminals connected to the telex network in the event of ineffective call attempts or signalling incidents
U.41	11-1988	Changed address interception and call redirection in the telex service
U.43	11-1988	Follow-on calls
U.44	11-1988	Multi-address calls in real time for broadcast purposes in the international telex service
U.45	03-1993	Response to the not-ready condition of the telex terminal
U.46	03-1993	Interruption of automatic transmission and flow control in the international telex service
U.60	11-1988	General requirements to be met in interfacing the international telex network with maritime satellite systems
U.61	03-1993	Detailed requirements to be met in interfacing the international telex network with maritime satellite systems
U.62	03-1993	General requirements to be met in interfacing the international telex network with the fully automated maritime VHF/UHF radio system
U.63	11-1988	General requirements to be met in interfacing the international telex network with the maritime "direct printing" system
U.70	11-1988	Telex service signals for telex to teletex interworking
U.74	11-1988	Extraction of telex selection information from a calling telex answerback
U.75	03-1993	Automatic called telex answerback check

U.80	03-1993	International telex store and forward access from a telex subscriber
U.81	10-1996	International telex store-and-forward – Delivery to a telex subscriber
U.101	03-1993	Signalling systems for the Intex service (types E and F signalling)
U.102	07-1996	Intex and similar services – Network requirements to effect interworking between terminals operating at different speeds
U.140	11-1988	Definitions of essential technical terms relating to telegraph switching and signalling
U.200	03-1993	The international telex service – General technical requirements for interworking
U.201	03-1993	Interworking between the teletex service and the international telex service
U.202	03-1993	Technical requirements to be met in providing the international telex service within an integrated services digital network
U.203	03-1993	Technical requirements to be met when providing real-time bothway communications between terminals of the international telex service and data terminal equipments on a PSPDN or via the PSTN
U.204	03-1993	Interworking between the international telex service and the public interpersonal messaging service
U.205	03-1993	Store-and-retrieve facility for the delivery of messages from a terminal of the international telex service to a data terminal equipment which connects to a packet-switched public data network over the public switched telephone network
U.206	03-1993	Technical requirements for interworking between the international telex service and the videotex service
U.207	03-1993	Technical requirements to be met for the transfer of messages between terminals of the international telex service and Group 3 facsimile terminals connected to the PSTN
U.208	10-1996	The international telex service – Interworking with the INMARSAT C system using one-stage selection
U.210	03-1993	Intex service network requirements to effect interworking with the international telex service
U.220	03-1993	The international telex service – Technical requirements for a status enquiry function in an interworking scenario

Series V : Data communication over the telephone network

Number	*Approval Date*	*Recommendation Title*
		Data communication over the telephone network
V.1	11-1988	Equivalence between binary notation symbols and the significant conditions of a two-condition code
V.2	11-1988	Power levels for data transmission over telephone lines
V.4	11-1988	General structure of signals of International Alphabet No. 5 code for character oriented data transmission over public telephone networks
V.7	11-1988	Definitions of terms concerning data communication over the telephone network
V.8	11-2000	Procedures for starting sessions of data transmission over the public switched telephone network
V.8bis	11-2000	Procedures for the identification and selection of common modes of operation between data circuit-terminating equipments (DCEs) and between data terminal equipments (DTEs) over the public switched telephone network and on leased point-to-point telephone-t
V.10	03-1993	Electrical characteristics for unbalanced double-current interchange circuits operating at data signalling rates nominally up to 100 kbit/s

V.11	10-1996	Electrical characteristics for balanced double-current interchange circuits operating at data signalling rates up to 10 Mbit/s
V.12	08-1995	Electrical characteristics for balanced double-current interchange circuits for interfaces with data signalling rates up to 52 Mbit/s
V.13	03-1993	Simulated carrier control
V.14	03-1993	Transmission of start-stop characters over synchronous bearer channels
V.14 (1993) Corrigendum 1	09-1998	
V.15	11-1988	Use of acoustic coupling for data transmission
V.16	11-1988	Medical analogue data transmission modems
V.17	02-1991	A 2-wire modem for facsimile applications with rates up to 14 400 bit/s
V.17 (1991) Corrigendum 1	09-1998	
V.18	11-2000	Operational and interworking requirements for DCEs operating in the text telephone mode
V.18 (2000) Amendment 1	11-2002	Harmonization with ANSI TIA/EIA-825 (2000) text phones
V.19	11-1988	Modems for parallel data transmission using telephone signalling frequencies
V.21	11-1988	300 bits per second duplex modem standardized for use in the general switched telephone network
V.22	11-1988	1200 bits per second duplex modem standardized for use in the general switched telephone network and on point-to-point 2-wire leased telephone-type circuits
V.22bis	11-1988	2400 bits per second duplex modem using the frequency division technique standardized for use on the general switched telephone network and on point-to-point 2-wire leased telephone-type circuits
V.23	11-1988	600/1200-baud modem standardized for use in the general switched telephone network
V.24	02-2000	List of definitions for interchange circuits between data terminal equipment (DTE) and data circuit-terminating equipment (DCE)
V.25	10-1996	Automatic answering equipment and general procedures for automatic calling equipment on the general switched telephone network including procedures for disabling of echo control devices for both manually and automatically established calls
V.25 (1996) Corrigendum 1	07-2001	
V.25bis	10-1996	Synchronous and asynchronous automatic dialling procedures on switched networks
V.26	11-1988	2400 bits per second modem standardized for use on 4-wire leased telephone-type circuits
V.26bis	11-1988	2400/1200 bits per second modem standardized for use in the general switched telephone network
V.26ter	11-1988	2400 bits per second duplex modem using the echo cancellation technique standardized for use on the general switched telephone network and on point-to-point 2-wire leased telephone-type circuits
V.27	11-1988	4800 bits per second modem with manual equalizer standardized for use on leased telephone-type circuits
V.27bis	11-1988	4800/2400 bits per second modem with automatic equalizer standardized for use on leased telephone-type circuits
V.27ter	11-1988	4800/2400 bits per second modem standardized for use in the general switched telephone network

V.28	03-1993	Electrical characteristics for unbalanced double-current interchange circuits
V.29	11-1988	9600 bits per second modem standardized for use on point-to-point 4-wire leased telephone-type circuits
V.31	11-1988	Electrical characteristics for single-current interchange circuits controlled by contact closure
V.31bis	11-1988	Electrical characteristics for single-current interchange circuits using optocouplers
V.32	03-1993	A family of 2-wire, duplex modems operating at data signalling rates of up to 9600 bit/s for use on the general switched telephone network and on leased telephone-type circuits
V.32bis	02-1991	A duplex modem operating at data signalling rates of up to 14 400 bit/s for use on the general switched telephone network and on leased point-to-point 2-wire telephone-type circuits
V.33	11-1988	14 400 bits per second modem standardized for use on point-to-point 4-wire leased telephone-type circuits
V.34	02-1998	A modem operating at data signalling rates of up to 33 600 bit/s for use on the general switched telephone network and on leased point-to-point 2-wire telephone-type circuits
V.36	11-1988	Modems for synchronous data transmission using 60-108 kHz group band circuits
V.37	11-1988	Synchronous data transmission at a data signalling rate higher than 72 kbit/s using 60-108 kHz group band circuits
V.38	10-1996	A 48/56/64 kbit/s data circuit-terminating equipment standardized for use on digital point-to-point leased circuits
V.41	11-1988	Code-independent error-control system
V.42	03-2002	Error-correcting procedures for DCEs using asynchronous-to-synchronous conversion
V.42 (2002) Corrigendum 1	07-2003	
V.42bis	01-1990	Data compression procedures for data circuit-terminating equipment (DCE) using error correction procedures
V.43	02-1998	Data flow control
V.44	11-2000	Data compression procedures
V.44 (2000) Corrigendum 1	03-2002	
V.50	11-1988	Standard limits for transmission quality of data transmission
M.729	11-1988	Organization of the maintenance of international public switched telephone circuits used for data transmission
V.53	11-1988	Limits for the maintenance of telephone-type circuits used for data transmission
V.54	11-1988	Loop test devices for modems
O.71	11-1988	Impulsive noise measuring equipment for telephone-type circuits
V.56	11-1988	Comparative tests of modems for use over telephone-type circuits
V.56bis	08-1995	Network transmission model for evaluating modem performance over 2-wire voice grade connections
V.56ter	08-1996	Test procedure for evaluation of 2-wire 4 kHz voiceband duplex modems
V.58	09-1994	Management information model for V-Series DCEs
V.59	11-2000	Managed objects for diagnostic information of public switched telephone network connected V-series modem DCEs

V.59 (2000) Corrigendum 1	07-2001	
V.59 (2000) Corrigendum 2	03-2002	
V.61	08-1996	A simultaneous voice plus data modem, operating at a voice plus data signalling rate of 4800 bit/s, with optional automatic switching to data-only signalling rates of up to 14400 bit/s, for use on the General Switched Telephone Network and on leased point
V.70	08-1996	Procedures for the simultaneous transmission of data and digitally encoded voice signals over the GSTN, or over 2-wire leased point-to-point telephone type circuits
V.75	08-1996	DSVD terminal control procedures
V.75 Appendix II	02-1998	Session establishment using V.75/H.245 procedures
V.76	08-1996	Generic multiplexer using V.42 LAPM-based procedures
V.80	08-1996	In-band DCE control and synchronous data modes for asynchronous DTE
V.80 (1996) Amendment 1	07-2001	Additional data signalling rate codes in support of cellular systems
V.90	09-1998	A digital modem and analogue modem pair for use on the Public Switched Telephone Network (PSTN) at data signalling rates of up to 56 000 bit/s downstream and up to 33 600 bit/s upstream
V.91	05-1999	A digital modem operating at data signalling rates of up to 64 000 bit/s for use on a 4-wire circuit switched connection and on leased point-to-point 4-wire digital circuits
V.91 (1999) Corrigendum 1	07-2001	
V.92	11-2000	Enhancements to Recommendation V.90
V.92 (2000) Amendment 1	07-2001	Update of Tables 18, 19, 31, 32, Figure 20 and Clauses 8.6.6, 8.7.6, 9.10.1, and 9.11
V.92 (2000) Amendment 2	03-2002	New interaction facilities for error-correcting procedures
V.92 (2000) Corrigendum 1	07-2003	
V.100	11-1988	Interconnection between public data networks (PDNs) and the public switched telephone networks (PSTN)
V.110	02-2000	Support by an ISDN of data terminal equipments with V-series type interfaces
V.120	10-1996	Support by an ISDN of data terminal equipment with V-series type interfaces with provision for statistical multiplexing
V.120 (1996) Corrigendum 1	05-1999	
V.130	08-1995	ISDN terminal adaptor framework
V.140	02-1998	Procedures for establishing communication between two multiprotocol audiovisual terminals using digital channels at a multiple of 64 or 56 kbit/s
V.150.0	01-2003	Modem-over-IP networks: Foundation
V.150.1	01-2003	Modem-over-IP networks: Procedures for the end-to-end connection of V-series DCEs
V.150.1 (2003) Corrigendum 1	07-2003	
V.150.1 (2003) Corrigendum 2	03-2004	
V.230	11-1988	General data communications interface layer 1 specification

V.250	07-2003	Serial asynchronous automatic dialling and control
V.250 Supplement 1	06-2001	Various extensions to V.250 basic command set
V.251	08-1996	Procedure for DTE-controlled call negotiation
V.251 (1996) Erratum 1	10-2003	
V.252	02-1998	Procedure for control of V.70 and H.324 terminals by a DTE
V.253	02-1998	Control of voice-related functions in a DCE by an asynchronous DTE
V.300	07-1999	A 128 (144) kbit/s data circuit-terminating equipment standardized for use on digital point-to-point leased circuits

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Number	*Approval Date*	*Recommendation Title*
		Data networks and open system communications
X.1	03-2000	International user classes of service in, and categories of access to, public data networks and Integrated Services Digital Networks (ISDNs)
X.2	03-2000	International data transmission services and optional user facilities in public data networks and ISDNs
X.3	03-2000	Packet Assembly/Disassembly facility (PAD) in a public data network
X.4	11-1988	General structure of signals of International Alphabet No. 5 code for character oriented data transmission over public data networks
X.5	10-1996	Facsimile Packet Assembly/Disassembly facility (FPAD) in a public data network
X.6	08-1997	Multicast service definition
X.6 (1997) Amendment 1	03-2000	Frame relay PVC multicast service definition
X.7	04-2004	Technical characteristics of data transmission services
X.8	07-1994	Multi-aspect PAD (MAP) framework and service definition
X.20	11-1988	Interface between Data Terminal Equipment (DTE) and Data Circuit-terminating Equipment (DCE) for start-stop transmission services on public data networks
X.20bis	11-1988	Use on public data networks of Data Terminal Equipment (DTE) which is designed for interfacing to asynchronous duplex V-Series modems
X.21	09-1992	Interface between Data Terminal Equipment and Data Circuit-terminating Equipment for synchronous operation on public data networks
X.21bis	11-1988	Use on public data networks of Data Terminal Equipment (DTE) which is designed for interfacing to synchronous V-Series modems
X.22	11-1988	Multiplex DTE/DCE interface for user classes 3-6
X.24	11-1988	List of definitions for interchange circuits between Data Terminal Equipment (DTE) and Data Circuit-terminating Equipment (DCE) on public data networks
X.25	10-1996	Interface between Data Terminal Equipment (DTE) and Data Circuit-terminating Equipment (DCE) for terminals operating in the packet mode and connected to public data networks by dedicated circuit
X.25 (1996) Corrigendum 1	09-1998	

V.10	03-1993	Electrical characteristics for unbalanced double-current interchange circuits operating at data signalling rates nominally up to 100 kbit/s
V.11	10-1996	Electrical characteristics for balanced double-current interchange circuits operating at data signalling rates up to 10 Mbit/s
X.28	12-1997	DTE/DCE interface for a start-stop mode Data Terminal Equipment accessing the Packet Assembly/Disassembly facility (PAD) in a public data network situated in the same country
X.28 (1997) Amendment 1	03-2000	Extensions of PAD parameter settings and PAD service signals
X.29	12-1997	Procedures for the exchange of control information and user data between a Packet Assembly/Disassembly (PAD) facility and a packet mode DTE or another PAD
X.30	03-1993	Support of X.21, X.21 bis and X.20 bis based Data Terminal Equipments (DTEs) by an Integrated Services Digital Network (ISDN)
X.31	11-1995	Support of packet mode terminal equipment by an ISDN
X.32	10-1996	Interface between Data terminal Equipment (DTE) and Data Circuit-terminating Equipment (DCE) for terminals operating in the packet mode and accessing a Packet-Switched Public Data Network through a public switched telephone network or an Integrated Servic
X.33	10-1996	Access to packet-switched data transmission services via frame relaying data transmission services
X.34	10-1996	Access to packet-switched data transmission services via B-ISDN
X.34 (1996) Corrigendum 1	03-2000	
X.35	11-1993	Interface between a PSPDN and a private PSDN which is based on X.25 procedures and enhancements to define a gateway function that is provided in the PSPDN
X.36	02-2003	Interface between Data Terminal Equipment (DTE) and Data Circuit-terminating Equipment (DCE) for public data networks providing frame relay data transmission service by dedicated circuit
X.37	04-1995	Encapsulation in X.25 packets of various protocols including frame relay
X.38	10-1996	G3 facsimile equipment/DCE interface for G3 facsimile equipment accessing the Facsimile Packet Assembly/Disassembly facility (FPAD) in a public data network situated in the same country
X.39	10-1996	Procedures for the exchange of control information and user data between a Facsimile Packet Assembly/Disassembly (FPAD) facility and a packet mode Data Terminal Equipment (DTE) or another FPAD
X.42	10-2003	Procedures and methods for accessing a public data network from a DTE operating under control of a generalized polling protocol
X.45	10-1996	Interface between data terminal equipment (DTE) and data circuit-terminating equipment (DCE) for terminals operating in the packet mode and connected to public data networks, designed for efficiency at higher speeds
X.46	09-1998	Access to FRDTS via B-ISDN
X.48	10-1996	Procedures for the provision of a basic multicast service for data terminal equipments (DTEs) using Recommendation X.25
X.49	10-1996	Procedures for the provision of an extended multicast service for data terminal equipments (DTEs) using Recommendation X.25
X.50	11-1988	Fundamental parameters of a multiplexing scheme for the international interface between synchronous data networks
X.50bis	11-1988	Fundamental parameters of a 48-kbit/s user data signalling rate transmission scheme for the international interface between synchronous data networks
X.51	11-1988	Fundamental parameters of a multiplexing scheme for the international interface between synchronous data networks using 10-bit envelope structure

X.51bis	11-1988	Fundamental parameters of a 48-kbit/s user data signalling rate transmission scheme for the international interface between synchronous data networks using 10-bit envelope structure
X.52	11-1988	Method of encoding anisochronous signals into a synchronous user bearer
X.53	03-1993	Numbering of channels on international multiplex links at 64 kbit/s
X.54	11-1988	Allocation of channels on international multiplex links at 64 kbit/s
X.55	11-1988	Interface between synchronous data networks using a 6 + 2 envelope structure and single channel per carrier (SCPC) satellite channels
X.56	11-1988	Interface between synchronous data networks using an 8 + 2 envelope structure and single channel per carrier (SCPC) satellite channels
X.57	11-1988	Method of transmitting a single lower speed data channel on a 64 kbit/s data stream
X.58	11-1988	Fundamental parameters of a multiplexing scheme for the international interface between synchronous non-switched data networks using no envelope structure
X.60	11-1988	Common channel signalling for circuit-switched data applications
X.70	11-1988	Terminal and transit control signalling system for start-stop services on international circuits between anisochronous data networks
X.71	11-1988	Decentralized terminal and transit control signalling system on international circuits between synchronous data networks
X.75	10-1996	Packet-switched signalling system between public networks providing data transmission services
X.75 (1996) Corrigendum 1	09-1998	
X.76	02-2003	Network-to-network interface between public networks providing PVC and/or SVC frame relay data transmission service
X.77	08-1997	Interworking between PSPDNs via B-ISDN
X.77 (1997) Corrigendum 1	03-2000	
X.78	06-1999	Interworking procedures between networks providing frame relay data transmission services via B-ISDN
X.78 (1999) Corrigendum 1	03-2000	
X.80	11-1988	Interworking of interexchange signalling systems for circuit-switched data services
X.81	11-1988	Interworking between an ISDN circuit-switched and a circuit-switched public data network (CSPDN)
X.82	11-1988	Detailed arrangements for interworking between CSPDNs and PSPDNs based on Recommendation T.70
X.84	03-2004	Support of frame relay services over MPLS core networks
X.85/Y.1321	03-2001	IP over SDH using LAPS
X.85/Y.1321 (2001) Amendment 1	04-2004	Bit-oriented method for LAPS
X.86/Y.1323	02-2001	Ethernet over LAPS
X.86/Y.1323 (2001) Amendment 1	04-2002	Using Ethernet flow control as rate limiting
X.87/Y.1324	10-2003	Multiple services ring based on RPR

X.92	11-1988	Hypothetical reference connections for public synchronous data networks
X.96	03-2000	Call progress signals in public data networks
X.110	04-2002	International routing principles and routing plan for Public Data Networks
X.111	02-2003	Principles for the routing of international frame relay traffic
X.115	04-1995	Definition of address translation capability in public data networks
X.115 (1995) Amendment 1	10-1996	Refinements
X.116	10-1996	Address translation registration and resolution protocol
X.121	10-2000	International numbering plan for public data networks
E.166/X.122	03-1998	Numbering plan interworking for the E.164 and X.121 numbering plans
X.123	10-1996	Mapping between escape codes and TOA/NPI for E.164/X.121 numbering plan interworking during the transition period
X.124	06-1999	Arrangements for the interworking of the E.164 and X.121 numbering plans for frame relay and ATM networks
X.125	09-1998	Procedure for the notification of the assignment of international network identification codes for public frame relay data networks and ATM networks numbered under the E.164 numbering plan
X.130	11-1988	Call processing delays in public data networks when providing international synchronous circuit-switched data services
X.131	11-1988	Call blocking in public data networks when providing international synchronous circuit-switched data services
X.134	08-1997	Portion boundaries and packet-layer reference events: basis for defining packet-switched performance parameters
X.135	08-1997	Speed of service (delay and throughput) performance values for public data networks when providing international packet-switched services
X.135 Suppl. 1	08-1997	Some test results from specific national and international portions
X.136	08-1997	Accuracy and dependability performance values for public data networks when providing international packet-switched services
X.137	08-1997	Availability performance values for public data networks when providing international packet-switched services
X.138	08-1997	Measurement of performance values for public data networks when providing international packet-switched services
X.139	08-1997	Echo, drop, generator and test DTEs for measurement of performance values in public data networks when providing international packet-switched services
X.140	09-1992	General quality of service parameters for communication via public data networks
X.141	11-1988	General principles for the detection and correction of errors in public data networks
X.142	10-2003	Quality of service metrics for characterizing Frame Relay/ATM service interworking performance
X.144	10-2003	User information transfer performance parameters for public frame relay data networks
X.145	10-2003	Connection establishment and disengagement performance parameters for public Frame Relay data networks providing SVC services
X.146	10-2000	Performance objectives and quality of service classes applicable to frame relay
X.147	10-2003	Frame Relay network availability

