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RECENT DEVELOPMENTS IN MULTIMEDIA VIDEO CODING TECHNOLOGY STANDARDIZATION PROCESS

Zoran Miličević[1], Zoran Bojković[2]
[1]Department of Telecommunications and IT Genaralstaff of the SAF in Belgrade
[2]University of Belgade

Abstract*: Standards are technical documents that define precisely the conformance required of users if interoperability is to be achieved. This work reports on recent developments in video coding standardization, particularly on multimedia video coding technology. The initiative is made jointly by ITU-T VCEG and ISO/IEC MPEG and is referred to as High Efficiency Video Coding (HEVC). Firstly, brief summaries of each of the video coding standards that support use in multimedia applications are provided. Next, it is demonstrated that the HEVC standard is intended to provide significantly better compression capability compared to the existing AVC (ITU-T H.264/ISO/IEC MPEG-4 Part10) standard. The first steps towards the definition of the HEVC standard are described, together with the progress of this standard activities. At the end, some research trends are pointed out, too.*

Key words: *ITU-T VCEG, ISO/IEC MPEG, standardization process, multimedia video coding, high efficiency video coding.*

1. Introduction

Advances in signal and video compression, in very-large-scale integration (VLSI) technology, in optical storage, combined with the work on high-speed delivery of digital information over one lines together would enable CD-interactive, the videophone, video on demand, the DVD and a multimedia-enabled Internet. At the basis of all these results lies the compressed digital representation of audio and video signals. The consumer's electronics (CE) and telecommunication companies that recognized the possibilities of these new technologies also recognized the benefits of standardizing them. The understanding shared by a handful of CE and Telecommunication companies was the basis for the creation of Moving Picture Experts Group (MPEG) in 1988 in the framework of the International Organization for Standardization (ISO). MPEG standards for the digital representation of audio, video and related integration have facilitated the transition of the media industry to the digital world. Since its establishment, MPEG has set many widely used standards. The group has expanded its scope from basic coding technologies to technologies that support audio and video compression formats [1].

Since its early days, MPEG has discovered that targeting its standards to satisfy the needs of a broad range of industries is an obviously laudable but often nearly impossible task to achieve. MPEG has found a solution to this problem with the adoption of Profiles and Levels [2]. With Profiles MPEG is able to control the amount of technology (features, performance and sometimes complexity) needed in an instance of the standard, while with levels MPEG is able to control the amount of "resources" e.g., video resolution involved.

MPEG exists to develop standards that can be widely deployed. According to its Terms of References, MPEG's area of work is the "development of international standards for compression, decompression, processing and coded representation, in order to satisfy a wide variety of applications" [3]. MPEG has developed the following sets of technical standards: ISO/IEC 11172 (MPEG-1), entitled "*Coding of Moving Pictures and Associated Audio at up to about 1,5 Mbps*"; ISO/IEC 13818 (MPEG-2), entitled "*Generic Coding of Moving Pictures and Associated Audio*"; ISO/IEC 14496 (MPEG-4), entitled "*Coding of Audio-Visual Objects*"; ISO/IEC 15938 (MPEG-7), entitled "*Multimedia Content Description Interfaces*"; ISO/IEC 21000 (MPEG-21), entitled "*Multimedia Framework*".

MPEG usually develops audio and video coding standards in parallel, together with the multiplexing and synchronization specifications. MPEG standards are organized in Parts, each one defining a major piece of technology.

The Advanced Video Coding Standardization (AVC) has achieved a significant improvement in compression capability compared to prior standards. It provides a representation of video that addresses both non-conversational (storage, broadcast, streming) and conversational (video-telephony) applications.

In what follows, the paper continuous with sections dealing with the past, present and future of MPEG video coding standards (MPEG-1 and MPEG-2). Next section brings MPEG-4 Part 2 and H.264/AVC standards, together with AVC video coding structure and important applications. The paper ends with discussion on High Efficient Video Coding (HEVC) including 3D Video upcoming standard.

