H.264

The Advanced Video Coding Standard

New opportunities for video communication

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Application Highlights

The increased compression efficiency of the updated ITU-T H.264/MPEG-4 Advanced Video Coding (AVC) standard has led to new application areas and business opportunities. Broadcasting over cable, satellite, cable modem, terrestrial, etc., is benefiting from the new standard. It is now possible to transmit video signals at about 1 Mbit/s with TV (PAL) quality, which enables streaming over xDSL connections. Another interesting business area is TV transmission over satellite. By choosing H.264, the number of programmes per satellite can be doubled in comparison to current systems using H.262 (MPEG-2). Also, in the field of mobile communication, H.264 plays an important role because the compression efficiency can be doubled in comparison to the coding schemes previously specified by Third-Generation Mobile (3GPP and 3GPP2) for streaming.

The Recommendation has influenced further application areas including but not limited to the following:

- Interactive or serial storage multimedia (ISM or SSM) on optical and magnetic devices, DVD, etc.
- Real-time conversational services (RTC), such as videoconferencing and videophone, over ISDN, Ethernet, LAN, DSL, wireless and mobile networks, modems or mixtures of these.
- Video-on-demand or multimedia streaming services, such as remote video surveillance (RVS), over ISDN, cable modem, DSL, LAN, wireless networks, etc.
- Multimedia Messaging Services (MMS) over ISDN, DSL, Ethernet, LAN, wireless and mobile networks, etc.
- Multimedia services over packet networks (MSPN), such as multimedia mailing (MMM), etc.

Video Coding and Still-Image Coding

Signal compression consists of reducing redundancy (by spatial/temporal prediction; by spatial/temporal decorrelating transformation; and by entropy coding) and reducing irrelevancy (by quantization) from the input signal. Video compression algorithms such as H.264 exploit two types of redundancy in the signal: temporal (changes from one frame to the next) and spatial (how the pixels change within the same frame). Still-image coding algorithms such as ITU-T Rec. T.81 (JPEG) and ITU-T Rec. T.800 (JPEG 2000) only exploit the spatial redundancy. Hence, the "motion JPEG" movies used in some digital photo cameras and video editing systems are a sub-optimal encoding scheme in terms of compression efficiency because they do not exploit the temporal redundancy.

H.264: A Flexible Toolkit

H.264 Advanced Video Coding (AVC) is the latest ITU-T Recommendation designed to enable the use of coded video in a flexible manner for a wide variety of network environments. It was developed together with ISO/IEC (where it is standardized as MPEG-4 part 10 AVC) in response to the growing need for higher compression of video for various applications including television broadcasting, videoconferencing, digital storage media, Internet streaming, wireless communication, etc.

H.264 contains a rich set of video coding tools, but not all of them are required for every application, so subsets of coding tools (called profiles) are defined. A decoder may choose to implement any number of profiles, depending on the needs of the application. The following three profiles were defined in the original H.264 specification that was completed in May of 2003:

- The Baseline and constrained Baseline Profiles (BP and CP)
- The Extended Profile (XP)
- The Main Profile (MP)

For applications such as high-resolution entertainment-quality video, content-contribution, content-distribution, studio editing and post-processing, it was necessary to develop some extensions of the tool set. This effort took about one year and these extensions are named the "fidelity range extensions" (FRExt). This project produced a suite of four new profiles:

- The High Profile (HP)
- The High 10 Profile (Hi10P)
- The High 4:2:2 Profile (H422P)
- The High 4:4:4 Profile (H444P)

Industry has been quick to embrace the new capabilities, and particularly the High Profile. The High Profile appears certain to be incorporated into several important near-term application specifications, including the BD-ROM Video specification of the Blu-ray Disc Association, the HD-DVD specification of the DVD Forum and the DVB (digital video broadcast) standards for European broadcast television. Several other environments such as major direct-broadcast satellite service providers may soon embrace it as well. Indeed, it appears that the High Profile may rapidly overtake the Main Profile in terms of dominant near-term industry implementation interest. This is because the High Profile adds more compression efficiency without adding a significant amount of implementation complexity beyond what is needed for the Main Profile.

tsbpromo@itu.int

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ITU-T Video Coding Standards and the H.264 / MPEG-4 AVC Project

Digital video coding for various applications has evolved over the last decade and a half, as demonstrated by the development of the ITU-T H.261, H.262 and H.263 standards. H.261, standardized in 1990, was the first successful such standard, enabling interoperable videoconferencing over dial-up digital telecommunication networks. H.262 (a standard jointly developed with ISO/IEC and more commonly known as MPEG-2 Video), developed a few years later, was the enabling technology for digital television systems worldwide. It allowed digital transmission of TV video over satellite, cable, and terrestrial platforms. And H.263 provided enhanced compression and robustness for various applications including Internet and wireless video. However, more continued to be learned to further improve video technology and to diversify the range of digital video applications.