X.147 (2003) Amendment 1	04-2004	Specification of availability objective values
X.148	02-2003	Procedures for the measurement of the performance of public data networks providing the international frame relay service
X.149	10-2003	Performance of IP networks when supported by public Frame Relay data networks
X.150	11-1988	Principles of maintenance testing for public data networks using Data Terminal Equipment (DTE) and Data Circuit-terminating Equipment (DCE) test loops
X.151	10-2003	Frame Relay operations and maintenance – Principles and functions
X.151 (2003) Erratum 1	03-2004	
X.160	10-1996	Architecture for customer network management service for public data networks
X.161	08-1997	Definition of customer network management services for public data networks
X.162	03-2000	Definition of management information for customer network management service for public data networks to be used with the CNMc interface
X.163	04-1995	Definition of management information for customer network management service for public data networks to be used with the CNMe interface
X.170	06-1999	Network-network management architecture for data networks
X.171	03-2000	Network-network management services for data networks
X.180	11-1988	Administrative arrangements for international closed user groups (CUGs)
X.181	11-1988	Administrative arrangements for the provision of international permanent virtual circuits (PVCs)
X.200	07-1994	Information technology – Open Systems Interconnection – Basic Reference Model: The basic model
X.207	11-1993	Information technology – Open Systems Interconnection – Application layer structure
X.210	11-1993	Information technology – Open Systems Interconnection – Basic Reference Model: Conventions for the definition of OSI services
X.211	11-1995	Information technology – Open Systems Interconnection – Physical service definition
X.212	11-1995	Information technology – Open Systems Interconnection – Data Link service definition
X.213	10-2001	Information technology – Open Systems Interconnection – Network service definition
X.214	11-1995	Information technology – Open Systems Interconnection -Transport service definition
X.215	11-1995	Information technology – Open Systems Interconnection – Session service definition
X.215 (1995) Amendment 1	08-1997	Efficiency enhancements
X.215 (1995) Amendment 2	12-1997	Nested connections functional unit
X.215 (1995) Technical Cor. 1	03-2000	
X.216	07-1994	Information technology – Open Systems Interconnection – Presentation service definition
X.216 (1994) Amendment 1	08-1997	Efficiency enhancements
X.216 (1994) Amendment 2	12-1997	Nested connections functional unit

X.217	04-1995	Information technology – Open Systems Interconnection – Service definition for the Association Control Service Element
X.217 (1995) Amendment 1	10-1996	Support of authentication mechanisms for the connectionless mode
X.217 (1995) Amendment 2	08-1997	Fast-associate mechanism
X.217bis	09-1998	Information technology – Open Systems Interconnection – Service definition for the Application Service Object Association Control Service Element
X.218	03-1993	Reliable Transfer: Model and service definition
X.219	11-1988	Remote Operations: Model, notation and service definition
X.220	03-1993	Use of X.200-Series protocols in CCITT applications
X.222	04-1995	Use of X.25 LAPB-compatible Data Link procedures to provide the OSI connection-mode Data Link service
X.222 (1995) Amendment 1	10-1996	Frame relay mapping
X.223	11-1993	Use of X.25 to provide the OSI connection-mode Network service for ITU-T applications
X.223 (1993) Amendment 1	10-1996	Transit delay and other refinements
X.224	11-1995	Information technology – Open Systems Interconnection – Protocol for providing the connection-mode transport service
X.224 (1995) Amendment 1	08-1997	Relaxation of class conformance requirements and expedited data service feature negotiation
X.225	11-1995	Information technology – Open Systems Interconnection – Connection-oriented Session protocol: Protocol specification
X.225 (1995) Amendment 1	08-1997	Efficiency enhancements
X.225 (1995) Amendment 2	12-1997	Nested connections functional unit
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X.226	07-1994	Information technology – Open Systems Interconnection – Connection-oriented Presentation protocol: Protocol specification
X.226 (1994) Amendment 1	08-1997	Efficiency enhancements
X.226 (1994) Amendment 2	12-1997	Nested connections functional unit
X.227	04-1995	Information technology – Open Systems Interconnection – Connection-oriented protocol for the Association Control Service Element: Protocol specification
X.227 (1995) Amendment 1	10-1996	Incorporation of extensibility markers
X.227 (1995) Amendment 2	08-1997	Fast-associate mechanism
X.227bis	09-1998	Information technology – Open Systems Interconnection – Connection-mode protocol for the Application Service Object Association Control Service Element
X.228	11-1988	Reliable Transfer: Protocol specification
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X.229	11-1988	Remote Operations: Protocol specification
X.233	08-1997	Information technology – Protocol for providing the connectionless-mode network service: Protocol specification
X.234	07-1994	Information technology – Protocol for providing the OSI connectionless-mode transport service
X.234 (1994) Amendment 1	11-1995	Addition of connectionless-mode multicast capability
X.235	04-1995	Information technology – Open Systems Interconnection – Connectionless Session protocol: Protocol specification
X.235 (1995) Amendment 1	06-1999	Efficiency enhancements
X.236	04-1995	Information technology – Open Systems Interconnection – Connectionless Presentation protocol: Protocol specification
X.236 (1995) Amendment 1	06-1999	Efficency enhancements
X.237	04-1995	Information technology – Open Systems Interconnection – Connectionless protocol for the Association Control Service Element: Protocol specification
X.237 (1995) Amendment 1	10-1996	Incorporation of extensibility markers and authentication parameters
X.237 Amd1 (10/96) Technical Cor.1	06-1999	
X.237bis	09-1998	Information technology – Open Systems Interconnection – Connectionless protocol for the Application Service Object Association Control Service Element
X.245	04-1995	Information technology – Open Systems Interconnection – Connection-oriented Session protocol: Protocol Implementation Conformance Statement (PICS) proforma
X.246	10-1996	Information technology – Open Systems Interconnection – Connection-oriented Presentation protocol: Protocol Implementation Conformance Statement (PICS) proforma
X.247	10-1996	Information technology – Open Systems Interconnection – Protocol specification for the Association Control Service Element: Protocol Implementation Conformance Statement (PICS) proforma
X.248	11-1995	Information technology – Open Systems Interconnection – Reliable Transfer: Protocol Implementation Conformance Statement (PICS) proforma
X.249	11-1995	Information technology – Open Systems Interconnection – Remote Operations: Protocol Implementation Conformance Statement (PICS) proforma
X.255	04-1995	Information technology – Open Systems Interconnection – Connectionless Session protocol: Protocol Implementation Conformance Statement (PICS) proforma
X.256	04-1995	Information technology – Open Systems Interconnection – Connectionless Presentation protocol: Protocol Implementation Conformance Statement (PICS) proforma
X.257	04-1995	Information technology – Open Systems Interconnection – Connectionless protocol for the Association Control Service Element: Protocol Implementation Conformance Statement (PICS) proforma
X.257 (1995) Amendment 1	10-1996	Support of authentication parameters
X.260	10-1996	Information technology – Framework for protocol identification and encapsulation
X.263	09-1998	Information technology – Protocol identification in the Network Layer
X.264	11-1993	Transport protocol identification mechanism
X.272	03-2000	Data compression and privacy over frame relay networks

X.273	07-1994	Information technology – Open Systems Interconnection – Network layer security protocol
X.274	07-1994	Information technology – Telecommunication and information exchange between systems – Transport layer security protocol
X.281	06-1999	Information technology – Elements of management information related to the OSI Physical Layer
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X.287	03-1999	Information technology – Open Systems Interconnection – Structure of management information: Managed objects for supporting upper layers
X.290	04-1995	OSI conformance testing methodology and framework for protocol Recommendations for ITU-T applications – General concepts
X.291	04-1995	OSI conformance testing methodology and framework for protocol Recommendations for ITU-T applications – Abstract test suite specification
X.292	05-2002	OSI conformance testing methodology and framework for protocol Recommendations for ITU-T applications – The Tree and Tabular Combined Notation (TTCN)
X.293	04-1995	OSI conformance testing methodology and framework for protocol Recommendations for ITU-T applications – Test realization
X.294	04-1995	OSI conformance testing methodology and framework for protocol Recommendations for ITU-T applications – Requirements on test laboratories and clients for the conformance assessment process
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X.300	10-1996	General principles for interworking between public networks and between public networks and other networks for the provision of data transmission services
X.301	10-1996	Description of the general arrangements for call control within a subnetwork and between subnetworks for the provision of data transmission services
X.302	11-1988	Description of the general arrangements for internal network utilities within a subnetwork and intermediate utilities between subnetworks for the provision of data transmission services
X.305	11-1988	Functionalities of subnetworks relating to the support of the OSI connection-mode network service
X.320	10-1996	General arrangements for interworking between Integrated Services Digital Networks (ISDNs) for the provision of data transmission services
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X.325	10-1996	General arrangements for interworking between Packet-Switched Public Data Networks (PSPDNs) and Integrated Services Digital Networks (ISDNs) for the provision of data transmission services
X.326	11-1988	General arrangements for interworking between Packet-Switched Public Data Networks (PSPDNs) and Common Channel Signalling Network (CCSN)
X.327	11-1993	General arrangements for interworking between Packet-Switched Public Data Networks (PSPDNs) and private data networks for the provision of data transmission services
X.328	10-1996	General arrangements for interworking between Public Data Networks providing frame relay data transmission services and Integrated Services Digital Networks (ISDNs) for the provision of data transmission services
X.329	03-2000	General arrangements for interworking between networks providing frame relay data transmission services and B-ISDN
X.340	03-1993	General arrangements for interworking between a Packet-Switched Public Data Network (PSPDN) and the international telex network
X.350	12-1997	General interworking requirements to be met for data transmission in international public mobile satellite systems
X.351	11-1988	Special requirements to be met for Packet Assembly/Disassembly facilities (PADs) located at or in association with coast earth stations in the public mobile satellite service
X.352	11-1988	Interworking between Packet-Switched Public Data Networks and public maritime mobile satellite data transmission systems
X.353	11-1988	Routing principles for interconnecting public maritime mobile satellite data transmission systems with public data networks
X.361	10-1996	Connection of VSAT systems with Packet-Switched Public Data Networks based on X.25 procedures
X.371/Y.1402	02-2001	General arrangements for interworking between Public Data Networks and the Internet
F.400/X.400	06-1999	Message handling services: Message handling system and service overview
X.402	06-1999	Information technology – Message Handling Systems (MHS): Overall architecture
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X.408	11-1988	Message handling systems: Encoded information type conversion rules
X.411	06-1999	Information technology – Message Handling Systems (MHS): Message Transfer System: Abstract Service Definition and Procedures
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X.445	04-1995	Asynchronous protocol specification – Provision of OSI connection mode network service over the telephone network
X.446	08-1997	Common messaging call API

X.460	04-1995	Information technology – Message Handling Systems (MHS) Management: Model and architecture
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X.481	06-1999	Message handling systems – P2 protocol PICS proforma
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X.485	09-1992	Message handling systems: Voice messaging system Protocol Implementation Conformance Statement (PICS) proforma
X.486	06-1999	Message handling systems – Pedi protocol PICS proforma
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X.500	02-2001	Information technology – Open Systems Interconnection – The Directory: Overview of concepts, models and services
X.501	02-2001	Information technology – Open Systems Interconnection – The Directory: Models
X.509	03-2000	Information technology – Open Systems Interconnection – The Directory: Public-key and attribute certificate frameworks
X.509 (2000) Technical Cor.1	10-2001	
X.509 (2000) Technical Cor.2	04-2002	
X.509 (2000) Corrigendum 3	04-2004	
X.511	02-2001	Information technology – Open Systems Interconnection – The Directory: Abstract service definition
X.518	02-2001	Information technology – Open Systems Interconnection – The Directory: Procedures for distributed operation
X.519	02-2001	Information technology – Open Systems Interconnection – The Directory: Protocol specifications
X.520	02-2001	Information technology – Open Systems Interconnection – The Directory: Selected attribute types
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X.521	02-2001	Information technology – Open Systems Interconnection – The Directory: Selected object classes
X.525	02-2001	Information technology – Open Systems Interconnection – The Directory: Replication
X.530	02-2001	Information technology – Open Systems Interconnection – The Directory: Use of systems management for administration of the Directory
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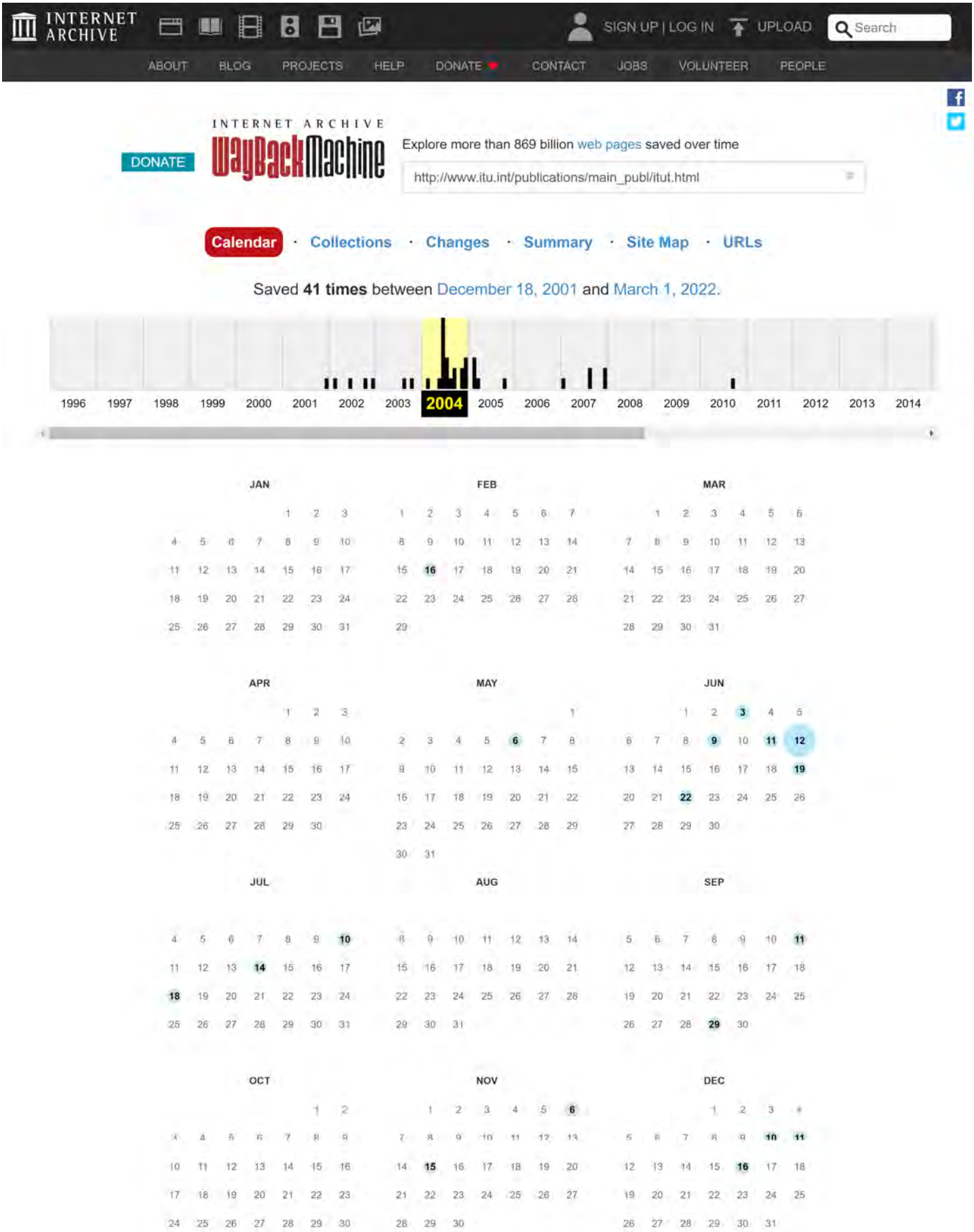
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Virtualized Reality: Constructing Virtual Worlds from Real Scenes

January-March 1997, pp. 34-47, vol. 4
DOI Bookmark: 10.1109/93.580394

Authors

Takeo Kanade
Peter Rander
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Abstract

Virtualized Reality is a new visual medium that immerses viewers in a virtual reconstruction of real-world events, i.e., a virtualized model of the real world. This medium addresses two fundamental limitations of other visual media such as motion pictures and video: fixed viewpoints and two-dimensional views. Virtualized Reality enables users to select their own viewpoints at view time, independent of the actual camera positions used to capture the event. It also provides stereoscopic reconstructions of the event, enabling a viewer to be completely immersed in the virtualized event. The Virtualized Reality world model consists of real images and depth information computed from these images. The depth information is converted into 3D triangle meshes representing the surfaces visible in each image. Virtual camera images are generated by rendering the 3D meshes into the virtual camera, mapping the real images onto the meshes as texture. The virtual images, therefore, preserve the visual realism of even complex scenes. In contrast, typical virtual worlds are built by hand or using CAD tools. They tend to be simple and often lack visual realism. Realistic training in a virtualized work space is an important application area of Virtualized Reality. For example, surgical training could be enhanced by enabling the trainees to explore the virtualized operation at their will. A new medium of entertainment can also develop from Virtualized Reality. This medium would allow a viewer to watch a ballet performance seated on the edge of the stage or a basketball game while standing on the court or running with a particular player. Readers may contact Rander at the Robotics Institute, Carnegie Mellon University, Smith Hall, Pittsburgh, PA 15213-3890, e-mail rander@cs.cmu.edu.

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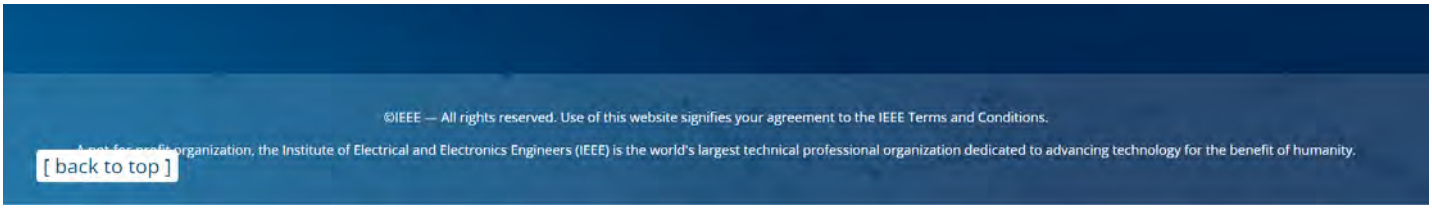
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Virtualized Reality: Constructing Virtual Worlds from Real Scenes

Takeo Kanade and Peter Rander
Carnegie Mellon University

P.J. Narayanan
Centre for Artificial Intelligence and Robotics

A new visual medium, Virtualized Reality, immerses viewers in a virtual reconstruction of real-world events. The Virtualized Reality world model consists of real images and depth information computed from these images. Stereoscopic reconstructions provide a sense of complete immersion, and users can select their own viewpoints at view time, independent of the actual camera positions used to capture the event.

The different visual media we have today share two shortcomings: director-decided viewpoints and two-dimensional views. *Virtualized Reality* is an immersive visual medium that lets the viewer select a (possibly time-varying) viewing angle at view time, freely moving throughout the *virtualized* event in ways even a mobile camera present at the event site could not. A viewer equipped with a stereo viewing system can even be immersed in a stereoscopic reconstruction of the live or recorded event. Viewers can thus watch a virtualized basketball game from a seat at the center of the court or from a viewpoint moving with the ball.

Like Virtualized Reality, virtual reality (VR) also immerses the viewer in a virtual environment. The two differ, however, in how the virtual world models are constructed. VR environments are typically created using simplistic CAD models and lack fine detail. Virtualized Reality, in contrast, automatically constructs the virtual model from images of the real world, preserving the visible detail of the real-world images. It is thus possible to create realistic virtualized environments of such complex environments as a surgery or a basketball game. Such environments lie beyond the scope of current VR systems.

The Virtualized Reality process involves three phases: transcribing the visual event, recovering 3D structure, and generating synthetic viewpoints. We transcribe a visual event using many cameras surrounding the scene. We compute the 3D structure of the event for some of these cameras using a multi-camera stereo method.[1] The views for which we compute structure are called *transcription angles*. The stereo process generates a depth map, which encodes the scene depth of each image point from the corresponding transcription angle. We call this combination of an image and an aligned depth map a *scene description*.

The virtualized model of one time instant consists of a collection of scene descriptions at that instant, each from a different transcription angle. A time-varying event is represented as a collection of successive time instants. Scene descriptions translate easily into computer graphics models with depth maps providing scene geometry and images providing scene texture. Novel views of the virtualized event can be synthesized easily from these models using graphics hardware.

Possible applications of Virtualized Reality include realistic training in a virtualized work space, true telepresence, and imaginative uses in entertainment. For example, surgical training could be enhanced by virtualizing a rare heart surgery. Students could then observe the operation in 3D from anywhere in the virtualized operating room, potentially standing in the same position as the actual surgeon. To achieve telepresence, reconstruction and display of the remote scene occurs simultaneously with the actual event. For entertainment, Virtualized Reality could make possible a whole new medium that would allow viewers to watch a ballet performance seated on the edge of the stage or a basketball game while standing on the court or running with a particular player.

View synthesis

Visual reconstruction from arbitrary viewpoints is an important component of Virtualized Reality. View synthesis, or view transfer, considers visual reconstruction as an image-to-image mapping designed to generate novel views of a scene given two or more real images of it. Additional knowledge about the scene or the imaging process may also contribute to synthesis.