2. MPEG-1 and MPEG-2 standards

The MPEG-1 standard is the first time multimedia standard with specifications for coding, compression and transmission of audio, video and data streams in a series of synchronized, mixed packets [4]. It was set up in the period from 1988 to 1991. At the end of the eighties, with ITU-T Recommendation H.261 [5] on video coding for communication purposes, it became clear that the same coding technology could provide a digital alternative to the widely spread analogue video cassette player. MPEG-1's goal was to provide a complete audio-visual digital coding solution for digital storage media (CD, optical drives, Winchester discs). Since CD was the major target the standard was optimized for the bit-rate range 1,5 Mbit/s, but it works at lower and higher bit-rates as well. Uncompressed digital video of full component TV resolution requires a very high transmission bandwidth. The required degree of compression is achieved by exploiting the spatial and temporal redundancy present in a video signal. As the compression process is inherently lossy, the signal reconstructed from the compressed bit stream is identical to the input video signal. Compression introduces some artifacts into the decoded signal.

MPEG-1 has five parts: Systems, Video, Audio, Conformance Testing and Software Simulation. MPEG-1 Video specifies a coding format (video stream and the corresponding decoding process) for video sequences set bit rate around 1,5 Mbps. The target operational environment was strong media at a continuous transfer rate of about 1,5 Mbps. The coding format is generic and can be used more widely. It support interactively function alive or special access models such as fast forward, fast reserve and random access into the coded bitstream. MPEG-1 video only supports progressive formats, while the number of lines is flexible.

The requirements for a common video representation solution in the area of audiovisual (AV) entertainment, both broadcasting and storage, brought together the coding experts of ITU-T and ISO/IEC (through MPEG), who jointly developed a generic video coding standard targeting medium and high-quality applications, including high definition TV (HDTV). This joint-specification was published as ISO/IEC 13818 Part 2 ("MPEG-2 Video and Audio") and as Recommendation ITU-T H.262 by ITU-T [6]. The different Parts of MPEG-2 are: Systems, Video, Audio, Conformance Testing, Software Solution, Digital Storage Media-Command and Control, Advanced Audio Coding, Real-time Interface, Digital Storage Media–Command and Control Conformance Extension, Intellectual Property Management and Protection. MPEG-2 Video specifies a generic coding format, video stream and the corresponding decoding process for video sequences up to HDTV resolution. MPEG-2 composes a large set of tools. In some applications, some of these tools are too complex for their utility, and MPEG-2 Video defines so-called profiles to be able to provide coding solutions with appropriate complexity. Profiles are tools subsets that address the needs of a specific class of applications. In order to limit the memory and computational requirements of a decoder implementation, a certain number of levels are defined for each profile. Levels provide an upper bound on complexity of the bit stream, and minimum capabilities for the decoder. An MPEG-2 Video decoder is able to decode MPEG-1 Video streams, which is called forward capability. Also, MPEG-2 involves generic codec for nonscalable and generic codec for scalable video coding.

3. MPEG-4 Part 2 and MPEG-4 Part 10 (H.264/AVC) standards

MPEG-4, launched by MPEG in 1993, embodies a significant computational jump in audio-visual content representation - the object – based model. By adopting the object-based model, MPEG-4 starts a new generation of content representation standards where the audio visual scene can be built as a composition of independent objects with their own coding, features and behaviors [7, 8].

MPEG-4 illustrate a simplified object-block based audio-visual coding architecture shaving that reproduce scene is the so-called composition information of a number of audio and visual objects that have been independently coded and thus are independently accessible. This architecture allows a full range of interactions, automatic and user driven, from the simple local composition interaction, where an object is removed or its position changed in the scene to the remote interaction with the sending side asking for an object not to be sent.

The power and advantages of the object-based representation, make MPEG-4 a standard that does not target a specific application domain, but may find application from low bit rate personal mobile communications to high-quality studio production. This broad range of applications associated with a large set of requirements, made the MPEG-4 standard grow to become large and organized in many Parts (totally 21). Today, MPEG-4 addresses the following main requirements: *content based access, universal accessibility and layer compression*. MPEG-4 codes individual visual objects and audio objects in the scene. In addition it delivers a coded description of the scene. At the decoding side, the scene description and individual media objects are decoded, synchronized and composed for presentation.