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One class of view synthesis techniques requires image flow or pixel correspondence, that is, knowledge about where points in one image move to in another image. Using this information, Tseng and Anastassiou[2] described a codec similar to MPEG-2 that can efficiently transmit a set of discrete viewpoints but cannot construct novel views. View interpolation is an image-based rendering technique that interpolates the image flow vectors between two images at each pixel to generate intermediate views for any viewpoint on the line connecting the original two viewpoints. Both Chen and Williams[3] and Werner et al.[4] used linear interpolation as an approximation of perspective viewing because of the simplicity and speed of implementation. Seitz and Dyer[5] demonstrated that this yields physically valid images only if the source images are rectified. Current view interpolation algorithms, however, restrict the synthetic view to a linear space defined by the reference viewpoints and cannot synthesize views from arbitrary viewpoints.

Laveau and Faugeras[6] developed a method that allows arbitrary viewpoints if the viewpoint is specified in terms of epipolar geometry with respect to the original viewpoints. McMillan and Bishop[7] and Kang and Szeliski[8] constructed cylindrical panoramic images from planar images before synthesizing new views from the implicit 3D structure. With no existing real-time cylindrical imaging systems, this approach cannot currently be extended to time-varying imagery. Multiple Perspective Interactive (MPI) Video[9] attempts to give viewers control of what they see using a different approach. This method computes 3D environments for view generation by combining a priori environment models with dynamic motion models recovered by intersecting the viewing frustums of the pixels that indicate motion.

A second class of view synthesis techniques eliminates the need for pixel correspondences by densely sampling the viewing space, possibly interpolating missing views. Katayama et al.[10] demonstrated that it is possible to generate images for arbitrary viewing positions from a dense set of images on a plane. Satoh et al.[11] used this property to develop a prototype 3D image display system with motion parallax. Two similar methods have been proposed recently: lightfield rendering by Levoy and Hanrahan[12] and the lumigraph by Gortler et al.[13] Both methods convert the given views into a four-dimensional field representing all light rays passing through a 3D surface. New view generation is posed as computing the correct cross-section of this field. These methods require the full calibration of each input view, but can generate correct synthetic views from any viewpoint outside of the convex hull of the scene.

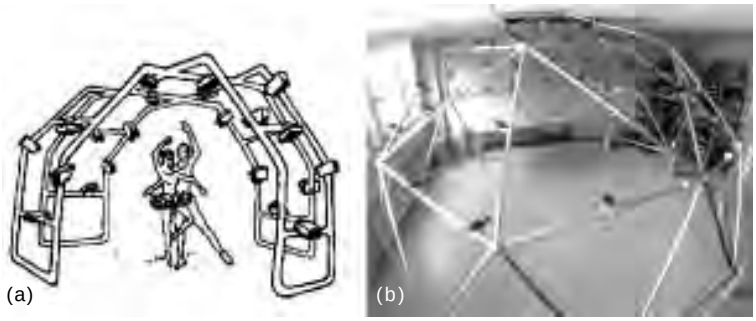


Figure 1. The Virtualized Reality studio: (a) conceptual; (b) 3D Dome.

We introduced Virtualized Reality and presented a few preliminary results in earlier work.[14] This article presents first results from a virtualizing facility that provides all-around coverage, presently consisting of 51 cameras mounted on a geodesic dome 5 meters in diameter.

3D Dome: The virtualizing studio

A *virtualizing studio* is a facility for making virtualized models. Our studio, 3D Dome, transcribes events from many angles to capture all-around scene structure. The studio can provide accurate scene structure for each video field—1/60th of a second in NTSC—of a time-varying event. For structure recovery, the studio captures every frame of each video stream, maintaining synchronization among the images taken at the same time instant from different cameras. Synchronization is crucial to correctly virtualize time-varying events because stereo (the structure extraction process) assumes that the images from the different viewpoints correspond to a static scene. This section provides a brief overview of the actual system. A more detailed discussion of the setup and the synchronous, multi-camera image acquisition system can be found elsewhere.[15]

The studio setup

Figure 1a shows the conceptual virtualizing studio, and Figure 1b shows 3D Dome, the studio we built using a geodesic dome 5 meters in diameter. Fifty-one cameras are placed at nodes and the centers of the bars of the dome, providing views from angles surrounding the scene. Currently, we use monochrome cameras, each equipped with a 3.6-mm lens for a wide view (about a 90-degree

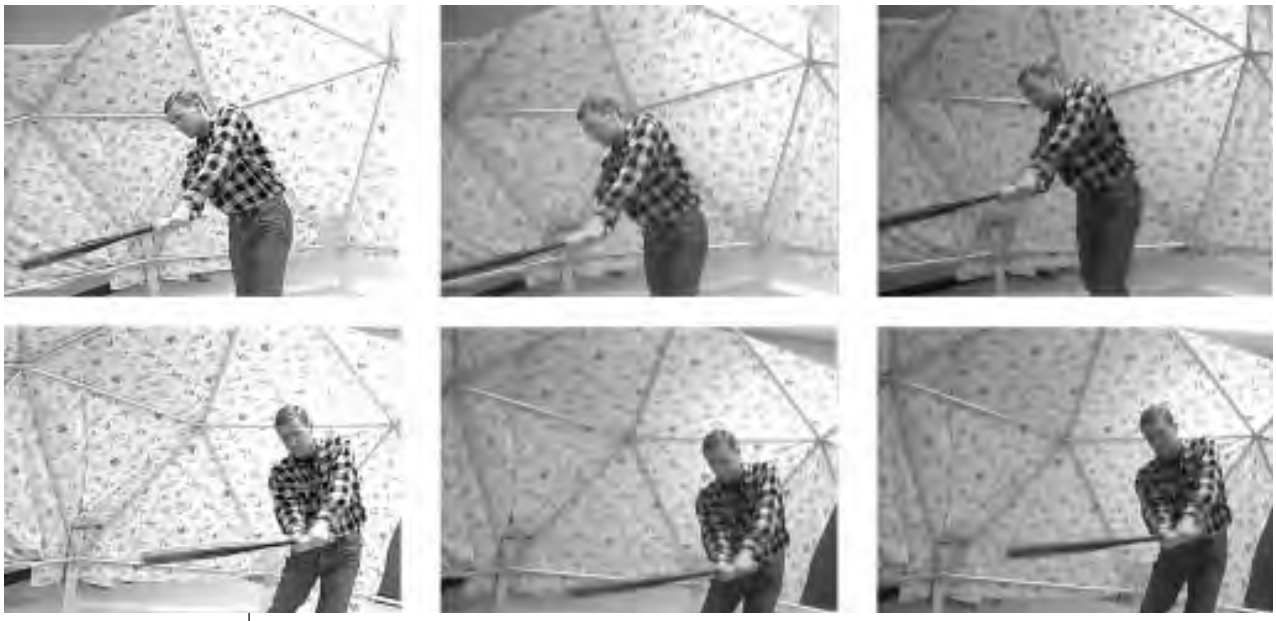


Figure 2. Six captured images to be used to compute scene descriptions.

horizontal field of view) of the dome. Color cameras can provide more realistic virtualization, but at higher costs.

Synchronous multi-camera image acquisition

Synchronous digital acquisition of many video streams is a difficult task because even a single monochrome camera providing 30 images per second, each image captured digitally to contain 512 by 512 8-bit pixels, represents a bandwidth of 7.5 Mbytes per second. The sustained bandwidth to store even a few video streams onto a secondary storage device exceeds the capabilities of typical image capture and digital storage systems, even with the best lossless compression technology available today. For example, our current system—a Sun Sparc 20 workstation with a standard 1-Gbyte hard drive and with a K^2T V300 digitizer—can capture and store only about 750 Kbytes per second. Specialized hardware can improve the throughput, but at a cost level unsuitable for replication.

To overcome these limitations, we perform digital acquisition in two steps: real-time recording and off-line digitization. The recording system uses standard CCD cameras and consumer-grade VCRs. The cameras are electronically synchronized to a common sync signal. Every field of each camera's video output is time stamped with a common Vertical Interval Time Code (VITC) before being recorded onto video tape. The hardware for this part of the system runs in real time, allowing continuous capture of long motion sequences. The tapes are digitized individually off line.

A computer program interprets the VITC time code of each field in real time as the tape plays. Given a list of frames to capture, the digitizing program captures as many from the list as it can. When the tape goes past the last required frame, the computer rewinds it to the starting frame, replays the tape, and repeats the process. The real-time VITC interpretation helps to identify frames missed in previous passes, guaranteeing capture of unique frames on each repetition.

In our experience, four passes suffice to capture every frame, as the V300 can transfer every fourth frame of a video stream to the computer memory. The VITC time code in each field of the captured image also serves to synchronize fields and frames from different cameras. Figure 2 shows a still frame as seen by six cameras of the virtualizing studio digitized using the setup described above. A separate report[15] gives more details on the synchronous multi-camera recording and digitizing setup.

Computing scene descriptions

Scene descriptions are analogous to the 2.5D sketch of the Marr paradigm, which encodes the geometric and photometric structure of all surfaces visible from a specific location. We use a stereo technique to compute the geometric structure, so this location coincides with the location of the reference camera used in stereo computa-

tion. Since the images themselves have limited field of view, the geometric extent of the scene description is limited to the viewing frustum of the reference camera. The transcription angle, then, must include orientation as well as position. Clearly, the distribution of the transcription angles is important to the quality of the virtualized reconstruction of the event.

Distribution of transcription angles

Our rendering strategy uses a scene description—more precisely, a textured triangle mesh model derived from this description—as the fundamental unit of structure. Each transcription angle specifies the location and orientation of one scene description. Using the model from one scene description, we can synthesize the appearance of the surfaces from arbitrary viewing positions. As the virtual camera moves away from the corresponding transcription angle, the quality of the reconstruction decreases because of occlusion and errors in the recovered structure. By minimizing the distance between any desired viewpoint and a real camera, we maximize the quality of the synthesized images.

This behavior implies that transcription angle density should be uniform and high to maximize the output quality. In fact, a high enough density eliminates the need for correspondences, allowing direct interpolation of the images using algorithms like the lumigraph[13] or light field rendering.[12] The problem with such techniques is that the density of camera views can easily become extremely high. For example, Levoy and Hanrahan use as many as 8,000 images to compute a light field for a single scene. For dynamic scenes, which require all the views to be captured simultaneously, the amount of hardware alone makes this strategy impractical. Either way, a trade-off must be made between the number of transcription angles and the quality of reproduction.

The number of cameras sets an upper limit on the number of transcription angles because each angle requires a real view of the scene. If all cameras are used to provide transcription angles, then the camera distribution should satisfy the same constraints as the transcription angle distribution. Another factor in determining the camera distribution is that stereo usually makes fewer mistakes as the cameras are moved closer together. Because we expected to use all cameras to obtain transcription angles, we selected the number of cameras (51) to meet these criteria. The initial experiments described in this article use all 51 of the transcription angles in the view synthesis process; we intend to investigate the economy of representation in the future.

Camera clusters

We compute stereo with each of the 51 cameras as reference and with several other cameras providing the baselines required for multi-baseline stereo (MBS). Using many cameras improves the extent and accuracy of stereo as long as features in the reference camera can be successfully matched to the features in the other cameras. The matching gets increasingly difficult the more the viewing angle differs. Arbitrarily adding more cameras provides little improvement in stereo accuracy while increasing the computational cost. We therefore use only the immediate neighbors—three to six depending on the specific camera in our setup—of the reference camera for stereo computations. These neighbors radiate out from the reference camera in all available directions. We modified the original formulation of MBS to handle verged cameras. We are thus free to place cameras in any orientation.

Camera calibration

Stereo programs require fully calibrated cameras to extract structure in metric units. We calibrate for the intrinsic and extrinsic camera parameters using Tsai's[16] approach modified and implemented by Reg Willson. We do this in two steps because our arrangement of cameras does not adapt very well to a simultaneous calibration procedure involving all cameras and all calibration parameters. We first calibrate each camera's intrinsic parameters—those that affect the projection of points from the camera's 3D coordinates to the image plane—individually using a movable planar calibration object. The calibration process estimates five intrinsic parameters: focal length, image center (two parameters), aspect ratio, and one radial lens distortion parameter. We then place the cameras in their positions on the dome and calibrate the six extrinsic parameters—rotation and translation relative to a world coordinate frame—using a set of dots on the floor visible to all cameras. The world coordinate frame is rooted on the floor in our case.

Multi-baseline stereo

We adapted the MBS algorithm developed by Okutomi and Kanade[1] for a general camera configuration (that is, nonparallel cameras) by incorporating the Tsai camera model. Two factors

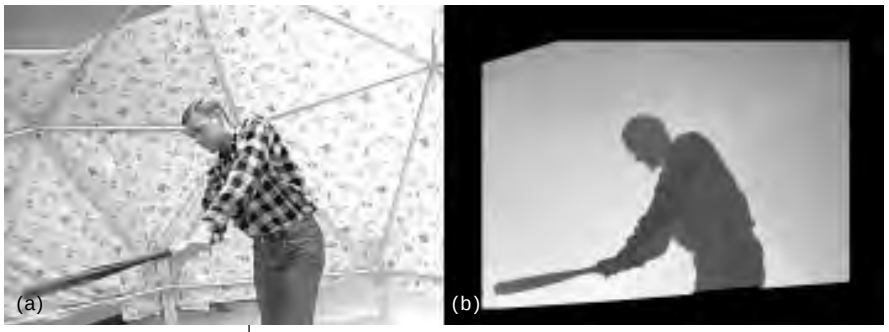


Figure 3. Scene description of one image. (a) Intensity image. (b) Aligned depth map.

primarily motivate the choice of MBS. First, MBS recovers dense depth maps, with a depth estimate for every pixel in the intensity image. Second, MBS takes advantage of the large number of cameras we use to improve the depth estimates.

To understand the MBS algorithm, we begin by considering two-camera stereo, with two parallel cameras with the same focal length F. The perpendicular distance z to a scene point is related to the disparity d (the difference in the image locations of the scene point) by

$$d = BF\frac{1}{z} \quad \textbf{(1)}$$

where B is the baseline, or distance between the two camera centers. The precision of the estimated distance increases as the baseline between the cameras increases. Increasing the baseline, however, also increases the likelihood of matching points incorrectly. The correctness of correspondence depends also on the image; the aperture problem makes it difficult to localize features parallel to the camera baseline. MBS attempts to improve matching by computing correspondences between multiple pairs of images, each with a different baseline. Since disparities are meaningful only for a pair of images, we reformulate Equation 1 to relate correspondences from multiple image pairs as

$$\frac{d}{BF} = \frac{1}{z} = \varsigma \quad \textbf{(2)}$$

The search for correspondences can now be performed with respect to the inverse depth ς, which has the same meaning for all image pairs with the same reference camera, independent of disparities and baselines. The resulting correspondence search combines the correct correspondence of narrow baselines with the precision of wider baselines. The effect of the image features' orientation with respect to the baselines can be mitigated by using baselines oriented in multiple directions.

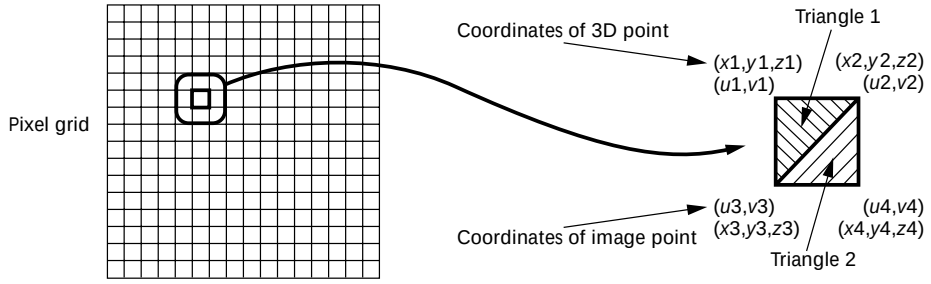
A popular method to compute correspondences between a pair of images compares a small window of pixels from one image to corresponding windows in the other image. The correct position of the window in the second image is constrained by the camera geometry to lie along the epipolar line of the position in the first image. The matching process for a pair of images involves shifting the window along this line as a function of ς, computing the match error—using normalized correlation or sum of squared differences—over the window at each position. MBS combines the error estimates for each camera pair by computing their sum before finding the minimum error. The inverse depth $\hat{\varsigma}$ for the point is the ς at this minimum.

Window-based correspondence searches do not localize matches well in regions of low image texture and along depth discontinuities, so we have incorporated an interactive depth map editor into our process of structure extraction. This step can roughly be compared to movie editing but is not as critical to the virtualizing process. We are currently exploring improvements to the stereo algorithm to make this step unnecessary. Figure 3b shows the edited depth map computed by MBS, aligned with the reference image of Figure 3a, from the images shown in Figure 2. The farther points in the depth map appear more white.

View generation

We *virtualize* an event using a number of scene descriptions. The other part of Virtualized Reality deals with synthesizing the scene from a viewer-specified angle using one or more scene descriptions. We first translate the scene description into a textured triangle mesh. We then synthesize new views by rendering this mesh to create novel views of the scene. This process takes advantage of the capabilities of graphics workstations, which have specialized hardware to render and texture map polygon meshes. We use Silicon Graphics workstations such as the Onyx/RE2 that can render about 1 million texture mapped triangles per second, though any rendering platform would suffice.

We first describe how new views are synthesized from a single scene description and how the view generated from a single scene description will be lower in quality as the virtual viewpoint moves



Triangle 1:
Vertex 1: ($x1$,$y1$,$z1$) Texture coord.: (u_1/m,v_1/n)
Vertex 2: ($x2$,$y2$,$z2$) Texture coord.: (u_2/m,v_2/n)
Vertex 3: ($x3$,$y3$,$z3$) Texture coord.: (u_3/m,v_3/n)

Triangle 2:
Vertex 1: ($x2$,$y2$,$z2$) Texture coord.: (u_2/m,v_2/n)
Vertex 2: ($x3$,$y3$,$z3$) Texture coord.: (u_3/m,v_3/n)
Vertex 3: ($x4$,$y4$,$z4$) Texture coord.: (u_4/m,v_4/n)

Figure 4. Triangle mesh and texture coordinate definition.

away from the transcription angle corresponding to that scene description. We then describe how other scene descriptions can be used to improve the quality of the synthesized image. Finally, we present a method of traversing the virtualized space in all directions using all the transcription angles.

Synthesizing views from one scene description

There are two aspects to view generation using one scene description: object definition and occlusion handling. Object definition is the process of converting a scene description into a textured triangle mesh model. A simple method of object definition is to construct one large surface that passes through all of the points in a depth map. Since real scenes frequently contain independent objects which may occlude each other, we introduce a method to handle these occlusions.

Object definition. There are two steps in defining the object from a scene description: converting depth into (x, y, z) coordinates and constructing a triangle mesh from these coordinates to describe the surfaces visible from the transcription angle. Converting depth into 3D coordinates is a simple transformation, since the depth values give the z-coordinates (in the camera-centered coordinate system) of the surface points at each pixel. To compute the (x, y) coordinates, we use the camera's intrinsic parameters to determine the viewing ray (the ray emanating from the camera center and passing through a given pixel) and intersect that ray with the plane at the given distance z read from the depth map. We then apply the camera's extrinsic parameters to convert the camera-centered (x, y, z) position into a position in the common-world coordinate frame.

We must now convert the 3D points into a surface representation. We treat the 3D points as vertices of a triangle mesh, which changes the task to selecting the 3D connectivity of the points. In general, this problem will have many solutions, but in our case we know more than just the 3D locations of the vertices: We also know how they project into the image plane. That is, we already have a local connectivity of 3D points because of their corresponding projections into the image plane. The task therefore reduces to selecting local connectivity in the image plane, a simpler problem than the general 3D one.

In addition, we can exploit the regular pixel grid to guide the connectivity process, because all the image projections of the 3D points lie exactly on the pixel grid. Using this information, we apply a simple pixel connectivity rule: Convert every 2×2 pixel area into two triangles by adding a diagonal, as shown in Figure 4. The only remaining question with this approach is which diagonal to select, a decision that affects the local surface properties of the mesh. Because our mesh is sampled extremely finely, however, the visible impact of the decision is small and we therefore always select the same diagonal. The texture to apply to each triangle is easily obtained by using the pixel coordinates of the triangle vertices.

This simple strategy for object definition has several important features. First, the 3D coordinates are quickly and easily extracted from the depth map using the calibration parameters. Second, the resulting "model" is little more than surface interpolation between 3D data points and therefore faithfully reproduces the exact structure inherent in the depth map. This fact implies that although we use a 3D model, we are essentially using the specialized rendering hardware as an efficient way to perform geometrically correct view synthesis, fundamentally eliminating the

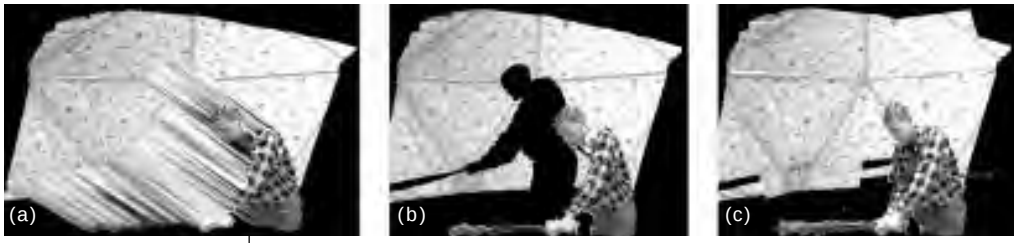


Figure 5. (a) Phantom surfaces at depth discontinuity. (b) Holes appear when phantom surfaces are removed. (c) Merged view using another scene description to fill holes.

geometric distortions that may exist in purely correspondence-based view interpolation.[3-5]

The major drawback of this method is that it generates $O(N^2)$ triangles for a depth map of size $N \times N$. The resulting object is simple and regular, though, making it suitable for efficient rendering on graphics workstations. In addition, the resulting mesh can be simplified easily by applying standard mesh decimation algorithms. According to our experiments, a reduction by a factor of 10 or 20 can be achieved without significant loss in quality.

Occlusion handling. A scene description encodes the 3D structure of the scene visible from the transcription angle. The object definition method just discussed implicitly assumes that only one continuous surface is visible from the transcription angle. If this assumption is violated, then the model will contain additional "phantom" surfaces that bridge depth discontinuities between real surfaces, as seen in Figure 5a. Even if the model is perfect everywhere else, the phantom surfaces cause the rendered view to become visually unrealistic as the viewing angle moves farther from the transcription angle.

We avoid phantom surfaces by eliminating triangles with large depth discontinuities along any edge. This results in "holes," as seen in Figure 5b. The holes correspond to areas not visible from the transcription angle. This behavior is desirable, since the scene description encodes information only about the visible 3D scene structure.

Merging multiple scene descriptions

Holes in the views synthesized using a single scene description correspond physically to the regions occluded from the transcription angle. In many cases, these regions are visible in the scene descriptions from other transcription angles. These scene descriptions can be used to fill the holes and therefore improve the visual realism of the synthetic views. Our rendering strategy uses two additional scene descriptions for this purpose. Our complete approach, then, uses three scene descriptions to construct each synthetic image. The *reference* scene description corresponds to the transcription angle "closest" to the desired synthetic viewpoint. The two scene descriptions used for hole filling are called *supporting* scene descriptions.

We can develop a number of methods to "merge" multiple scene descriptions. For example, we could merge these different 3D views into a single 3D model. Because our goal is only to construct a synthetic image, we developed a simpler merging strategy that works only with renderings of the objects defined by the scene descriptions. This strategy requires only 2D merging, making it faster and simpler than 3D merging. We first synthesize the desired view using the reference scene description. To identify "hole" pixels, we render separately the triangles that were eliminated because of large depth variation. The synthetic view is then re-rendered using the supporting scene descriptions, with the rendering limited to the hole pixels.

For example, Figure 5c shows the results of filling the holes of Figure 5b using one supporting view. Notice that the background and the right shoulder of the person have been filled properly. The holes remaining in the image correspond to the portion of the scene occluded from both the reference and supporting transcription angles.

It is insightful to compare this algorithm to a simpler one that identifies hole pixels by finding pixels not touched after rendering the objects from the reference scene description. This strategy is appealing because of its simplicity and because the eliminated triangles do not need to be rendered.

However, under certain conditions this strategy avoids filling regions that are obviously incorrect. In Figure 5b, for example, the reference scene description did not see all of the person's right shoulder, so the synthesized view fills in this region with pixels from the background. Using this simpler merging strategy would not allow the supporting view to correct these pixels, resulting in the obvious error in the synthesized output.

Selecting reference transcription angle. Our view generation strategy exhibits a highly desirable property: The synthesized view is exact and

hole-free when the desired view coincides with a transcription angle, even with arbitrary errors in calibration and depth estimation. In addition, for a general scene, the quality of the view synthesized from a single scene description deteriorates as the viewing angle moves away from its transcription angle. This can happen even with ideal models because of foreshortening.

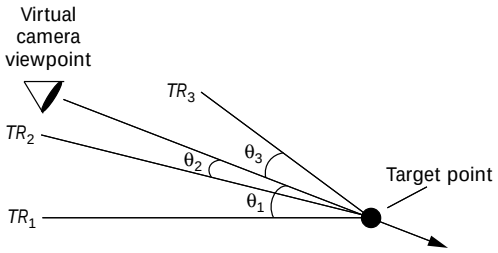


Figure 6. Selecting the reference transcription angle. θ_i ***is the angle between the virtual camera's line of sight and the line joining the target point with the position of the transcription angle*** TR_i***. We select the transcription angle*** TR_i ***with the smallest angle*** θ_i ***as the reference transcription angle.***

Consider, for example, a scene containing a single receding plane as viewed from a transcription angle. Because of foreshortening, the image of the scene has less texture resolution for far parts of the plane than for near parts. Even if the structure of this scene is recovered perfectly, the texture provided by a single scene description will be forced to expand as the virtual camera moves to view the plane frontally.

These properties suggest that the transcription angles used to synthesize a virtual image should be as "close" as possible to the desired viewpoint. Despite its seeming simplicity, finding a good definition of "close" is, in general, a highly complex problem because of the possibility of occlusion. Intuitively, we would expect the usefulness of a transcription angle to increase as the virtual camera moves closer (in physical space) to it.

Because the transcription angle has a limited field of view, however, this intuitive metric is insufficient. Using direction of gaze alone also has clear problems. Potentially serious problems due to occlusion arise even if we combine these two metrics. For example, even if the virtual camera is close to a real transcription angle and oriented in the same direction, the desired viewpoint can lie beyond the visible surfaces in the scene description—that is, the desired viewpoint can lie in the region occluded from the transcription angle. As a result, this transcription angle would be a poor choice for synthesizing this image.

The metric we use to evaluate the "closeness" of a virtual viewpoint to a transcription angle is based on several assumptions about the distribution (3D placement) and orientation (field of view) of the transcription angles and about the general regions of interest in a typical scene. The viewing direction of the virtual camera is specified in terms of an eye point and a target point. The virtual camera is situated at the eye point and oriented so that its line of sight passes through the target point. We measure closeness as the angle between this line of sight and the line connecting the target point to the 3D position of the transcription angle, as shown in Figure 6. This measure works well when both the virtual viewpoint and all the transcription angles point at the same general region of space. In our system, the assumption about transcription angle is true by design, which tends to focus the user's attention on this same region.

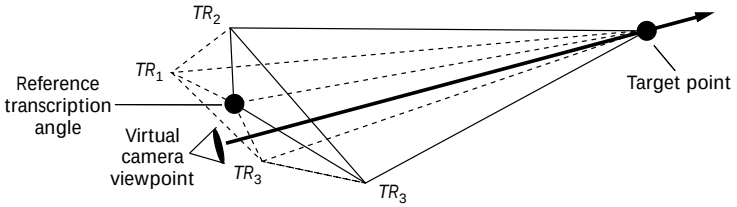


Figure 7. Selection of supporting transcription angles. Given a reference transcription angle, we determine the supporting angles by first enumerating the neighboring angles (TR_i***) of the reference and then forming the triangles containing the reference transcription angle and two of the neighbors. The triangle pierced by the line of sight of the virtual camera determines the supporting angles.***

Selecting supporting transcription angles. We use supporting angles to compensate for the occlusion in the reference description. The general problem of covering all occlusions with a few transcription angles relates to the convex covering problem and has no general solutions. That is, for any given configuration of transcription angles, it is possible to construct a scene in which certain surfaces are occluded from all the transcription angles. However, it is frequently possible to obtain adequate coverage of occluded regions by concentrating only on the neighbors of the reference transcription angle, especially when the transcription angles are densely distributed.

Consider the triangles formed by the locations of the reference transcription angle and all adjacent pairs of its neighbors, as in Figure 7. If the transcription angle has *n* neighbors, there are *n*

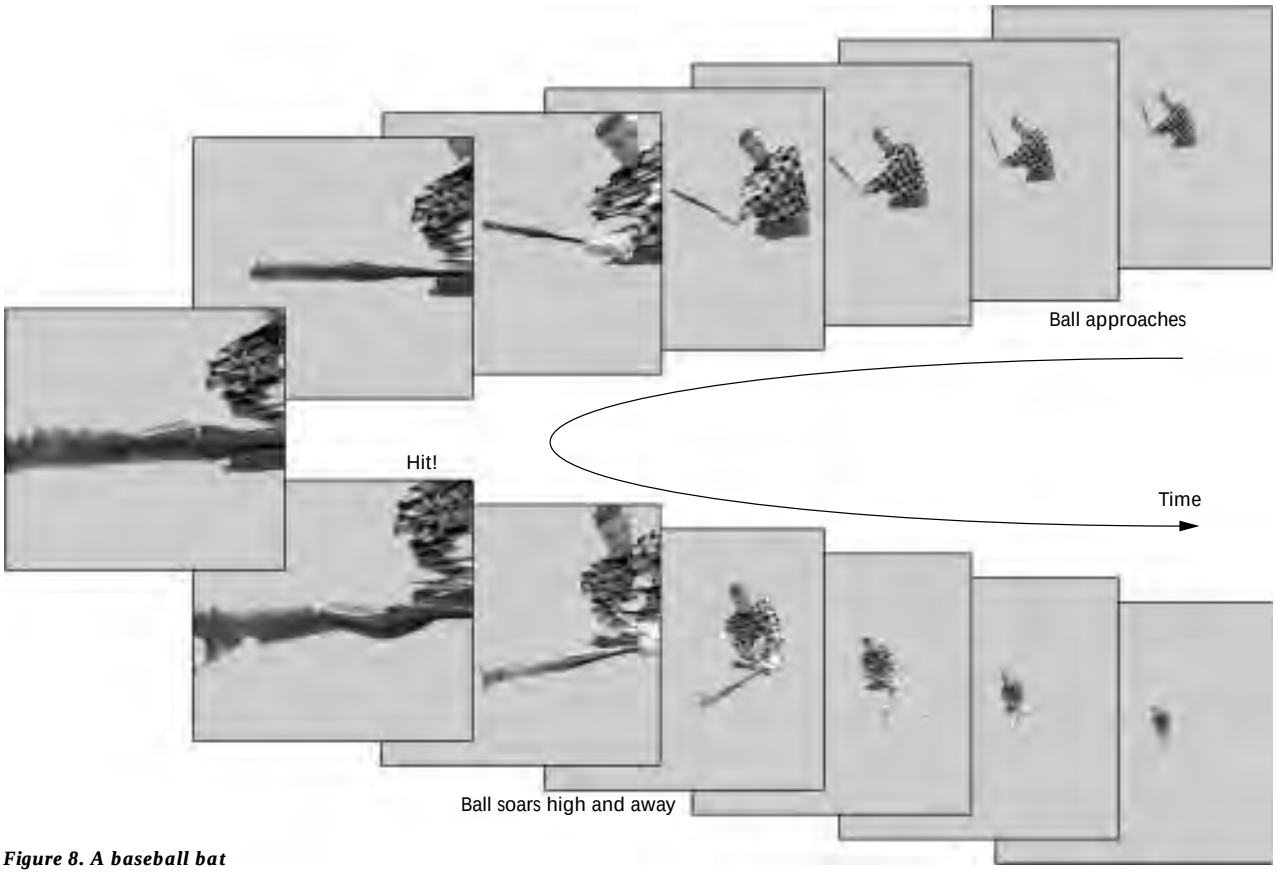


Figure 8. A baseball bat swing from the baseball's point of view.

such triangles. We determine which of these triangles is pierced by the line of sight of the virtual camera. The non-reference transcription angles that form this triangle are selected as the supporting transcription angles. Using this approach, the reference and supporting views "surround" the desired viewpoint, essentially reducing the view synthesis process to interpolation of an intermediate viewpoint from three real views.

Experimental results

We now present a few examples using real data, including both static and dynamic scenes. While the earlier sections on computing scene descriptions and generating new views only discussed static scene analysis, the extension to dynamic scenes is straightforward. Recall that video is simply a sequence of images sampled and displayed fast enough to give the illusion of continuous motion. Exploiting the same phenomenon in our 3D environment, we apply static scene analysis at each sample of a 3D time-varying event to create the illusion not only of continuous scene motion but also of a continuous user-controlled viewpoint. (Note that examples of this nature are best seen as a movie. You can find a few movies at the project's Web page, http://www.cs.cmu.edu/Groups/VirtualizedR/.)

Ball's eye view

Because the virtual camera can move through the virtualized environment without interfering with the scene, it is possible to maneuver the camera through paths that would be impossible in the real world. To demonstrate this capability, we reconstructed the flight of a virtual baseball thrown at and hit by a batter. The real images (the same images used throughout this paper to explain the various components of Virtualized Reality) come from a dynamic sequence of a person swinging a baseball bat.

We collected the image sequences using our initial hardware configuration of 10 cameras (recall that six camera views for one time instant appear in Figure 2). We distributed these 10 cameras into two clusters of five cameras and computed stereo



Figure 9. Comparing generated virtual-camera views with real-camera views, located near the middle of the two transcription angles. Views from a real camera (top row). Views generated for the same positions using Virtualized Reality (bottom row).

for a single camera in each cluster, resulting in only two transcription angles. The virtual images (in Figure 8) show the trajectory of a ball pitched to the batter, hit by the bat, and knocked high after being hit (in baseball terms, a popup). The transcription angles were about 2,750 mm and 3,000 mm away from the baseball bat at the point of the virtual camera's closest approach (the image labeled "Hit!" in Figure 8), while the virtual camera was approximately 250 to 300 mm away from the bat. As the images demonstrate, the synthetic output is qualitatively correct even for this large change in depth.

The distortions present in this example result from three sources. Fundamentally, the real images limit the texture resolution, so as the virtual camera moves into the scene, the texture mapping may zoom in beyond this available resolution. Second, scene structure is limited by the quality of camera calibration and correspondence estimation and by the available image resolution (which affects stereo). Therefore, the movement of the camera "deep" into the scene also highlights any inaccuracies in the computed scene structure. Finally, the system has only two transcription angles from which to work, and these viewpoints are physically separated by almost two meters, representing a rotation of nearly 60 degrees around the person. Having only two views leaves more holes in the synthetic output, while wide separation of those views requires more accurate surface reconstruction to maintain consistency of structure between the transcription angles.

Virtual camera versus real camera

Virtualized Reality seeks only to provide "believable" views of a scene at times, which requires some internal consistency but not necessarily consistency with the real world. This example explores the more difficult case requiring faithful, accurate reconstruction. Here we compare the virtual view generated using Virtualized Reality with what a real camera placed at that location sees for three frames of a golf swing. The scene was again captured from two transcription angles (four cameras in a cluster), located at (821, –74, –2,502) and (–968, –35, –2,334) in the world coordinate frame (units are millimeters). The person was approximately 2,500 mm away from the transcription angles.

Figure 9 shows the virtual and real camera views located at (–228, –353, –2,580), near the middle of the two transcription angles. Figure 10 does the

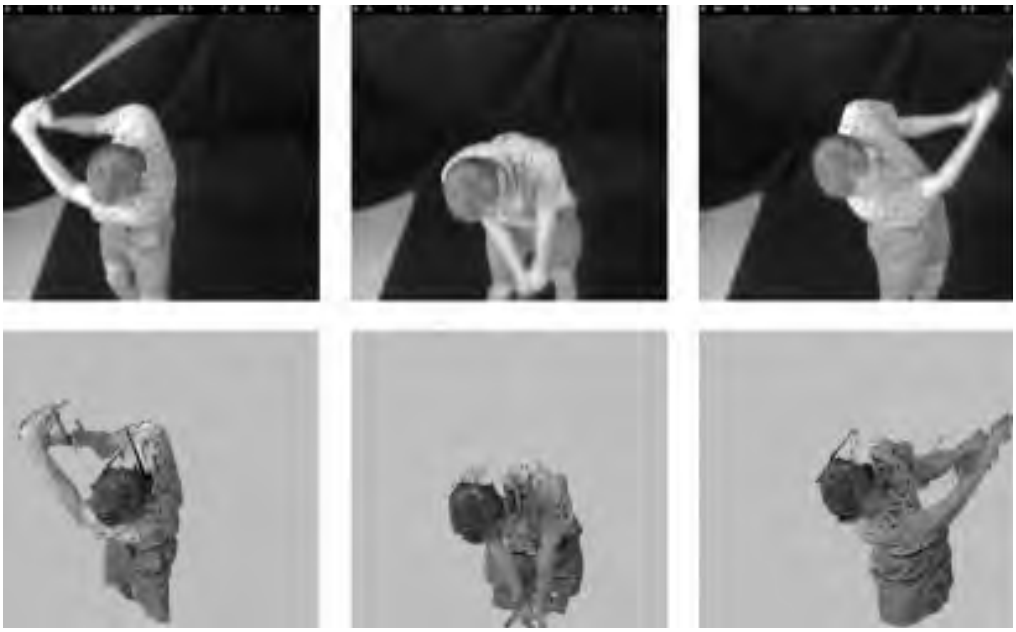


Figure 10. Comparing generated virtual-camera views with real-camera views, located far from the two transcription angles. Views from a real camera (top row). Views generated for the same positions using Virtualized Reality (bottom row).



Figure 11. Some views from a spiraling path in a static scene.

same for the virtual and real camera position (181, –1,050, –1,500), significantly far from the transcription angles in x, y, and z directions. The gap at the back of the person's neck corresponds to the region occluded from both transcription angles. The virtual camera view is quite faithful to the real camera view, though the errors in recovering the structure show up more prominently when the virtual camera is far from the transcription angles. Note that this scene was processed using full-image frames, each of which contains two image fields taken at different times—clearly visible in the real images of the golf club, for example. Even without compensation for this effect, the recovered structure was sufficient to produce realistic output.

All-around view

As noted, the two examples above used an early setup for studying Virtualized Reality that consisted of two transcription angles. We have subsequently expanded the setup to 51 transcription angles to virtualize the event from all directions. We expected the increase in the number of transcription angles to improve the overall synthetic image quality in three ways. First, with more than two views, we expected that hole filling would work better since we could always select three transcription angles from which to render the scene. Second, the cameras were more closely spaced than before, reducing the space over which each transcription angle was required to assist with the rendering. Finally, because the cameras surrounded the scene, the viewer could move nearly anywhere in the scene and still see a reasonable reconstruction.

We demonstrate this updated system using a simple static scene of a person sitting on a table. Figure 11 shows a few views of this scene from a virtual camera winding through the dome. As expected, the number of unfilled pixels dropped significantly. Almost all of the remaining holes



Figure 12. Introducing a virtual ball into a virtualized scene.

occur because the virtual camera has moved below all of the real transcription angles, which requires extrapolation rather than interpolation of the scene descriptions at the reference and supporting transcription angles.

Two significant errors are still detectable in the output, however. The first is a "ghosting" effect, something like a shadow around the person. This occurs in the holes present in the rendering of the reference scene description. It results from inconsistencies in the video gain and offset levels of each camera. If a "bright" camera is used as a supporting angle of a "dark" camera, then even correctly matched regions can exhibit significant differences in apparent brightness. This problem is compounded because the absolute intensity received from a real surface usually varies with the viewing angle, but our system does not currently model this effect.

The second error, not really discernible in a set of static renderings, is the inaccuracies in reproducing motion parallax. That is, as the virtual camera moves around a static scene, the viewer expects to see continuous motion in the virtual image sequence, but the actual virtual image motion exhibits occasional discontinuities. This "jerkiness" occurs when the reference transcription angle switches, which may reveal the inconsistencies between the structures recovered from the two angles.

Combining virtual and virtualized environments

Because a virtualized environment is a metric description of the world, we can introduce virtual objects into it. A virtual ball, for example, is introduced into a virtualized baseball scene as shown in Figure 12. Note that the rendering of the virtual object can be performed after the synthesis of the virtual camera image without the objects or concurrently with the virtual objects. We can use this approach to extend chromakeying, which uses a fixed background color to segment a region of interest from a real video stream and then insert it into another video stream. Because we have depth, we can perform *z*-keying, which combines the multiple streams based on depth rather than on color.[17] In fact, we can even simulate shadows of the virtual object on the virtualized scene, and vice versa, further improving the output image realism.

Conclusions and future work

Our examples prove that useful and interesting applications of Virtualized Reality are just around the corner. We intend to pursue such possibilities in the coming months. We also plan to integrate a stereoscopic display with head tracking to give viewers the feeling of true immersion in the scene.

An open issue concerns the combined effect of imperfect calibration, correspondence finding, and mesh generation. The experiments presented here reveal a clear need to improve the rendering system to be more resilient to these inaccuracies. This would affect the filling of holes and the motion parallax of the synthesized output—a dynamic property that has received almost no attention from the view synthesis community in the past. In addition, it is clear that systems with many cameras require synthesis algorithms capable of handling images of varying brightness to prevent "ghosts" in the holes present in the image synthesized from the reference transcription angle.

A research effort currently under way involves creating object-centered models of the scene by merging the scene descriptions. We use a voxel-based approach for the merging, with each scene description voting for the presence or absence of surfaces in the 3D world based on the depth map from that transcription angle. The contribution of each depth map is only one of many, providing a significant degree of robustness in the presence of noise in the depth maps. The final model is recovered by triangulating an isosurface extracted from the merged voxel space, providing an object-centered model for the scene such as the one in

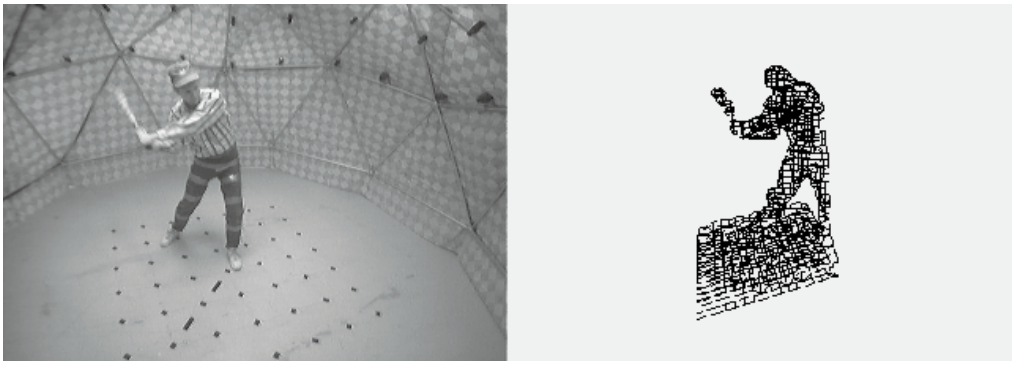


Figure 13. An object-centered model (right) computed by merging 51 depth maps and shown aligned with an actual camera view (left).