While the MPEG-4 Visual coding includes coding not only of natural video, but also coding of synthetic visual (graphics, animation) objects. The concept of Video Objects (VO) and their temporal instances, Video Object Planes (VOPs) is central to MPEG-4 video. A temporal instance of a video object can be thought of as a snapshot of arbitrary shaped object that occurs within a picture, such that like a picture it is intended to be an access unit, and, unlike a picture, it is expected to have a semantic meaning. MPEG-4 extends the concept of intra (I) picture, predictive (P) and bidirectionally predictive (B) picture of MPEG 1/2 video to VOPs. Results are I-VOP, P-VOP and B-VOP. In MPEG-4, a VOP can be represented by its shape (boundary), texture (luma and chroma variations), and motion (parameters). The extractions of shape of VOPs per picture of an existing scene by semiautomatic or automatic segmentation result in a binary shape mask. In special mechanisms like blue-screen composition are employed for generation of video scenes, either binary or grey scale (8-bit) shape and can be extracted.

Block scheme of the MPEG-4 video encoder is the high level structure which codes a number of video objects of a scene. The MPEG-4 main components are: *Motion Coder, Texture coder* and *Shape Coder*. The Motion Coder performs motion estimation and compensation for macroblok and block modified to work with arbitrary shapes. The Motion Coder consists of a *Motion Estimator, Motion Compensator, Previous/Next Reconstructed VOPs Store* and *Motion Vector Predictor and Coder*. The Texture Coder uses block DCT (Discrete Cosines Transform) coding which is adapted to work with arbitrary shapes. The entirely new concept component not present in previous standards is the Shape Coding. The coded data of multiple VOPs representing multiple simultaneous video objects is buffered and sent to the System Multiplexer. The Shape coder allows efficient compression of both binary and the gray-scale shapes.

MPEG-4 support *Temporal*, and *Spatial* scalability of video objects. MPEG-4 supports spatial and temporal scalability of both rectangular and arbitrary shaped video objects.

MPEG-4 includes a number of error resilience tools to increase robustness of coder data: *packet approach, insertion of header extension information in bit stream, data partitioning, reversible variable length codes for DCT coefficient coding*.

The AVC standard has achieved a significant improvement in compression capability compared to prior standards, and it provides a network-friendly representation of video that addresses both non-conversational (storage, broadcast, or streaming) and conversational (videotelephony) applications. Extensions of AVC have given it efficient support for additional functionality such as scalability at the bitstream level and 3D stereo/multiview coding [9, 10].

The AVC standard was jointly developed by MPEG (the ISO/IEC Moving Picture Experts Group) and the ITU-T Video Coding Experts Group (VCEG). It is published both as ISO/IEC International Standard 14496-10 (informally known as

MPEG-4 Part 10) and ITU-T Recommendation H.264 [11, 12]. H.264 fulfills significant coding efficiency, simple syntax specifications, and seamless integration of video coding into all current protocols and multiplex architectures.

H.264 video coding standard has the same basic functional elements as previous standards (MPEG-1, MPEG-2, MPEG-4 part 2, H.261, H.263), i.e., transform for reduction of spatial correlation, quantization for bitrate control, motion compensated prediction for reduction of temporal correlation, entropy encoding for reduction of statistical correlation. However, in order to fulfill better coding performance, the important changes in H.264 occur in the details of each functional element. Some functionalities were introduced in H.264/AVC as: intra-prediction in spatial domain, hierarchical transform with (4x4, 8x8) integer DCT transforms and (2 times 2, 4x4) Hadamard transforms, multiple reference pictures in inter-prediction, generalized bidirectional prediction (forward/forward, backward/backward), weighted prediction, deblocking filter, Context – Based Adaptive Variable Length Coding (CAVLC) and Context Adaptive Binary Arithmetic Coding (CABAC) entropy coding, parameter setting, flexibile macroblock ordering, redundant slices, and SP (Switched P)/SI (Switched I) slices for error resilience.