Figure 13. Using the recovered structure, it is also possible to accumulate texture from the 51 intensity images.

The virtualizing facility itself opens up possibilities for interesting research in other areas as well. For example, other view generation strategies, image-based rendering or view interpolation in particular, can be studied and compared with the depth map-based view generation. We could also extend the capabilities of Virtualized Reality to let the viewer interact with the virtualized world. For instance, modeling a scene as a collection of distinct objects lets the viewer manipulate the position and appearance of each independently. We intend to pursue these directions in the near future. MM

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APPENDIX OHM01

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Stereo/multiview video encoding using the MPEG family of standards

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Abstract

Compression of stereoscopic and multiview video data is important, because the bandwidth necessary for storage and transmission linearly increase with the number of camera channels. This paper gives an overview about techniques that ISO's Moving Pictures Experts Group has defined in the MPEG- 2 and MPEG-4 standards, or that can be applied in the context of these standards. A good tradeoff between exploitation of spatial and temporal redundancies can be obtained by application of hybrid coding techniques, which combine motion-compensated prediction along the temporal axis, and 2D DCT transform coding within each image frame. The MPEG-2 multiview profile extends hybrid coding towards exploitation of inter-viewchannel redundancies by implicitly defining disparity-compensated prediction. The main feature of the new MPEG-4 multimedia standard with respect to video compression is the possibility to encode objects with arbitrary shape separately. As one component of the segmented object's shape, it shall be possible to encode a dense disparity map, which can be accurate enough to allow generation of alternative view s by projection. This way, a very high stereo/multiview compressions ratio can be achieved. While the main application area of the MPEG-2 multiview profile shall be in stereoscopic TV, it is expected that multiview aspects of MPEG-4 will play a major role in interactive applications, e.g. navigation through virtual 3D worlds with embedded natural video objects.

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Stereo/Multiview Video Encoding Using the MPEG Family of Standards

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ABSTRACT

Compression of stereoscopic and multiview video data is important, because the bandwidth necessary for storage and transmission linearly increases with the number of camera channels. This paper gives an overview about techniques that ISO's Moving Pictures Experts Group (MPEG) has defined in the MPEG-2 and MPEG-4 standards, or that can be applied in the context of these standards. A good tradeoff between exploitation of spatial (intra-frame) and temporal (inter-frame) redundancies can be obtained by application of hybrid coding techniques, which combine motion-compensated prediction along the temporal axis, and 2D DCT transform coding within each image frame. The MPEG-2 multiview profile extends hybrid coding towards exploitation of inter-viewchannel redundancies by implicitly defining disparity-compensated prediction. The main feature of the new MPEG-4 multimedia standard with respect to video compression is the possibility to encode objects with arbitrary shape separately. As one component of the segmented object's shape, it shall be possible to encode a dense disparity map, which can be accurate enough to allow generation of alternative views by projection. This way, a very high stereo/multiview compression ratio can be achieved. While the main application area of the MPEG-2 multiview profile shall be in stereoscopic TV, it is expected that multiview aspects of MPEG-4 will play a major role in interactive applications, e.g. navigation through virtual 3D worlds with embedded natural video objects.

1. INTRODUCTION

The Moving Pictures Experts Group (MPEG) was established by ISO/IEC to standardize techniques for digital compression of time-varying audiovisual signals. So far, MPEG has produced 3 different standards :

- MPEG-1 (finalized 1990) is dedicated to the compression of audiovisual material at “up to 1.5 Mb/s”, the original intention being the storage of compressed video with associated audio on conventional (audio) compact discs ;
- MPEG-2 (finalized 1992) is a generic audiovisual compression standard, which in addition to the techniques of MPEG-1 defines methods for compression of interlaced video material, a more efficient audio compression, and a systems layer which allows a flexible use of compressed audiovisual streams in storage, networking and broadcast environments ;
- MPEG-4 (version 1 to be finalized February 1999) does not only support compression of ready-composed (frame-based) video and audio signals, but allows compression of arbitrary-shaped video objects as well, and defines combination of video, still image and graphics data in a scene composition ; MPEG-4 is especially suitable for interactive multimedia applications, where it shall be possible to play with varying content of a scene.

MPEG-2 and MPEG-4 also include elements that allow compression of stereoscopic or multiview video data. Multi-camera acquisition of scenes or single objects is applied in situations where a multiview reconstruction is required. For example, if the camera signals are reproduced on a stereoscopic display device, the viewer is given a spatial illusion by presenting slightly different images to the left and right eyes, such that the brain can interpret the visible depth of each point by the perceived stereoscopic parallax shift between both views. Besides the stereoscopic effect, a human being normally gets knowledge about the spatial environment by walking around. A quite accurate impression about the distance of a particular static object can be experienced by a small change of the own viewpoint. Basically, the action of the brain in this case is not much different from the binocular case, with the exception that the reference view is remembered instead of simultaneously viewing it. This effect of motion parallax, due to an altered viewpoint, appears to be almost equally important for spatial perception as the binocular stereoscopic parallax, and is inherent part of our way to experience the 3-dimensional world. Hence, we would like to see the aspects of 3D representation and presentation in a much wider sense, especially in the context of multimedia systems and virtual environments. Here, an important feature is the interaction of the viewer with the scene by adapting the individual viewpoint either manually (by some input device) or automatically (by tracking the

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egomotions of the head and/or body). Of course, such a system can also include a stereoscopic presentation, if two different views are generated to simulate the stereoscopic parallax.

For transmission and storage of stereoscopic and multiview data, compression is important in general, because the necessary bandwidth linearly increases with the number of camera channels. Compression techniques usually exploit the *redundancy* inherent within signals. In addition to the intraframe redundancy (due to similarity of adjacent pixel values) and interframe redundancy (due to similarity of subsequent image frames), a multiview compression system can be based on inter-viewchannel redundancy. This is the approach taken in the MPEG-2 multiview profile [7], which additionally makes use of psycho-visual properties of the binocular perception in the human brain.

For interactive applications, which require reconstruction of multiple views, the presentation quality of scenes and objects, which can be displayed with variable viewpoint, is also of key importance for the acceptability of a system. Unlike 3D graphics techniques, which render deterministic synthetic content with high quality, the inclusion of natural video elements may be problematic due to lack in accuracy of analysis. Video data are merely a 2-dimensional (2D) projection of the three-dimensional (3D) outside world. If a multiview capture of a scene or an object is taken, the task of viewpoint adaptation can be accomplished by extracting information from several available camera views. Two commonly used approaches suitable for this purpose are :

- Intermediate viewpoint interpolation [1][2][3] : Disparities are estimated from adjacent camera views, and an intermediate view is generated by disparity-compensated interpolation from the original views. To extract objects, it is sufficient to apply a conventional 2D segmentation technique to the separate camera views. One remaining problem with this technique is the lack of natural illumination and reflectance changes if the viewpoint is altered. It is not directly possible, like e.g. in computer graphics, to change the position of a light source, such that the best application is in a diffuse lighting environment.
- 3D modeling [4][5] : The true 3D shapes of scene parts or single objects are determined and represented by a 3D shape approximation, e.g. a 3D mesh or wireframe. Surface textures visible in the camera views are also extracted, and mapped onto the corresponding patches of the 3D model. Viewpoint generation is then performed by projection of texture data to a virtual camera plane, based on some camera model. This approach has many relations to rendering techniques popular in computer graphics [6].

In both techniques mentioned, only low attention is usually paid to the interdependencies between data representation/compression and viewpoint synthesis. In intermediate image interpolation, it is generally necessary to perform encoding of the views separately. However, disparity data derived for optimum encoding are often not appropriate for viewpoint interpolation [8]. In 3D modeling, though texture information from all available camera views is largely condensed, the complexity of the model (e.g. number of vertices in a mesh, which is mostly derived from a synthesis point of view), takes high influence on the rate necessary for data representation. Moreover, analysis for 3D modeling is computationally much more burdensome than a plain disparity-based scheme.

In the context of MPEG-4, we have developed a new technique denominated as *Incomplete 3D* (I3D) representation for video objects, which combines the advantage of simple disparity-based viewpoint projection in intermediate viewpoint interpolation with the advantage of largely-condensed texture information inherent in 3D modeling. The basic idea is to combine the aspects of data compression and view reconstruction to achieve best results in data compression efficiency and reconstruction quality. Both of these aspects are implicitly related to the correspondence problem in multiview acquisition, i.e. in order to perform these tasks, it is necessary to identify those points in the particular images which represent an identical point in the 3D scene or object which is acquired. This relation is usually expressed by the *disparity shift*, which is the discrete expression of the stereoscopic parallax in the image planes of the acquisition systems. To enable multiview applications, MPEG-4 version 2 will include the capability to encode accurate disparity data as so-called “auxiliary channels” associated with a video object.

The organization of the paper is as follows. In section 2, the main properties of the MPEG standards are reviewed, and the aspect of disparity-compensated data compression is discussed. Section 3 is dedicated to the aspect of view reconstruction, that can be achieved by disparity-compensated projection from the available original views on a pixel-by-pixel basis. Section 4 discusses the aspect of scene composition, i.e. how arbitrary-view objects can be included in 2D or 3D scenes, and how synchronization of viewpoint adaptation between foreground and background can be achieved. Section 5 gives some application examples, and in Section 6, conclusions are drawn and possible future developments are discussed.

2. THE MPEG STANDARDS AND COMPRESSION OF MULTIPLE CAMERA VIEWS

For data compression of video signals in the MPEG standards, the basic principle of *hybrid coding* is used. This term expresses a combination of *transform coding*, making use of the decorrelation properties of the Discrete Cosine Transform (DCT) for *intraframe* coding, and motion-compensated prediction from frame to frame to exploit the redundancy in *interframe coding*. MPEG standards merely define the syntax and semantics of bitstreams, which means that it is prescribed which actions a decoder would perform if it is fed by a specific bitstream syntax. The block diagram of a hybrid encoder is given in Fig.1. The whole image is subdivided into blocks, and for each block, a motion vector describes the relative shift of a reconstructed block from a previously-decoded image, which will be used as a prediction for the actual block. The difference between the actual block values and the prediction values is calculated, and a DCT is applied to this prediction error signal. Due to the decorrelation property of the transform, usually a smaller number of transform coefficients is a good representation of all pixels within the block. The dominant coefficients are quantized and encoded, using a combination of run-length and variable-length entropy coding. Since only blocks from frames already transmitted are used for prediction, the inverse operation is possible at the decoder, such that a reconstruction can be performed. from the output stream.

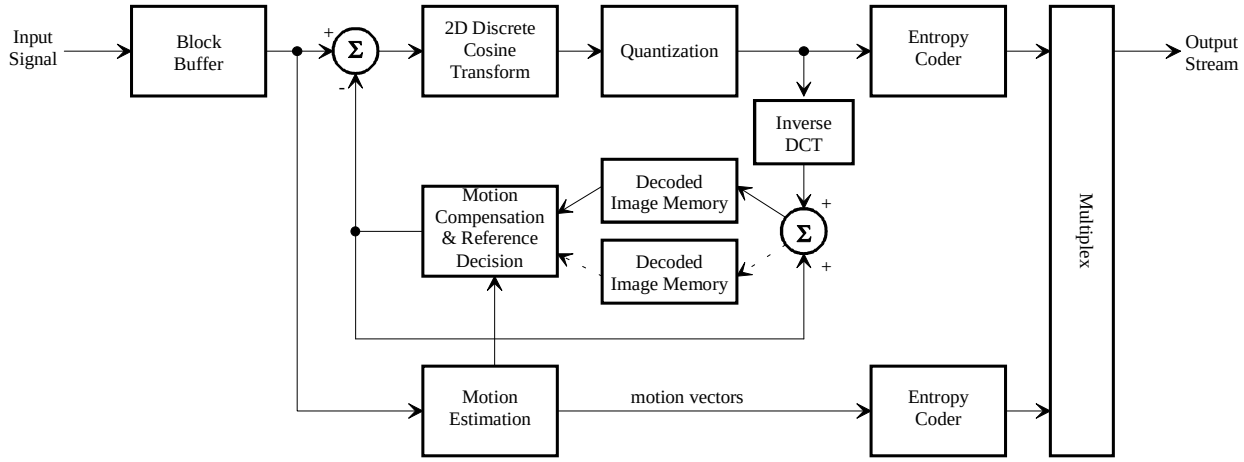


Fig.1. Structure of a hybrid video encoder according to an MPEG standard.

The MPEG standards support different modes of motion compensation, which can be used to achieve a higher performance in data compression. A high coding efficiency can be gained by usage of so-called “B”-images, which can be predicted from two different previously-decoded reference images. To indicate these options, two different decoded image memories are included in Fig.1. For each block within an “B”-image, it is possible to indicate whether the prediction should be switched off, whether it should be performed from the first or second reference image, or by an averaging (interpolation) from both. This step is called the “reference selection”. Motion vectors can be defined independently for both of the reference images. The term “B”-image originally means “bidirectional prediction”, because the “B”-images are usually predicted from one temporally-preceding and one subsequent frame in the original sequence. A very powerful application of bidirectional prediction is in the context of temporal scalability, which is defined in both MPEG-2 and MPEG-4 standards. It is possible to encode a sequence with lower frame rate as a base layer, and define an enhancement layer which only contains “B”-images that can be used to reconstruct the sequence with full frame rate, if both base and enhancement streams are available.

If a scene or an object is acquired simultaneously with two or more cameras, there will in addition exist redundancy between the particular camera channels. This can be exploited for the purpose of further reduction of the data rate by introduction of *inter-viewchannel* coding. The approach introduced for inter-viewchannel coding in the MPEG-2 Multiview Profile [7] is an extension of the temporal scalability (TS) mode.

2.1 The MPEG-2 Multiview Profile

“Profiles” in the notion of MPEG are a collection of encoding tools that define a conformance point of the standard. Since the MPEG standards contain a huge collection of different tools, it is unlikely that each possible application will make use of all of them. Hence, if a decoder is conformant to a specific profile, it will be suitable for a certain application area this profile was intended for. The MPEG-2 multiview profile was defined in 1996 as an amendment to the MPEG-2 standard,

and its main new elements are the definition of usage of the TS mode for multi-camera sequences, and definition of acquisition camera parameters in the MPEG-2 syntax.

The operation of TS is illustrated in Fig. 2. It is possible to encode a base layer stream representing a signal with a reduced frame rate, and then define an enhancement layer stream, which can be used to insert additional frames in between to allow reproduction with full frame rate if both streams are available. A very efficient way to encode the enhancement layer allows decision about the best motion-compensated prediction for each macroblock in the enhancement layer frame : either from a base layer frame, or from the recently-reconstructed enhancement layer frame (Fig.2a). Only a subset of the prediction modes possible for TS is shown here. For presentation on a video screen, e.g. using shutter glasses, left and right views of a stereo signal are often combined in a temporal multiplex. For such a signal, it is straightforward to perform stereo and multi-viewchannel encoding using the temporal scalability syntax. For this purpose, frames from one camera view (usually the left) are defined as the base layer, and frames from the other one(s) as enhancement layer(s). The enhancement-from-base-layer prediction then turns out as a disparity-compensated prediction instead of a motion-compensated prediction, which nicely coincides with our previous notion about the analogy between the motion parallax and the stereoscopic parallax (Fig.2b). If the disparity-compensated prediction fails, it is still possible to achieve compression by motion-compensated prediction within the same channel. At the same time, the base layer represents a monoscopic sequence.

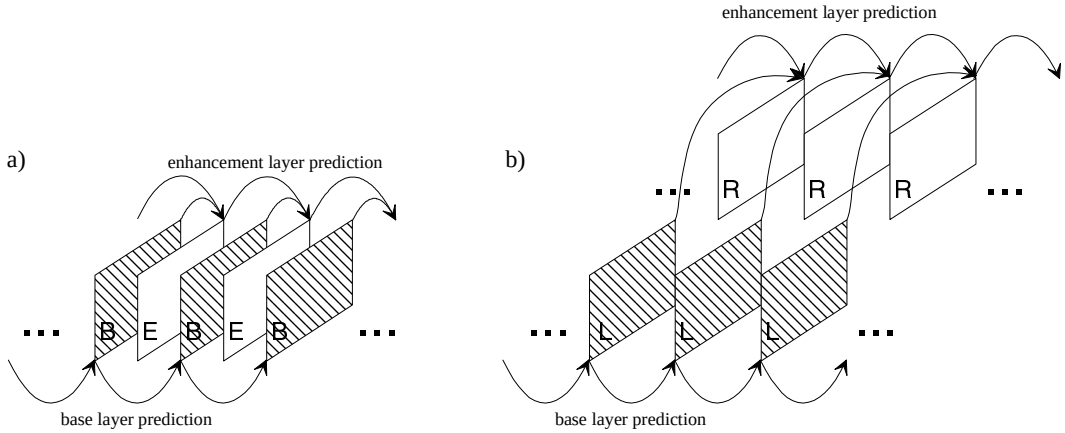


Fig.2. The temporal scalability concept **a** in multi-framerate encoding **b** in stereoscopic encoding.

Unfortunately, disparity vectors defined on a block-by-block basis of size 16x16 pixels, as used in the TS of MPEG-2, are not accurate enough to minimize the inter-viewchannel prediction error to the possible extent. It can be observed that in many cases (with exception of high motion) the similarity between subsequent frames within one of the views is much higher than the similarity between the different views, such that the motion-compensated interframe prediction is most likely preferred over the disparity-compensated inter-viewchannel prediction. As a consequence, the temporal scalability concept can only be marginally superior over a separate encoding (so-called simulcast) of the channels, both concepts requiring approximately doubled rate as compared to encoding a signal from a single camera. This fact was shown in extensive subjective tests that were performed in the context of the definition of the MPEG-2 multiview profile. A slight gain seems to be possible if one of the channels is encoded with higher quality, where the human perception seems to neglect distortions in one channel in favor of an increased quality in the other channel [11]. Such an approach, however, is not applicable in general for all cases of stereoscopic encoding.

This limitation can only be overcome if the reconstruction of views, including the original camera views, is regarded as an integral part of the decoding process, by systematically suppressing encoding of all the areas within one view that may as well be reconstructed from another view. To enable applications of this kind, the multiview profile amendment defines a syntax extension for MPEG-2, which allows to encode parameters of the acquisition cameras, like orientation, position, size of image plane and focal length. However, since it is not possible to solve effects of occluding objects, a view-reconstruction approach can better be applied in combination with the object-based encoding techniques of MPEG-4.

II.2 MPEG-4 and "Incomplete 3D" technique

The MPEG-4 coding algorithm for 2D "natural" video signals is designed for compression of pixel values from so-called *video objects* (VOs), which are represented by the entities of shape, motion and texture. Instead of a rectangular frame at a

specific time instant, MPEG-4 defines the *video object plane* (VOP), which can have an arbitrary shape. A block diagram of the video decoder is given in Fig. 3. Like in preceding MPEG standards, the basic principle is a hybrid coding scheme, a compression based on motion-compensated DCT with appropriate representation of blockwise-defined motion vectors and quantized transform coefficients. As a new component, the shape of the object is represented either as a binary shape (with only yes/no decision about the visibility of the all-opaque object at a specific position), or as a gray-level shape (which also allows transparency of the object). For a detailed description of these techniques, the interested reader is referred to [10][12]. Version 2 of the MPEG-4 video object decoding syntax provides definition of so-called auxiliary components, which are encoded similar to the gray-level shape and the texture, using a motion-compensated DCT. One or two auxiliary components can be reserved to encode disparity maps, indicating the correspondences between the pixels within multiple views. These can be used for view reconstruction at the receiver end, as described in section 3. To achieve this, areas must be identified first which have to be encoded and transmitted.

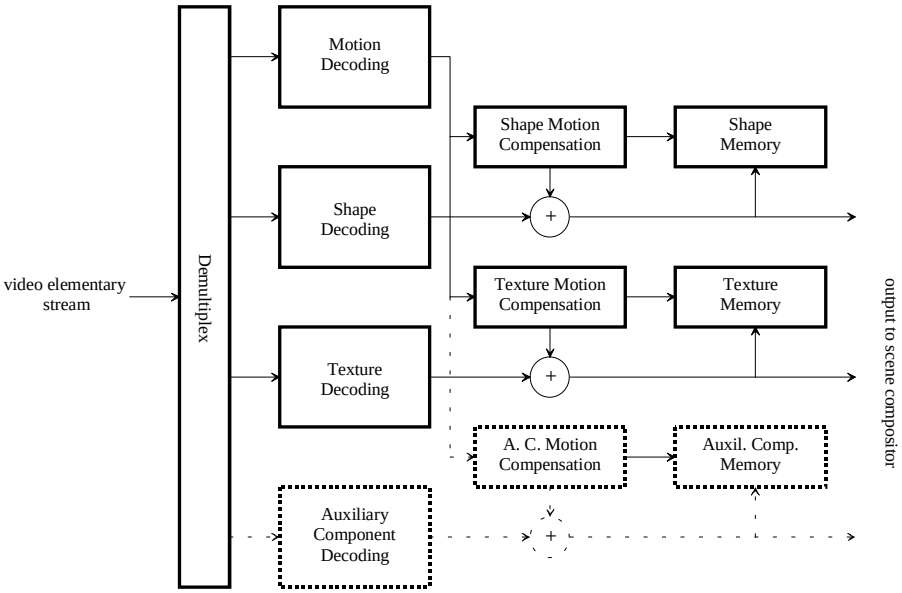


Fig.3. MPEG-4 video decoder.