To address the need for flexibility and customizability, the AVC design covers a *video coding layer* (VCL), which is designed to efficiently represent the video content, and a *network abstraction layer* (NAL), which formats the VCL representation of the video and provides header information in a way that enables the coded video to be conveyed by a variety of transport layers or storage media (Figure 1) [10, 13].

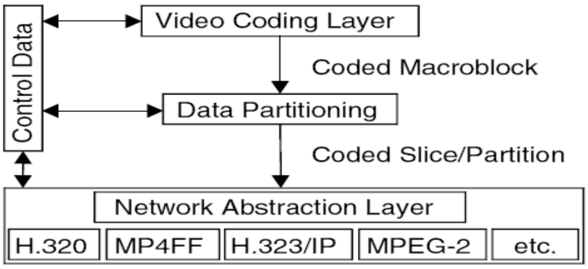

Figure 1. *AVC layer structure* [10].

Technically, the design of the H.264/MPEG4-AVC video coding layer is based on the traditional hybrid concept of block-based motion-compensated prediction (MCP) and transform coding. The encoder runs the same prediction loop as the decoder to generate the same prediction signal and subtracts it from the original picture to generate the residual. The most difficult task of the encoder is to determine its choices for prediction (such as motion vectors, block sizes, and inter/intra prediction modes) and residual difference coding, for which the encoder tries to use as few bits as possible after entropy coding to obtain adequate decoded quality [10].

The improvement in coding performance comes mainly from the prediction part. Intra prediction significantly improves the coding performance of H.264/AVC intra frame coder [14]. On the other side, inter prediction is enhanced by motion estimation with quarter-pixel accuracy, variable block sizes, multiple reference frames and improved spatial/temporal direct mode.

H.264/AVC defines a set of Profiles, each supporting a particular set of coding functions and each specifying what is required of an encoder or decoder that complies with the Profile. Also, profiles are defined to cover the various applications from the wireless networks to digital cinema.

In 2004 Joint Video Team (JVT) added new extensions known as the Fidelity Range Extensions (FRExt), which provide a number of enhanced capabilities relative to the base specification. Also, the Scalable H.264/AVC extension is applied to extend the hybrid video coding approach of H.264/AVC in a way that a wide range of spatial-temporal and quality scalability is achieved. The SVC approach of AVC is based on the "layered coding" principle, which encodes differential information between layers of different quality or resolution [10]. The next major feature added to the standard was Multiview Video Coding (MVC). In its basic design concepts, MVC is an extension of the inter-view prediction principle similar as implemented in the MPEG-2 multiview profile (assuming two or multiple cameras shooting the same scene). Compared to MPEG-2, MVC benefits from the more flexible multiple reference picture management capabilities in AVC [10]. Important applications of AVC are: *mobile telephony, mobile TV, mobile video players, TV broadcast, camcorders, Blu-ray disc, videotelephony/ videoconferencing, Internet video* [15].

4. High Efficient Video Coding and 3D Video

Since H.264/MPEG-4 Advanced Video Coding (AVC) standard was finalized in 2003, many people have tried to design a video coding algorithm more efficient than AVC. In February 2010, 27 proposals were submitted to the ITU/ISO joint committee competing for the next generation video standard. The proposal evaluation results in the April standard meeting indicated that a better coding scheme is possible and thus the High Efficiency Video Coding (HEVC) work item was launched [16]. The current plan foresees the final approval of the standard by January 2013.

High-efficiency video coding (HEVC) is the emerging video coding standard developed by the efforts of Joint Collaborative Team on Video Coding (JCTVC) that operates under the MPEG and ITU-T parent bodies [10]. HEVC is targeted at increased compression efficiency compared to AVC, with a focus on video sequences with resolutions of HDTV and beyond. In addition to broadcasting applications, HEVC will also cater towards the mobile market [17]. The goal of the HEVC project is 50% bit rate reduction with the same visual quality, when compared with state-of-the-art H.264/AVC. Additionally, the project seeks to provide a low complexity operating point with coding performance similar to H.264/AVC, but significantly with less complexity [18]. The goal of a 50% gain in coding efficiency will be made possible due to modern video cameras that have different statistical properties compared to cameras produced in last millennium. The requirements that the new standard will fulfill are various [17]:

- Compression performance: HEVC will enable a substantially greater bitrate reduction over AVC High Profile. Therefore, HEVC will have to outperform AVC by 50%, i.e. the same quality will be delivered using half the bitrate.