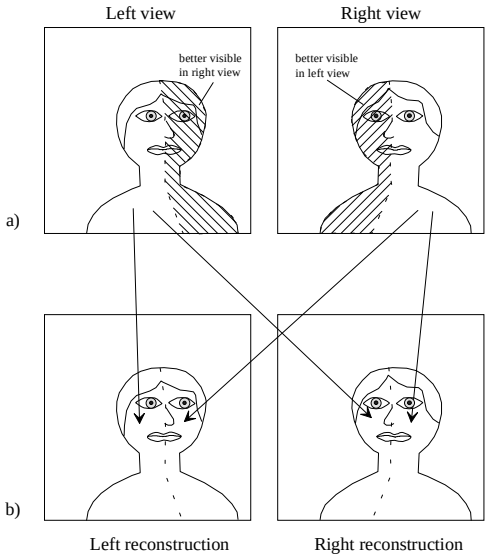


Fig.4. **a** Elimination of areas in multiple views **b** reconstruction by disparity-compensated projection.

In the context of view reconstruction, common encoding criteria like the Signal-to-Noise Ratio are no longer effective, because they are based on pixel differences. For example, disposal of reflection effects may have high impact on the pixel value accuracy, while the structure of the texture may still be reproduced with high quality. This statement applies to the 3D modeling of objects with natural texture mapping [13], and as well to the disparity-based reconstruction techniques we are describing here. We denominate the disparity-based multiview representation that was developed in the context of MPEG-4 as “Incomplete 3D” (I3D) technique. This incompleteness is two-fold : The technique does not retain the full pixel representation of all the views available, thus resulting in higher compression ; and it does not perform full 3D modeling analysis, with the advantage of a simplified complexity.

The general concept is : to limit the number of pixels that have to be encoded by analysis of the correspondences between the particular views available, such that for an object, each area that is visible within more than one camera view is encoded only once, with the highest possible resolution. If the disparity correspondences are estimated from the original views and encoded as part of the representation, it is straightforward to reconstruct all the areas that were excluded from encoding by use of disparity-compensated projection (see Fig. 4).

The “best visibility” of a particular area from one out of several camera views can be determined by an analysis of the disparity maps. Assume that P_1 and P_2 are two points on the object’s surface, which become visible in the image plane of any of the cameras. The distances between observed point positions will deviate between different cameras’ image planes, and it is the goal to retain the area in that view, which exhibits the highest resolution, or the highest distance between the points. With regard to disparities, this means that the disparity field “spreads” towards this view. In particular, if the object has a smoothly-varying surface, there will not be abrupt transitions in the visibility quality of an area ; moreover, when an area is becoming better visible within another camera, this will be observed as a local maximum in the disparity between these two cameras [14]. This is strictly true with convex-surface objects, and it is still true in most cases for objects with non-convex surfaces, if the camera positions are not too far from each other. Otherwise, partial occlusions may occur, which would cause discontinuities in the disparity map.

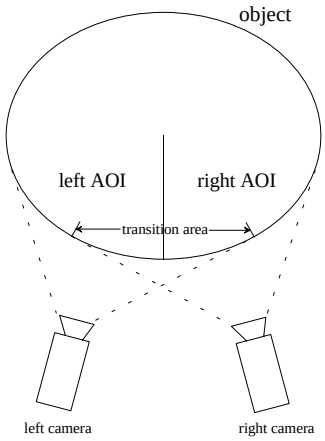


Fig.5. Multiple cameras, associated "areas of interest" (AOI) and transition area at the AOI border

We denominate the areas which are retained for encoding from each of the particular camera views as the “areas of interest” (AOI). These AOIs can now be encoded as MPEG-4 VOPs with associated disparity values, which can later be used to reconstruct different views by projection. Due to the possible reflection effects mentioned above, but as well due to exposure or color deviations between the cameras, borders between the areas which are to be reconstructed from different original views might become visible. To circumvent this problem, it is useful to preprocess pixels near the borders of an AOI, such that a smooth transition is achieved by interpolating pixels from different adjacent views within a transition area (see Fig. 5). Usually, the weights of adjacent cameras should be set to 0.5 each at the AOI borders, and be increased in favor of the “proprietary” camera towards the inner of the AOI.

The AOI concept can be applied to parallel and convergent camera setups, and to convex and non-convex objects. However, in the case of almost convex object surfaces, it turns out that the AOIs form nicely closed areas instead of widely dotted patches for each of the available camera views. Especially for VOPs showing human head-and-body subjects, which nicely follow the convex-surface prerequisite, and for acquisition with a parallel or near-parallel camera setup, it is possible to “glue” the adjacent AOIs together, such that only *one texture surface* results, which contains all the available texture

acquired from the different views, and can be encoded as *one single video object*. This technique was described in more detail in [14], and in the combination with MPEG-4, it has the nice property that a (even though geometrically distorted) reconstruction remains possible with any MPEG-4 terminal, even if the viewpoint adaptation capability described in the following section is not implemented. An example is given in Fig.6, where the common texture surface is composed from the segmented left and right views towards the object, retaining all necessary information for view reconstruction by encoding the associated disparity map additionally. It is evident, that the number of pixels in the common texture surface, which consumes up the highest amount of bits, can be drastically reduced compared to the sum of the number of pixels in the left and right original camera views.

a)  **b)** 

Fig.6. Image sequence MAN, examples of I3D generation. **a** Left and right original image frames **b** final texture surface and disparity map.

3. VIEW RECONSTRUCTION BY DISPARITY-COMPENSATED PROJECTION

The I3D representation contains information about views towards the video object from any viewpoint in between the original camera positions. In order to reconstruct different viewpoints from the I3D texture surface, the texture data within the particular AOIs can be projected onto a view plane with virtual camera position anywhere on the interocular axis between the cameras. If slight distortions near the edges of the object are acceptable, it is also possible to reconstruct views that are beyond the available camera positions. The viewpoint adaptation is performed by disparity-controlled projection from the final texture surface, with disparities from the disparity map available within the auxiliary component decoded from the MPEG-4 video stream. During synthesis, each of the AOIs is processed separately, and then the projected images from all AOIs are assembled to obtain the final view towards the video object from the selected viewpoint. This procedure was originally developed for two cameras with parallel setup [14], but meanwhile extended to convergent and multiple-camera cases as well [17]. The two steps described subsequently have to be performed.

1. Contraction of the AOI textures according to the selected viewpoint. The factor, by which the texture surface has to be contracted at a specific position, depends on the viewpoint, and is different for each AOI. The texture information within the AOI remains as it was acquired with a specific camera, and hence, the projection equations of that camera influence the relationship of the data to the outside 3D world. For example, if the original left camera view shall be reconstructed, the left AOI must not be contracted at all, while the part of the texture that is reconstructed from the right AOI has to undergo a contraction as indicated by the unscaled disparities estimated between these two views. In the case of a view between two cameras, both AOIs have to be contracted, but with scaled disparities, and for reconstruction of the right camera view, only the left AOI has to be contracted with unscaled disparities [15].

It has to be observed that certain pixels of any AOIs may not be visible from a selected viewpoint. It may happen that a pixel in the synthesized image is addressed twice during the projection, either from one, or from different AOIs. In that case, only the texture value that belongs to the real object's point that is nearer to the selected viewpoint has to be retained (assuming that the object's surface is opaque). Within one AOI, this will usually be the point with the higher disparity. With multiple AOIs and convex objects, it is reasonable to start the synthesis with that AOI which belongs to real camera(s) nearest to the selected virtual viewpoint, and never overwrite a pixel that already was written from a "nearer" AOI ; a description of a low-complexity decision technique was given in [14].

2. Interpolation of missing information. After projection for all areas of interest has been performed, certain areas of the synthesized object may still contain "holes", which would be caused either by false estimates in the disparity information (the worse case), or due to selection of viewpoints that are beyond the available camera views, e.g. with $v<0$ and $v>1$ in the

case of 2 cameras (v is the disparity scaling factor to be applied within the left AOI). The pixel resolution of the texture available from any AOI may then not be sufficient. These holes must be filled by an interpolation procedure, where linear interpolation was applied and found to work appropriate in our experiments.

Fig.7 shows examples for the synthesis of view planes at v=-0.3 (left beyond camera base), v=0 (left camera view), v=0.5 (mid between both cameras), v=1 (right camera view), v=1.3 (right beyond camera base), as produced from the texture surface and the disparity map in Fig. 6b.



Fig.7. Image from sequence MAN, synthesis examples with v=-0.3, 0.0, 0.5, 1.0, 1.3.

4. SCENE COMPOSITION WITH MULTIVIEW VIDEO OBJECTS

MPEG-4 allows description of scenes, the particular objects contained therein, and their interrelationships. Scenes are described by a specific description syntax, the *binary format for scene description* (BIFS), which allows the definition of 2D or 3D scene graphs. Links to data streams of audiovisual objects contained in the scene can be defined. The reproduction is then done by a *scene composition* step, which forces rendering of the scene to be viewed on a particular output screen (see Fig. 8). This conception has the following advantages :

- Manipulation in the content of the scene becomes possible at the receiver side on an object-by-object basis (e.g. removing or adding particular objects) or on a complete-scene basis (e.g. altering the view angle of the rendering).
- Composition of natural and synthetic audiovisual content, as it is often performed during production, is retained at the receiver side, e.g. to allow specific user interactivity.
- Prioritization of particular objects or scene parts is possible for encoding and transmission.

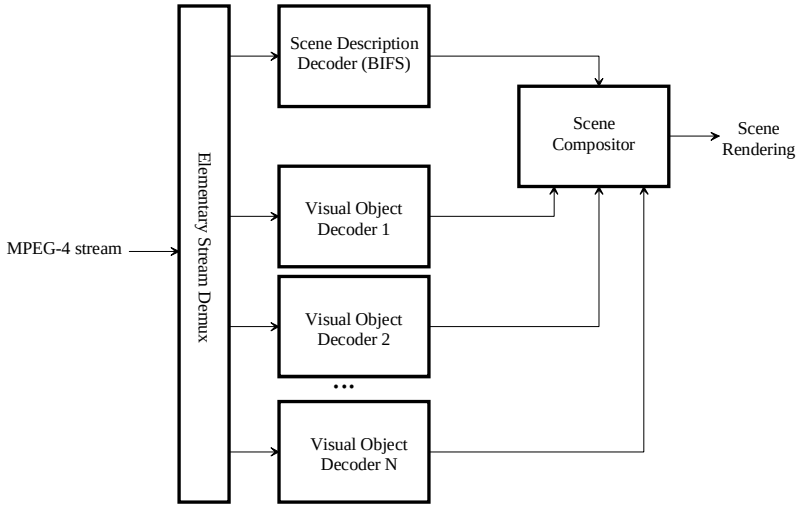


Fig.8. General structure of MPEG-4.

The scene composition process itself is not normative, which allows a certain degree of freedom for specific implementations. The viewpoint adaptation based on disparity-compensated projection or interpolation falls under these non-normative aspects of scene composition, where the reproduction quality highly depends on the specific technique applied, but also on the performance of the rendering engine used for the final reproduction of the scene (mapping onto the pixels of an output device). In this section, we want to discuss how the aspect of viewpoint adaptation towards video objects can be embedded into the 2-dimensional or 3-dimensional scene composition.

1. The 2D case. In 2D scene composition, the positioning of one or several foreground object(s) in front of a background is the key issue. If a viewpoint adaptation shall be performed, it is necessary to simulate the motion parallax as introduced in section 1, i.e. usually the foreground object will be shifted relative to the background when the viewpoint is altered. This can be combined with a simultaneous viewpoint adaptation (e.g. by disparity-compensated projection) towards the foreground object. Of course, if the background is acquired with a multiple-camera configuration as well, it can undergo a separate viewpoint adaptation. This would make sense, for example, in the case of room scenes with different wall orientations, but will be problematic in the case where the background consists of different objects occluding each other. In the case of a far background, the motion parallax effect is sufficient to simulate the viewpoint adaptation. One specific case is where one (stereoscopic) camera system is used to acquire foreground object and background simultaneously, but segmentation is performed, and foreground/background are encoded as separate MPEG-4 video objects. Here, it is well possible to form a combined texture surface, including AOIs from the two cameras, for the background as well. This combined texture will always contain more information from "behind the object" than one of the views alone. It is possible to reconstruct any view along the axis between the two cameras, including the effect of motion parallax, if viewpoint adaptation is performed on foreground and background separately, and scene composition is performed afterwards [15]. In any case, it is necessary to adjust the scaling factors and/or the amount of motion parallax shift, which can be done if either the camera parameters are known, or at least the distances of foreground object and background from the cameras during the acquisition are known. If neither is available, adjustment must be done by setting parameters a priori, such that the subjective impression of naturalness is achieved.

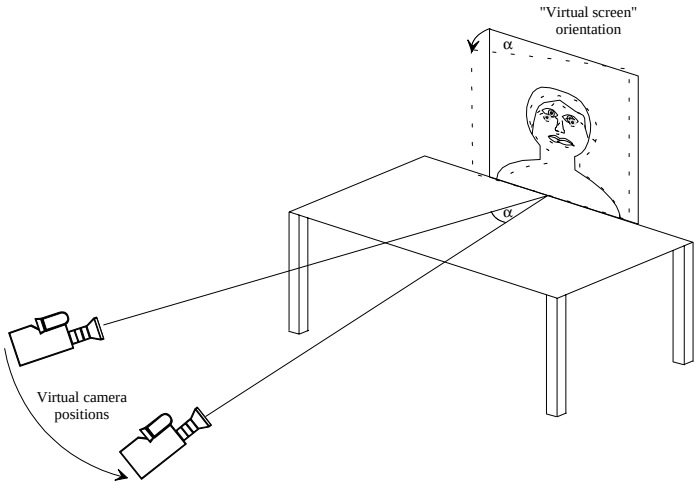


Fig.9. Inclusion of a viewpoint-adapted video object into a 3D scene.

2. The 3D case. In the 3D scene composition, which is derived from computer graphics techniques, parameters of a virtual camera are used to control the rendering (projection) towards a viewing plane that will be displayed. Unlike a complete 3D modeling of video objects (e.g. using a 3D mesh), which can be placed arbitrarily in the 3D space, an adjustment between the virtual camera parameters and the real-acquisition camera parameters is necessary, if a natural video object with disparity-based viewpoint adaptation capability shall be embedded into the scene. A simple approach is the projection of the viewpoint-adapted video object onto a flat, transparent surface ("virtual screen"), which is positioned within the 3D scene at the position where the object shall appear. This virtual screen is now positioned always perpendicular to the view axis of the virtual camera used for rendering. The adjustment between the disparity scaling parameter v and the view direction of the camera can be performed straightforwardly, if the distance between the original cameras and the object, and the baseline distance of the cameras are known (see Fig.9).

5. EXPERIMENTS AND APPLICATIONS

We have investigated the I3D technique with different stereoscopic [14] and 3-camera sequences [17] of head-and-shoulder type, for which the assumption of convex object shape approximately holds true [9]. For disparity estimation and segmentation, we have used the system described in [3], which also exists as a hardware implementation [18]. For encoding, we have used the MPEG-4 software provided by MOMUSYS. Texture, shape and motion were encoded like a conventional 2D video object, disparity data were encoded as an auxiliary component. Fig.10a shows left and right original image frames of the sequences CLAUDE and ACTRESS, Fig.10b are the MPEG-4 decoded texture surfaces and disparity maps at 64 kb/s. Fig. 11 shows the synthesis results at the center position (v=0.5, just in middle between the two original views) with the same rate. It is not possible to achieve the same lowest rates at same frame rate with left/right simulcast (separate encoding of left and right original views) or temporal scalability techniques. From the results, it is obvious that the quality of I3D viewpoint synthesis is quite insensitive to encoding distortions present within the disparity data, and moreover, that these data can be extremely compressed.

To demonstrate the 3D scene composition quality, we have realized a realtime system which is running on an PC, and can perform both the disparity-based projection and the rendering of the viewpoint-adapted video object within a 3D scene with more than 15 frames/s on a 266 MHz Pentium II processor. The disparity-based projection by itself is extremely fast, it would be possible to produce more than 60 frames/s from a video object of size 256^2 pixels. Example of the viewpoint-adapted video object CLAUDE within a 3D scene with different view angles are shown in Fig. 12. One of the applications we see for this technique is virtual videoconferencing / virtual meeting point with navigation capability, where several persons located at different places are brought together in a virtual environment.

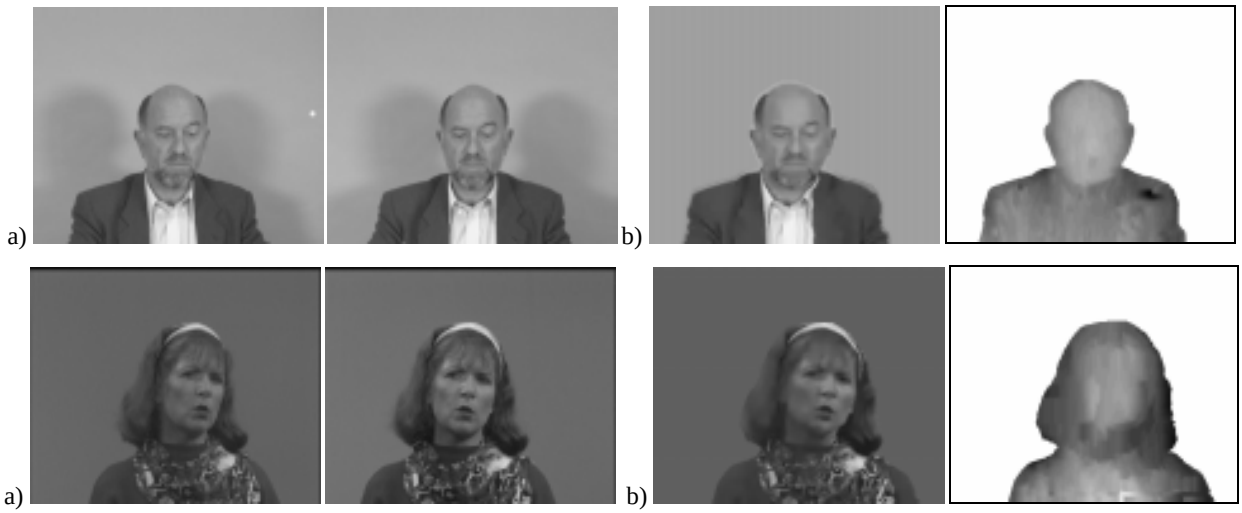


Fig.10. CLAUDE (top) and ACTRESS (bottom) **a** original left and right images **b** decoded I3D texture surfaces and disparity maps



Fig.11. CLAUDE and ACTRESS reconstructed images for synthesized viewpoint v=0.5 with 64 kb/s.

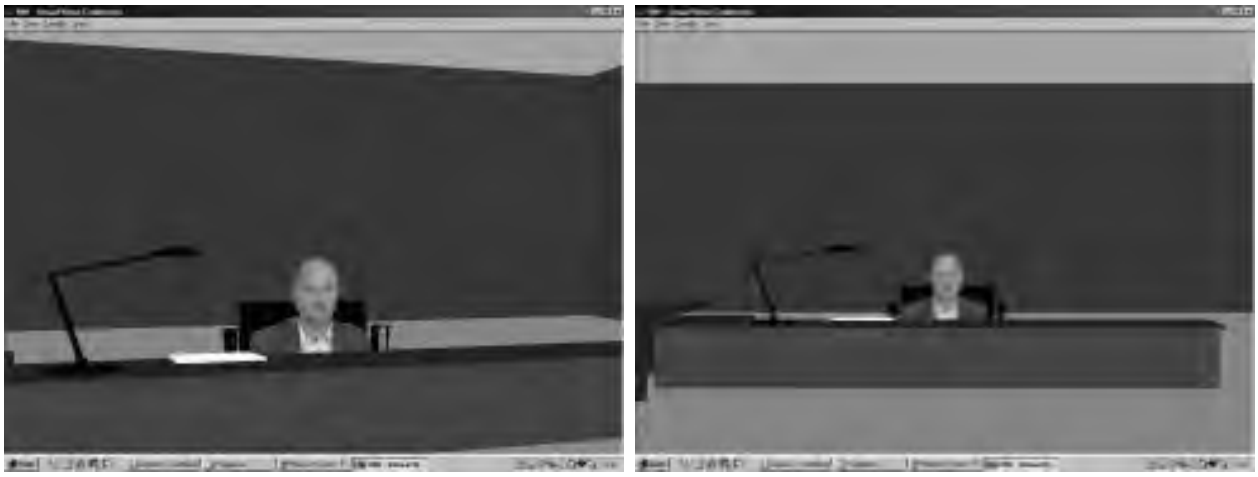


Fig.12. Examples of CLAUDE embedded into a 3D scene with different view angles.