- Picture formats: HEVC will support rectangular progressively scanned picture formats of arbitrary size ranging at least from QVGA to 8000 × 4000 pel. In terms of color, popular color spaces like YCbCr and RGB as well as a wide color gamut will be supported. The bit depth will be limited to 14 bits/component.
- The support for interlaced material is not foreseen. While interlace was important in the past, modern screens always convert interlaced material into progressive picture formats. The artifacts of this conversion as well as the compute power can be avoided when using progressively scanned material.
- Complexity: There are no measurable requirements on complexity. Obviously, the standard has to be implementable at an attractive cost in order to be successful in the market.
- Video bit stream segmentation and packetization methods for the target networks will be developed allowing for efficient use of relevant error resilience measures for networks requiring error recovery, e.g. networks subject to burst errors.

In Table 1 major potential tools for HEVC in comparison to previous MPEG standards are listed.

Table 1: *Comparisons of tools features between HEVC and previous MPEG standards*

Features	MPEG-1	MPEG-2	MPEG-4 part 2	MPEG-4 part 10 (H.264/AVC)	HEVC
Block size	8x8	8x8	16x16, 16x8, 8x8	from 4x4 up to 16x16	from 8x8 up to 64x64
Transform	8x8 DCT	8x8 DCT	8x8 DCT/Wavelet transform	8x8, 4x4 integer DCT, 4x4, 2x2 Hadamard	MDDT, Rotational transform (up to 32x32 block size)
Intra prediction	No	No	Transform domain	Spatial domen (up to 9 modes)	up to 33 modes
MV precision	1/2-pel	1/2-pel	1/4-pel	1/4 -pel	1/2-, 1/4-, 1/8-, 1/12-pel adaptive
Weighted prediction	No	No	No	Signaled at slice level	Signaled at partition level
Entropy coding	VCL	VCL	VCL	VLC, CABAC, CAVLC	Modified CABAC, CAVLC, V2V
Deblocking filter	No	No	No	8x8 based parallel filter	Adaptive filter

MPEG envisions HEVC to be potentially used in the following applications: *home and public cinema, surveillance, broadcast, real-time communications including video chat and video conferencing, mobile streaming, personal and professional storage, video on demand, Internet streaming and progressive download, 3D video, content production and distribution* as well as *medical imaging*.

A new 3D Video (3DV) initiative is underway in MPEG. 3DV supports new types of audio-visual systems that allow users to view videos of the real 3D space from different user viewpoints [17]. In an advanced application of 3DV, denoted as Free-viewpoint Television (FTV), a user can set the viewpoint to an almost arbitrary location and direction, which can be static, change abruptly, or vary continuously, within the limits that are given by the available camera setup. Similarly, the audio listening point is changed accordingly. 3DV is a standard that targets serving a variety of 3D displays. A new 3DV format goes beyond the capabilities of existing standards to enable both advanced stereoscopic display processing and improved support for auto-stereoscopic multiview displays. Here, stereo and multiview are words related to the number of captured and displayed views. Stereo means two views and multiview means two or more views. On the other side, free-viewpoint is a word related to the position of displayed views. Free-viewpoint means the position of displayed views can be changed arbitrarily by users. This is the feature of FTV. View synthesis is needed to realize the free-viewpoint. The captured views are stereo and the displayed views are multiview. View synthesis is used to generate multiple views at the receiver side, since the number of required views to be displayed is more than the transmitted captured views.

The 3DV reference model with items considered for standardization is shown in Figure 2. The input is M views captured by cameras, and the output is N views to be displayed. N can be different from M. At the sender side, a 3D scene is captured by M multiple cameras. The captured views contain the misalignment and luminance differences of the cameras. They are corrected, and depth for each view is estimated from the corrected views. The 3DV encoder compresses both the corrected multiview and depth, for transmission and storage. At the receiver side, the 3DV decoder reconstructs the multiview and depth. Then, N views are synthesized from the reconstructed M views with the help of the depth information, and displayed on an N-view 3D display.