6. CONCLUSIONS

In this contribution, concepts have been investigated, how disparity-based processing can be used both for compression of multiview video data and generation of arbitrary viewpoints from the available information of multiple cameras. Techniques that can be applied in combination with the standards MPEG-2 and MPEG-4 have been reviewed. A new technique was presented for representation of video objects captured with two- or multiple-camera configurations, which allows a very simple synthesis of different viewpoints by disparity-compensated projection. The method is compatible with existing object-based encoding methods defined in MPEG-4, where disparity information can be added to the encoded representation. The examples and results presented in this paper show, that the feature of viewpoint adaptation towards a video object can be accomplished with a low-complexity scheme, while high quality of the results is preserved. Presently, we are investigating extensions of this technique to multiple cameras with convergent axes, which allows a much higher degree of view angle adaptation, and to more general classes of video objects, especially with non-convex surfaces. However, since these extensions require only modified preprocessing and scene composition/rendering steps, the compatibility with the existing MPEG-4 syntax would still be retained. At the same time, the applicability to multiview video is an example of the high flexibility of the MPEG-4 standard, which may be applicable to various new challenging services in the multimedia market.

ACKNOWLEDGEMENTS

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APPENDIX PATENT01

SHEET 1 OF 1

FORM PTO-1449 U.S. Department of Commerce Patent and Trademark Office INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Use several sheets if necessary)	ATTY. DOCKET NO 500.43122X00	SERIAL NO 10/659,393
	APPLICANT Yuichi ONAMI	
	FILING DATE September 11, 2003	GROUP 2624

U.S. PATENT DOCUMENTS

EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DA IF APPROPR

FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUBCLASS	ABSTRACT YES

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		International Standard ISO/IEC 13818-2: 2000 (E), "Information Technology-Generic Coding of Moving Pictures and Associated Audio Information: Video", vii, viii.
		International Standard ISO/IEC 13818-2: 2000 (E), AITU-T Rec., H.262 (200 E), pp. 12, 16, 27, 36, 47, 61.

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s): Yuichi ONAMI

Serial No.: 10/659,393

Filed: September 11, 2003

For: METHOD AND APPARATUS FOR DISPLAYING NOTICEABLE IMAGE AND SYSTEM FOR REMOTELY MONITORING IMAGE

INFORMATION DISCLOSURE STATEMENT
UNDER 37 CFR §1.97 & 1.98

MS Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

March 7, 2005

Sir:

In the matter of the above-identified application, applicants are submitting herewith a copy of a communication from a foreign patent office in a counterpart foreign application and copies of the documents listed in the attached form equivalent to Form PTO-1449 for the Examiner's consideration.

This information disclosure statement is being submitted before the mailing date of a first office action on the merits.

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It is respectfully requested that this information disclosure statement be considered by the Examiner.

Please charge any shortage in the fees due in connection with the filing of this paper, including extension of time fees, to the deposit account of MATTINGLY, STANGER, MALUR & BRUNDIDGE, P.C., Deposit Account No. 50-1417 (500.43122X00) please credit any excess fees to such deposit account.

Respectfully submitted,



Carl I. Brundidge
Registration No. 29,621
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W1054-01EU

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(For Initial Filing)

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1. INTERNATIONAL STANDARD ISO/IEC 13818-2: 2000(E), "Information technology-Generic coding of moving pictures and associated audio information: Video", vii,viii	○		○				
2. INTERNATIONAL STANDARD ISO/IEC 13818-2: 2000(E), AITU-T Rec. H.262(200 E), pp12,16,27,36,47,61	○		○				
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APPENDIX PATENT02

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: John Sievers, et al.	§	Group Art Unit: 2613
	§	
	§	Examiner: Unknown
Assignee: Polycom, Inc.	§	
	§	Examiner phone: Unknown
Serial No.: 10/798,519	§	
	§	Attorney Docket No.: 199-0231US
Filed: March 11, 2004	§	
	§	
For: Method and Apparatus for Improving the Average Image Refresh Rate in a Compressed Video Bitstream	§	

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In compliance with the duty of disclosure under 37 C.F.R. § 1.56, it is respectfully requested that this Information Disclosure Statement be entered and the documents listed on attached Form PTO-1449 be considered by the Examiner and made of record. Copies of the cited references are included.

In accordance with 37 C.F.R §§ 1.97(g),(h), this Information Disclosure Statement is not to be construed as a representation that a search has been made, and is not to be construed to be an admission that the information cited is, or is considered to be, material to patentability as defined in 37 C.F.R. § 1.56(b), or that such information constitutes prior art.

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Applicant respectfully requests the listed documents be considered and made of record in the present case, and that the Examiner initial the appropriate spaces on the Form 1449 to evidence the same.

Respectfully submitted,

Billy C. Allen III, Reg. No. 46,147

Wong, Cabello, Lutsch, Rutherford
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20333 SH 249
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(832) 446-2409
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Form PTO-1449 (modified)	Atty. Docket No. 199-0231US	Serial No. 10/798,519
List of Patents and Publications for Applicant's INFORMATION DISCLOSURE STATEMENT (Use several sheets if necessary)	**Inventor/Applicant** John Sievers, et al. / Polycom, Inc. **Title: Method and Apparatus for Improving the Average Image Refresh Rate in a Compressed Video Bitstream**	
	Filing Date: 03/11/04	**Group:** 2613

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	C1	International Telecommunication Union, ITU-T Recommendation H.120, March 1993, Pgs. 1-60.
	C2	International Telecommunication Union, ITU-T Recommendation H.261, March 1993, Pgs. 1-25.

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(Use several sheets if necessary)	**Filing Date:** 03/11/04	**Group:** 2613

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	C3	International Telecommunication Union, ITU-T Recommendation H.262, February 2000, Pgs. 1-207.
	C4	International Telecommunication Union, ITU-T Recommendation H.263, February 1998, Pgs. 1-155.
	C5	International Telecommunication Union, Advanced Video Coding for Generic Audiovisual Services, Pgs. 1-269.
	C6	International Standard, ISO/IEC 11172-2, Information Technology-Coding of Moving Pictures and Associated Audio for Digital Storage Media at up to About 1,5 Mbit/s, August 1, 1993, Pgs. 1-114.
	C7	International Standard, 11172-2, Technical Corrigendum 1, Information Technology-Coding of Moving Pictures and Associated Audio for Digital Storage Media at up to About 1,5 Mbit/s, April 15, 1996, Pgs. 1-2.
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	C12	International Standard, 13818-2, Technical Corrigendum 1, Information Technology-Generic Coding of Moving Pictures and Associated Audio Information: Video, March 1, 2002, Pgs. 1-2.
	C13	International Standard, 14496-2, Information Technology-Coding of Audio-Visual Objects-Part 2: Visual, June 1, 2004, Pgs. 1-708.

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List of Patents and Publications for Applicant's INFORMATION DISCLOSURE STATEMENT	**Inventor/Applicant** John Sievers, et al. / Polycom, Inc. **Title: Method and Apparatus for Improving the Average Image Refresh Rate in a Compressed Video Bitstream**	
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Other Art (Including Author, Title, Date Pertinent Pages, Etc.)

Exam. Init.	Ref. Des.	Citation
	C14	International Standard, 14496-2, Amendment 1, Information Technology-Coding of Audio-Visual Objects Part 2: Visual, June 1, 2004, Pgs. 1-12.

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362	0			a| Vol. 1, no. 1 (Mar. 1991)-
500				a| Title from cover.
550				a| "A publication of the Circuits and Systems Society.
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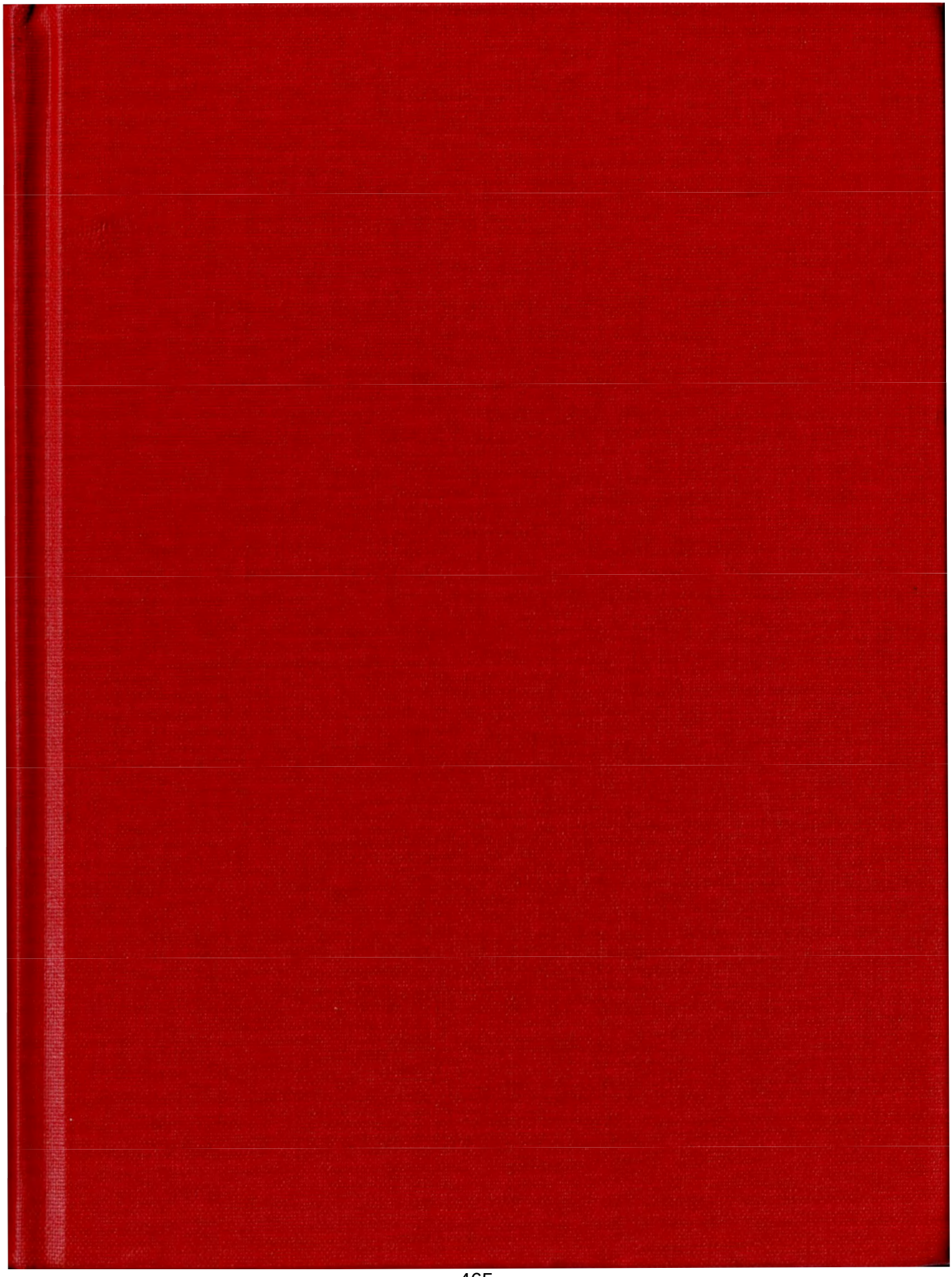
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EXPRESS LETTERS

Face Location in Wavelet-Based Video Compression for High Perceptual Quality Videoconferencing ..... *J. Luo, C. W. Chen, and K. J. Parker* 411

Multiviewpoint Video Coding with MPEG-2 Compatibility ..... *B. L. Tseng and D. Anastassiou* 414

A Block-Based Gradient Descent Search Algorithm for Block Motion Estimation in Video Coding ..... *L.-K. Liu and E. Feig* 419

A Note on "Block Wavelet Transforms for Image Coding" ..... *A. Sharaf and F. Marvasti* 422

The image quality evaluation using both subjective and objective criteria is given in Table II.

The rate-distortion performance of the result is not among the best for current schemes (e.g., H.263 standard). In this simulation, we achieved a bit rate of 48 kb/s at a peak signal-to-noise ratio (PSNR) of 33 dB. However, the simulation has not taken full advantage of the potential of this wavelet-based discriminative coding scheme. First, we use only one level of wavelet decomposition. Consequently, efficient zerotree coding technique is not applicable [8]. In general, more decomposition levels enable better energy compaction and more efficient zerotree coding. Second, two-tap Haar filter is inadequate to exploit the temporal redundancies in the video signal. In spite of these facts, the simulation clearly demonstrates that the wavelet-based discriminative coding scheme can outperform nondiscriminative schemes by a significant margin, especially in terms of the perceptual quality of the reconstructed images.

V. Conclusion and Future Work

A new face location technique based on the extraction of the facial contour is proposed. It has been applied to a wavelet-based image and video compression scheme designed primarily for videoconferencing. An approximate face region mask is generated and used for a discriminative quantization of the decomposed subbands. Simulation results have shown that this approach is promising in videoconferencing applications since the perceptual image quality of the face region can be greatly improved. Motion information can certainly be incorporated for robust location and tracking of the face region in a more complex background using complete three-dimensional information. Semantic information, such as the detection of the mouth and the eyes, can also be incorporated to confirm the face detection [3]. We are convinced that computer vision techniques can be incorporated into compression schemes to improve the performance of the overall coding system.

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Multiviewpoint Video Coding with MPEG-2 Compatibility

Belle L. Tseng and Dimitris Anastassiou

***Abstract*—An efficient video coding scheme is presented as an extension of the MPEG-2 standard to accommodate the transmission of multiple viewpoint sequences on bandwidth-limited channels. With the goal of compression and speed, the proposed approach incorporates a variety of existing computer graphics tools and techniques. Construction of each viewpoint image is predicted using a combination of perspective projection of three–dimensional (3-D) models, texture mapping, and digital image warping. Immediate application of the coding specification is foreseeable in systems with hardware-based real-time rendering capabilities, thus providing fast and accurate constructions of multiple perspectives.**

I. Introduction

Recent interests in three-dimensional (3-D) technologies prompt the addition of depth impression onto the otherwise common two-dimensional (2-D) video signals. Two major processes to perceiving 3-D can be categorized. The first is due to the two slightly different perspectives of the world offered simultaneously to our left and right eyes. The human visual system then converts these two stereo images into one single fused 3-D perception. The other approach to sense depth, even with only one eye-viewpoint, is through motion parallax. Due to motion from our head movements, the relative object displacements of the resulting perspective view are sufficient cues in deriving the 3-D sensation. Accordingly, in our presentation, the depth appearance is contributed by both processes where construction of stereo and virtual viewpoint images is possible.

A multiviewpoint video, multiview for short, is a 3-D extension of the traditional movie sequence, in that there are multiple perspectives of the same scene at any one instance in time. Comparable to a movie made by a sequence of holograms, a multiview video offers a similar look-around capability. An ideal multiview system allows any user to watch a true 3-D stereoscopic sequence from any perspective the viewer chooses. Such a system has practical uses in interactive applications, medical technologies, educational and training demonstrations, remote sensing developments and is a step toward virtual reality.

With the development of digital video technology, a video data compression standard, namely the second Motion Picture Experts Group specification (MPEG-2), has been adopted by the International Standards Organization (ISO) and the International Telecommunications Union (ITU). MPEG-2 specifies the coding process for one video sequence; detailed descriptions can be found in [1]. Recently, MPEG-2 has also been shown to be applicable to two sequences of stereoscopic signals through the use of spatial and temporal scalability extensions [2]–[5]. However, extending the number of video viewpoints beyond two cannot be done practically by using the same methodology. For this motivation, a novel multiview codec is presented to complement the MPEG-2 standard.

II. Geometric Definitions and Notations

An ordinary 2-D video sequence offers only one perspective of the acquired scene. For a 3-D viewing experience, at least two viewpoints are required to obtain the depth impression from the left and right

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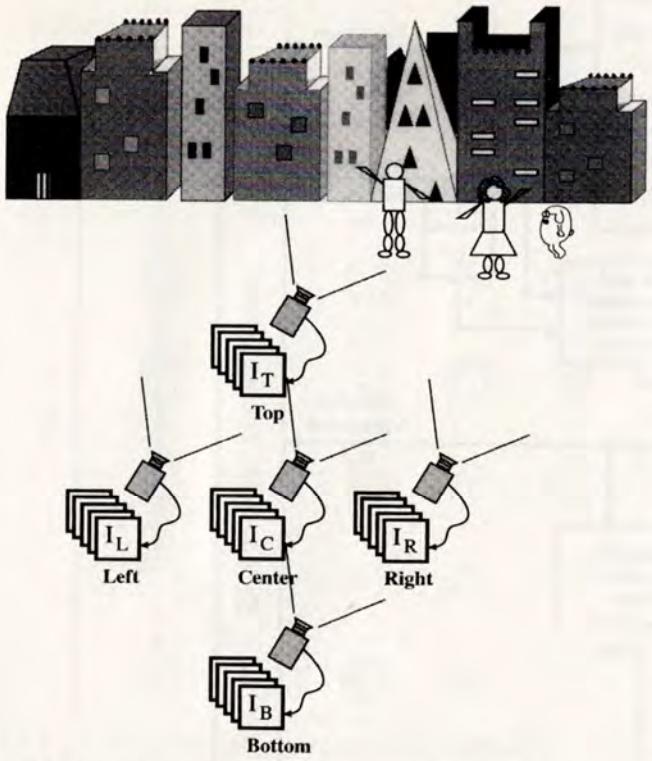


Fig. 1. Camera configuration of multiple viewpoint images.

perspectives of a stereoscopic signal. In a multiview system, multiple viewpoints are involved. Let N be the number of viewpoint sequences where the minimum number of viewpoints is equal to three for the presented specification, i.e., $N \geq 3$. The number of viewpoints must be extendable in the future, thus accommodation of additional viewpoints is an essential feature.

One central viewpoint image is designated to be the principal view from which the other multiview images are predicted. Let the central image be denoted by I_C from viewpoint V_C. The central viewpoint, usually the middle viewpoint, is chosen so that its image has the highest collection of overlapping objects with each of the other viewpoint images. In this manner, the central viewpoint image can be used to interpolate and predict most of the other views.

The other multiview images are designated by I_X from corresponding viewpoints V_X. An example of four additional views is illustrated in Fig. 1, where cameras positioned at viewpoints $V_X = \{V_L, V_R, V_T, V_B\}$ capture respective images $I_X = \{I_L, I_R, I_T, I_B\}$ corresponding to the left, right, top, and bottom. These camera-captured images available at the encoder are referred to as *real* views, whereas images not directly taken by a camera, but derived by prediction or interpolation methods, are called *virtual* views. Virtual pictures include those viewpoint images seen between two real cameras, thus having such virtual constructions allows the viewer to see a smoother video transition between two real views.

The image coordinate system corresponding to each viewpoint is independently defined as (X_i, Y_i), where viewpoint index $i = \{C, L, R, T, B\}$ for the five multiview configurations of Fig. 1. Let the global rectangular coordinate system (X, Y, Z) be defined as corresponding to the image coordinate system (X_C, Y_C) of the central viewpoint, where Z defines the orthogonal axis from the central image plane.

Each multiview camera position is represented by the global coordinates (vx_i, vy_i, vz_i), with the camera zooming parameter described by F_i. In addition, the camera rotations are given by the vertical tilting angle α_i, the horizontal panning angle β_i, and the axial revolving angle γ_i. The total viewpoint vector for some viewpoint index i is denoted as $V_i = [vx_i, vy_i, vz_i, F_i, \alpha_i, \beta_i, \gamma_i]$. Viewpoint vectors are obtained relative to the central viewpoint, where $V_C = [0, 0, 0, 1, 0, 0, 0]$. Thus for a given acquisition camera configuration, viewpoint directions are relative 3-D translations and rotations with respect to the central view. If camera configurations are unknown, then locating several fixed points between multiviews allows determination of the relative orientation transformation [6], [7].

III. Depth and Disparity Estimation

Possessing the depth position of an object in one image allows for geometric prediction of the object location in all other viewpoint images. Consequently, our desire to determine the depth of every object in a scene permits construction of the scene from any viewpoint. The depth of an object can be geometrically calculated if two or more perspectives of the object are given, as in a collection of multiviews. First, the positions of the object in each of the available viewpoint images must be located; this problem is widely known as the *correspondence problem*. After locating the object positions from two views, the difference in image coordinates is termed *disparity*. Following, it can be shown mathematically that the depth is inversely proportional to the derived disparity [7].

Under the block-based motion characterization constraint of MPEG-2, one disparity vector corresponding to each block of an image can be incorporated for prediction of a second image. Block-based disparity compensation is the dominant approach for the coding of stereoscopic video sequences. These approaches are sufficient for coding and transmission of two stereo signals without entailing true depth details to the decoding system. For acceptable predictions of multiviewpoint images however, accurate depth information for every pixel is required for multiple spatially-continuous interpolations of intermediate viewpoint images. Thus a depth map is required covering every pixel whose quantized values can be transmitted as the gray-level intensity of a second "image." Since the majority of the depth image is quite flat and relatively object oriented, the depth map can be considerably compressed as illustrated in [8]. To obtain a dense depth map, many efficient techniques have been developed for stereo image pairs as well as for multiple views, including [7], [9], and [10].

IV. MPEG-2 Compatible Multiviewpoint Video Coding

The delivery of two viewpoint video sequences is accomplished by the scalability extensions of the MPEG-2 video coding standard, where spatial predictions are obtained by disparity-compensation on a macroblock basis. As mentioned in Section III, however, for multiview video coding, a dense depth map is required for accurate predictions of multiple views. Seeking compatibility with the compression standard, an ad hoc group of MPEG-2 is established to investigate a new profile for multiviewpoint systems [11]. For conformity, the multiview profile is to supplement the main profile of MPEG-2 so that all standardized systems are capable of deciphering at least one video sequence from one viewpoint. Consequently, the central viewpoint is selected to be processed and transmitted in accordance with the main profile. The remainder of this section is devoted to describing the proposed encoding and decoding systems for the processing of the other viewpoints.

A. Multiviewpoint Encoding System

A block diagram of the proposed multiview encoding system is illustrated in Fig. 2 for five multiview sequences: $I_C^t, I_L^t, I_R^t, I_T^t$,

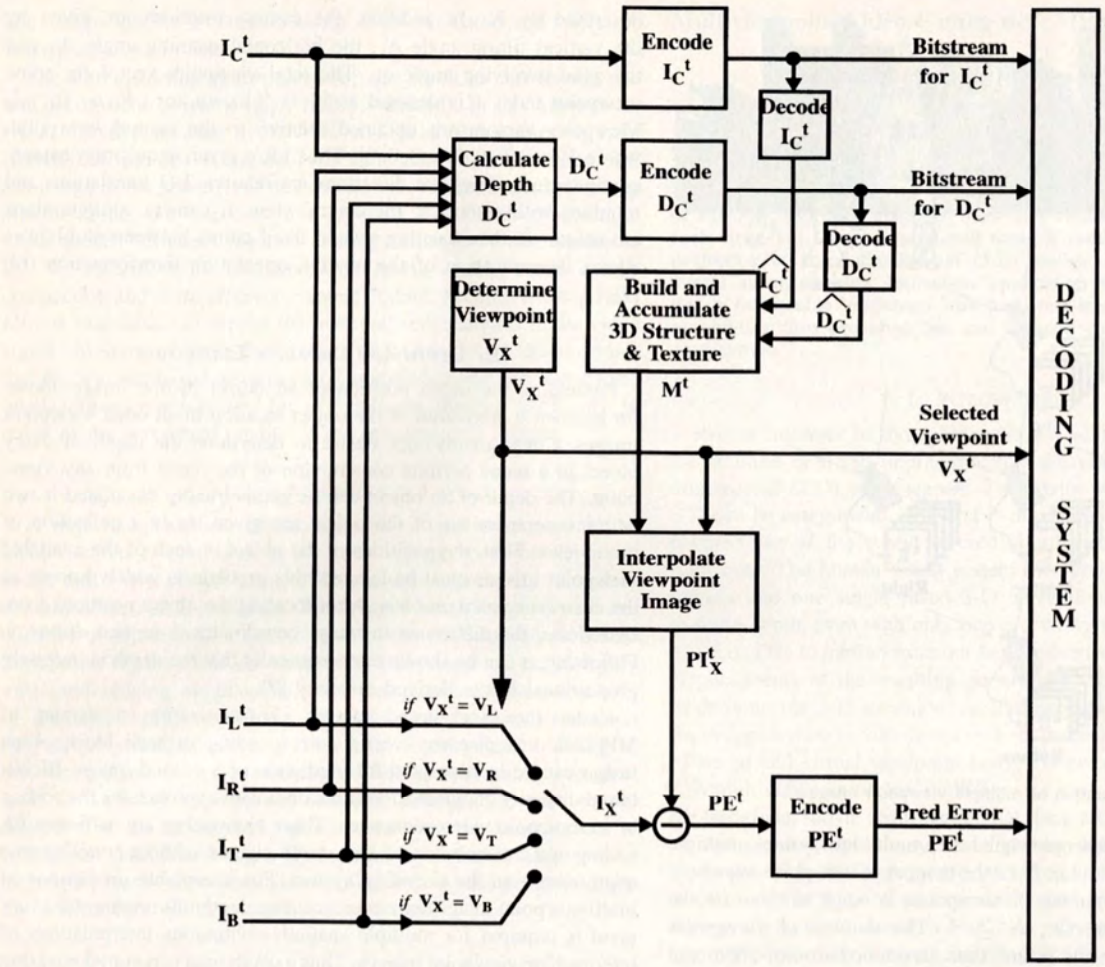


Fig. 2. Block diagram of multiview encoding system.

and I_B^t. First, determine all viewpoint vectors, $V_C^t, V_L^t, V_R^t, V_T^t$, and V_B^t from the acquisition camera configurations positioned in Fig. 1. Find the central viewpoint image, in our case I_C, achieving the best predictions for the other views. The central image sequence I_C^t is then processed in the main profile of MPEG-2. Next, the encoded bitstream for I_C^t is ready for transmission and in parallel is decoded to determine the receiver-reconstructed central images, denoted $\widehat{I_C^t}$.

Starting with the central viewpoint image I_C^t at time t, a depth value $z_C = D_C^t(x_C, y_C)$ is calculated for every pixel $I_C^t(x_C, y_C)$, thus forming a depth map image, named D_C^t, corresponding to the central viewpoint image. Afterwards, encode the depth map D_C^t as a secondary highly compressible image, and transmit the encoded bitstream for D_C^t. Simultaneously, the encoded bitstream for D_C^t is decoded to determine the receiver-reconstructed depth map, assigned $\widehat{D_C^t}$.

Obtain a 3-D mesh model representation [12], called M^t, for the central image $\widehat{I_C^t}$ of time t by associating each coordinate pair (x_C, y_C) with its corresponding depth value $\widehat{D_C^t}(x_C, y_C)$. Consequently, the 3-D surface texture is derived from the 2-D image intensity $I_C^t(x_C, y_C)$, and a graphical model of the scene is obtained. This geometric representation offers ease in interpolating different viewpoints. Similar to rendering approaches in computer graphics [13], [14], given a 3-D geometrical model and its associated texture intensity, every viewpoint can be effectively and efficiently constructed by simple geometric transformations followed by 3-D texture mapping. Furthermore, interpolating virtual viewpoint images is facilitated and feasible.

Select a noncentral viewpoint, designated as V_X^t, chosen from the set of original real viewpoints in which the best construction of its image I_X^t is desired for time t. The selection of viewpoint V_X^t is based on a round-robin schedule where every viewpoint is successively selected in a cycle. In Fig. 3, a round-robin rotational scheme for four noncentral views is shown where the selection of each image is related to time t in the following manner: $I_L^t, I_R^{t+1}, I_T^{t+2}, I_B^{t+3}, I_L^{t+4}, I_R^{t+5}, I_T^{t+6}$, etc., distinguished by a double border. Next, transmit the selected viewpoint vector V_X^t for time t.

The next step is to interpolate the selected noncentral viewpoint image, referred to as predicted image PI_X^t, by rendering the 3-D mesh model M^t in the specified viewpoint V_X^t. This interpolation step requires rendering a wireframe image of the desired viewpoint by simple geometric transformations with perspective projections of the mesh model, followed by texture mapping the corresponding areas of the central image onto the appropriate wireframe substructures.

Subsequently, calculate the prediction errors PE^t required for the final reconstruction of the selected view by examining the difference between the original image I_X^t and the predicted image PI_X^t. Finally, encode and transmit the residual prediction errors PE^t. Before

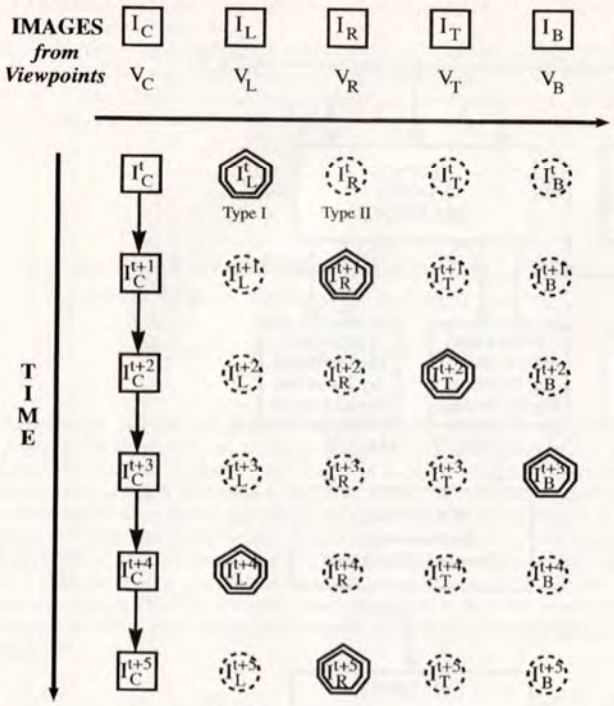


Fig. 3. A round-robin rotational schedule for encoder selection of one viewpoint.

moving on to the next frame, determine if the allocated bit rate allows transmission of an additional noncentral image. If bandwidth allows, the prediction errors for another view can be determined and sent. Alternatively, a new round-robin schedule can be adopted where two viewpoints are selected for every time, thus perfect reconstruction is always achievable with unlimited bandwidth. Subsequently, the entire process starts all over for the next time frame.

B. Multiviewpoint Decoding System

A block diagram of the proposed multiview decoding system is illustrated in Fig. 4 for construction of any viewpoint images. First, the received bitstream of the central view is decoded on the main profile of MPEG-2, whose decoded images, denoted $\widehat{I_C^t}$, are stored in memory. Second, the bitstream of the depth map is decoded and hereafter referred to as $\widehat{D_C^t}$. Next, obtain a 3-D mesh model, called M^t, for the central image $\widehat{I_C^t}$ as performed in the encoding system. Consequently, store the model M^t for time t in memory.

Upon receiving the encoder-selected viewpoint vector V_X^t for time t, store the vector in memory. Next, the prediction errors associated with the selected viewpoint V_X^t are decoded, denoted as $\widehat{PE^t}$. Now, determine the viewpoint requested from the user at the decoding system for time t, assigned V_U^t. Subsequently, the user-requested viewpoint image (whether real or virtual) is interpolated, referred to as predicted image PI_U^t, where the index U designates the appropriate viewpoint V_U^t. The prediction PI_U^t is constructed by rendering the 3-D mesh model M^t in the specified viewpoint V_U^t by the same viewpoint image interpolation procedure as in the encoder.

Determine if the encoder-selected noncentral viewpoint V_X^t is similar to the user-requested viewpoint V_U^t. If the same, $V_U^t = V_X^t$, then the user can immediately construct the desired image. The final reconstructed image $\widehat{I_X^t}$ is obtained by combining the prediction errors $\widehat{PE^t}$ with the predicted image PI_X^t. This kind of reconstruction is thereafter defined as *Type I Prediction*. Next, the reconstructed noncentral image $\widehat{I_X^t}$ is stored in memory for later reference. Satisfying the user's request for this viewpoint image, the whole process is repeated for the next time frame.

On the other hand, if the user did not request the same viewpoint as the one selected by the encoder, $V_U^t \neq V_X^t$, the following steps are carried out to generate such a view. Given the user-requested viewpoint V_U^t, retrieve from memory the image $\widehat{I_U^{t-f}}$ corresponding to the nearest past image I_U reconstructed by a Type I Prediction. Similarly, retrieve the image $\widehat{I_U^{t-b}}$ corresponding to the nearest future image I_U reconstructed by a Type I Prediction. For example, referring to Fig. 3, if the user requests viewpoint V_R at time $t+2$, then the front image is $I_R^{t+1}(f=1)$ and the back image is $I_R^{t+5}(b=3)$. Due to the round-robin schedule for one noncentral viewpoint selection during each time frame, the maximum value of f and b is limited by $N-2$, where N is the number of viewpoints. Note that a delay may be required in order to access the future image.

Next, load the 3-D mesh model M^{t-f} created at time $t-f$ from $\widehat{I_C^{t-f}}$ and $\widehat{D_C^{t-f}}$. In parallel, load the 3-D mesh model M^{t+b} created at time $t+b$ from $\widehat{I_C^{t+b}}$ and $\widehat{D_C^{t+b}}$. Next, generate the front mesh image MI_U^{t-f} by locating a grid of fixed points on the image $\widehat{I_U^{t-f}}$. Also, generate the back mesh image MI_U^{t+b} by locating a corresponding grid of fixed points on the image $\widehat{I_U^{t+b}}$. Afterwards, generate the intermediate mesh-predicted image MPI_U^t for time t by digitally image warping between the front mesh image MI^{t-f} and the back mesh image MI^{t+b}. The image warping technique and generating mesh images by locating appropriate fixed points are well explained in [15].

Finally, a construction for $\widehat{I_U^t}$ is obtained by combining the intermediate mesh-predicted image MPI_U^t with the predicted image PI_U^t. The method for this final combination is left to the decoding system using any image fusion techniques [16], [17], e.g., XOR operator, average, etc. Construction of this final image $\widehat{I_U^t}$ is termed as *Type II Prediction*. At this point, if other viewpoint images are requested by the users, the prediction steps may be repeated to generate other multiviews. Otherwise, the decoding process starts at the beginning to decode the next time frame.

V. Conclusion

The proposed MPEG-2 compatible video coding specification for multiviewpoint systems offers many advantages. In addition to providing a structural framework for the new multiview profile of the MPEG-2 coding standard, this codec retains the same encoding and decoding processing for one basic viewpoint sequence based on the main profile. Furthermore, because the standard only defines the bitstream syntax and the decoding process, there is freedom in designing very high quality encoders and very low cost decoders. Similarly, the presented specification suggests the same flexibility, providing for creativity and enhancements in accordance with advanced technologies.

To accommodate the delivery of an adaptive number of viewpoint sequences in an MPEG-2 compatible coding structure, a resilient and flexible multiview codec is required where reducing the image data by exploiting redundancy among the multiple views becomes crucial. Our novel contribution to the multiview coding research is mainly due to the concept of combining 2-D image processing with 3-D computer graphics, where 3-D model representations of the captured scene are incorporated with computer graphics tools and image warping techniques to construct the desired views. Many existing graphical tools and animation facilities, currently available in hardware, offer speedy rendering capabilities. Thus, interpolation of any viewpoint image sequence can be generated quickly and

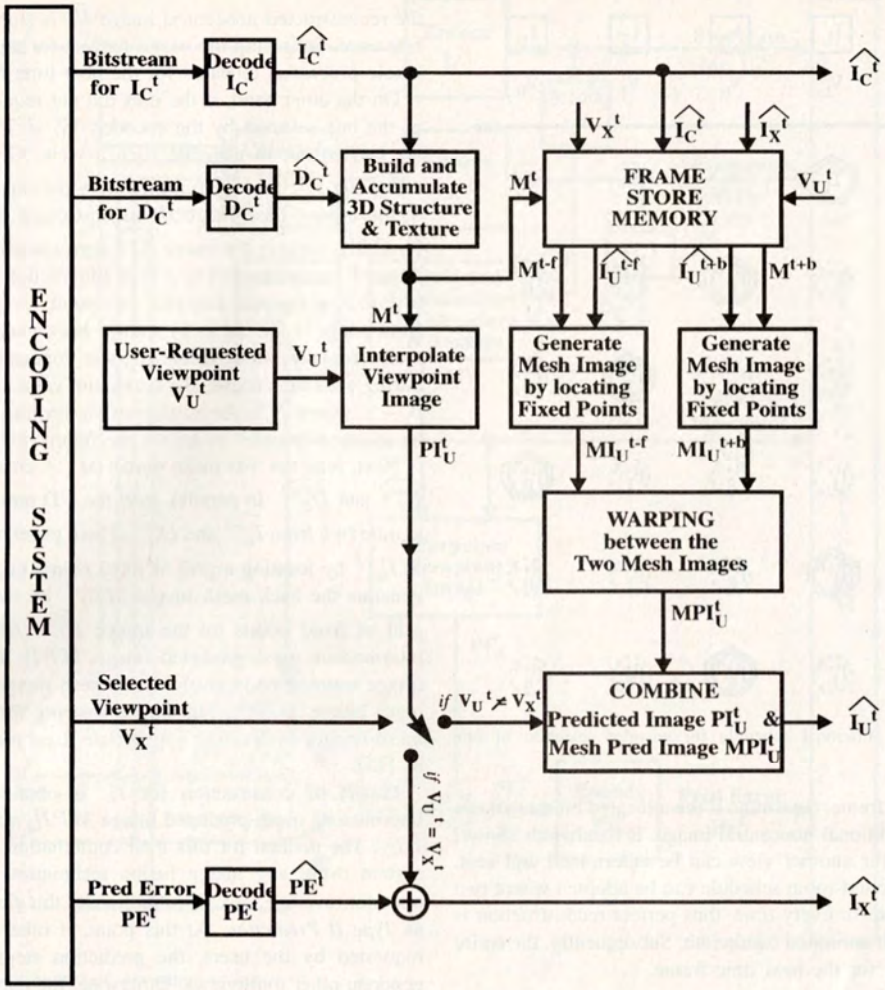


Fig. 4. Block diagram of multiview decoding system.

efficiently. Also, construction of nontransmitted virtual viewpoints is possible due to availability of 3-D models.

In rendering an image of a 3-D surface structure, the textured image data are mapped onto corresponding 3-D geometric meshed surfaces. Consequently, texture mapping automatically incorporates the fore-shortening effect of 3-D surface curvatures. In addition, since the texture is a 3-D function of its position in the object, tracking of image points is facilitated by knowing the real world 3-D coordinates of each point. Furthermore, additional enhancements on the constructed images may be obtained by incorporating other graphical tools, e.g., illumination and shading. Thus, innovative ideas can be freely augmented onto our system as technologies progress.

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A Block-Based Gradient Descent Search Algorithm for Block Motion Estimation in Video Coding

Lurng-Kuo Liu and Ephraim Feig

***Abstract*—A block-based gradient descent search (BBGDS) algorithm is proposed in this paper to perform block motion estimation in video coding. The BBGDS evaluates the values of a given objective function starting from a small centralized checking block. The minimum within the checking block is found, and the gradient descent direction where the minimum is expected to lie is used to determine the search direction and the position of new checking block. The BBGDS is compared with full search (FS), three-step search (TSS), one-at-a-time search (OTS), and new three-step search (NTSS). Experimental results show that the proposed technique provides competitive performance with reduced computational complexity.**

I. Introduction

The high correlation between successive frames of a video sequence makes it possible to achieve high coding efficiency in a video coding system by reducing the temporal redundancy. Motion compensated video coding technique, which predicts current frame from previous frame (or reference frame), has been used to exploit the temporal redundancy between successive frames. Motion estimation plays an important role in such an interframe predictive coding system. Among many types of motion estimation algorithms, block-matching technique has been adopted in many video compression standards, such as MPEG [1], [2], H.261 [3], and H.263 [4], due to its simplicity. In block-matching technique, frames are divided into blocks and one motion vector is associated with each block. For each block in the current frame, the motion estimation searches for a motion vector which points to the best match block in the reference frame. The best match block is then used as the predictor for the current block.

The full search (FS) block-matching algorithm is the simplest, but computationally very intensive. It provides an optimal solution by exhaustively evaluating all the possible candidates within the search range in the reference frame. Several fast algorithms, such as the three-step search (TSS) [5], the 2-D logarithmic search (LOGS) [6], one-at-a-time search (OTS) [7], and the new three-step search (NTSS) [8] have been developed to reduce the computational complexity by reducing the number of checking points. Of these, the first three can be easily trapped into a local minimum, thereby degrading performance; see, for example [9]. The NTSS takes into account the fact that the distribution of global minimum in real world video sequences is centered at zero. This is especially true for head-and-shoulder sequences typical in video conferencing. The NTSS adds checking points which are centered about zero to the first step of the TSS. But usually the search stops after the first step, and then the second most likely scenario has the search ending after a second step which searches close to the first. So, on average, NTSS is somewhat faster than TSS. More significantly, for head-and-shoulder sequences, NTSS yields significant SNR gains over TSS.

In the present work we push the idea of utilizing the statistical nature of the motion even further. We further assume that the global minimum has a monotonic distortion in its neighborhood. In our first step we only search around the center point. If the optimum is found at the center, the procedure stops. This will be more than 80% of the time. Otherwise, we proceed to search around the point where the minimum was found. The procedure continues until the winning

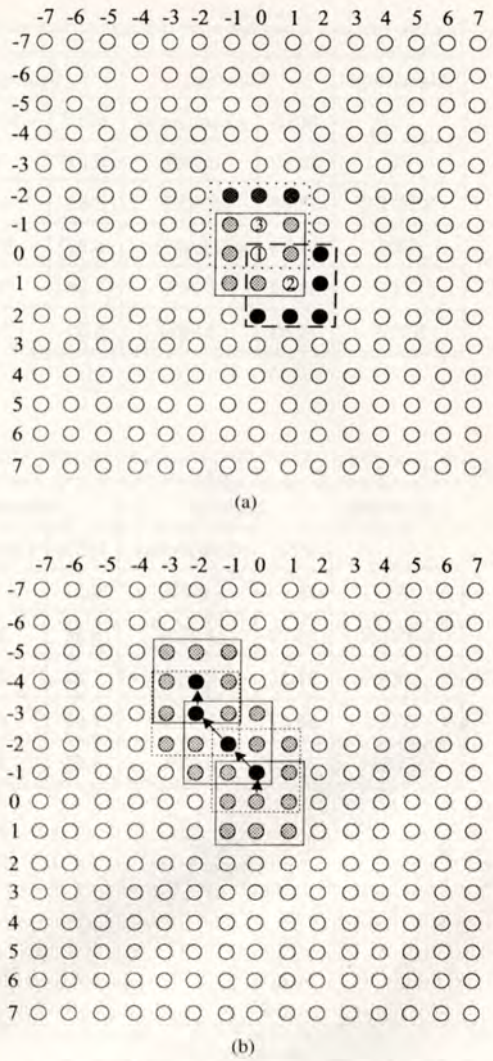


Fig. 1. (a) The first pass of BBGDS is centered around pixel (1); the second pass is centered around either pixel (2) or pixel (3). The shading highlights those new pixels that have to be checked in the second pass. (b) Example of the BBGDS search procedure, where motion vector $(-2, -4)$ is found.

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