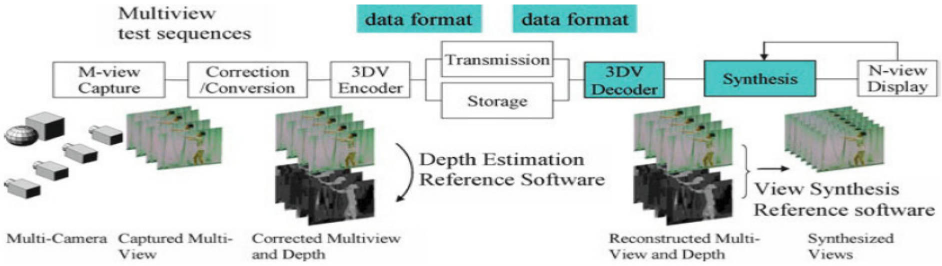

Figure 2. *3DV reference model* [17].

Multiview test sequences, depth estimation reference software, and view synthesis reference software are developed in the 3DV standardization activity.

5. Conclusion

An overview of the MPEG standards including requirements technology and applications is provided. MPEG has set a number of highly successful standards. Their technical quality is a result of well-defined standardization process, which also served to bring together many companies and institutions around the globe. After the coding standard of MPEG-1, MPEG-2, MPEG-4, the working group has been developing standards of broader scope, aiming to further facilitate the seamless trade, involving the exchange and use of digital content across different service, devices networks and business models. The challenge is formidable and complex.

The H.264/AVC encoder has the significant computational complexity, because it selects the best coding mode by employing the rate-distortion optimization (RDO) to take full advantage of the mode selection terms of maximizing coding quality and minimizing data bits. AVC is the dominant video coding design and it is used in essentially all applications that use video. The core design of the standard has given it strong compression capability relate to prior designs together with the flexibility and robustness to enable its use in an extremely broad variety of network and application environments.

There exists technology that can deliver significantly better compression performance than AVC. The new standardization initiative proposed jointly by ITU-T and ISO/IEC is known ad High Efficient Video Coding (HEVC). The vision of the new HEVC standard is expected to be completed soon, depending on the progress of the further work and the eventual final scope of selected target applications. With upcoming standard, HEVC and 3DV, MPEG and Joint Collaborative Team on Video Coding (JCT-VC) will provide the codec's to deliver highest quality video content in 2D and 3D. Due to the limitation of bandwidth and stereo TV, markets for the new standards will develop quickly.

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Sadržaj: *Standardi predstavljaju tehničke dokumente koji precizno definišu sveobuhvatne zahteve korisnika, kako bi se postigla interoperabilnost. U ovom radu predstavljen je najnoviji razvoju u oblasti standardizacije video kodovanja, posebno u domenu multimedijanih tehnologija za video kodovanje. Inicijativa je potekla i razvija se zajedničkim naporima ITU-T VCEG i ISO/IEC MPEG, a odnosi se na High Efficiency Video Coding (HEVC). Prvo, u radu je dat kartak prikaz svih standarda za video kodovanje koji se koriste kao podrška za multimedijalne aplikacije. Sledeće, u radu je predstavljeno da HEVC standard ima intenciju da obezbedi značajne mogućnosti za kompresiju u poređenju sa postojećim AVC (ITU-T H.264/ISO/IEC MPEG-4 Part10) standardom. Opisani su prvi koraci u procesu definisanja HEVC, kao i napredak u aktivnostima radi njegove konačne standardizacije. Na kraju su naglašene još neki trendovi u istraživanju u ovoj oblasti.*

Ključne reči: *ITU-T VCEG, ISO/IEC MPEG, proces standardizacije, multimedijalno video kodovanje, visoko efikasno video kodovanje.*

NAJNOVIJI RAZVOJ U PROCESU STANDARDIZACIJE MULTIMEDIJALNIH TEHNOLOGIJA ZA VIDEO KODOVANJE

Zoran Milićević, Zoran Bojković