In early 1998, the ITU-T Video Coding Experts Group (VCEG) issued a call for proposals on a project it called H.26L, with the target of doubling the coding efficiency (which means halving the bit rate necessary for a given level of video quality) in comparison to any existing video coding standard. Then, in December of 2001, VCEG and the Moving Picture Experts Group (MPEG) of ISO/IEC formed a Joint Video Team (JVT), with the charter to finalize the draft new Advanced Video Coding (AVC) standard which would become ITU-T Recommendation H.264. MPEG approved identical technical content in its corresponding standard called MPEG-4 part 10 (ISO/IEC 14496-10).

H.264/MPEG-4 AVC represents a major step forward in the development of video coding standards. It typically outperforms prior standards by roughly a factor of two or more, particularly in comparison to H.262/MPEG-2. This improvement enables new applications and business opportunities to be developed. Additional computational resources are needed for implementing H.264, but have been supplied by the phenomenon known as Moore's Law. Furthermore, H.264 is a collaboratively designed open standard allowing all manufacturers to produce encoders and decoders based on it. This will help to create a competitive market, keeping prices down and ensuring that products made by a wide variety of different manufacturers will be fully compatible with each other.

Building on the success of H.264, ITU-T SG 16 and MPEG agreed to start working on the next generation video coding under the Joint Collaborative Team on Video Coding (JCT-VC). First results are expected for 2012.

Performance of H.264 and Comparison with Prior Coding Standards

To illustrate performance gains that can be achieved when using the H.264 standard, the results of a comparison with some successful prior coding standards are reported below. The four codecs compared produce bit streams conforming to the following standards:

- H.262, Main Profile (MP)
- H.263, High Latency Profile (HLP)
- H.264, Main Profile (MP)

The input video for this comparison consists of a set of well-known lower-rate Quarter Common Intermediate Format (QCIF) (10 Hz and 15 Hz) and higher-rate Common Intermediate Format (CIF) (15 Hz and 30 Hz) sequences with different amounts of motion and spatial detail.

All video encoders were optimized with regards to their rate-distortion efficiency using Lagrangian techniques. These techniques have gained importance due to their effectiveness, conceptual simplicity, and ability to evaluate a large number of possible coding choices in an optimized fashion. In addition to performance gains, the use of a specific and efficient coder control for all video encoders allowed a fair comparison between them in terms of coding efficiency.
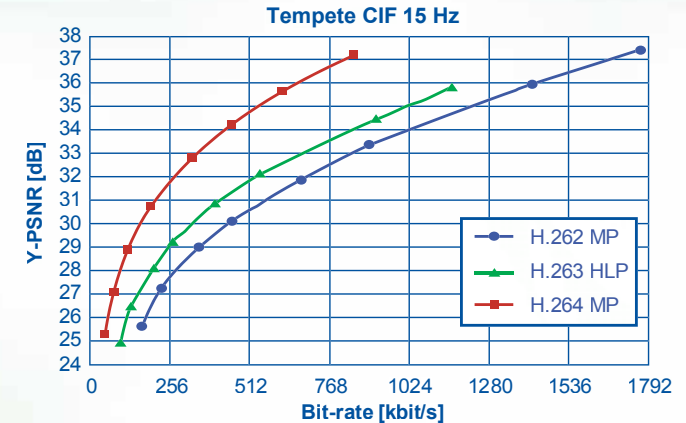
	Average rate savings relative to:	
Codec	H.263 HLP	H.262 MP
H.264 MP	49 %	64 %
H.263 HLP	–	31 %

The above table presents the average bit-rate savings provided by each encoder relative to the other tested encoders, averaged over this set of test sequences and bit rates. It can be seen that H.264 significantly outperforms all other ITU-T video coding standards.

(Quality study reference: T. Wiegand *et al.*, "Rate-Constrained Coder Control and Comparison of Video Coding Standards", in *IEEE Trans CSVT Special Issue on H.264/AVC Video Coding Standard*, July 2003.)

Rate-Distortion Performance Curves

In the following chart, Peak Signal-to-Noise Ratio (PSNR) vs. bit-rate curves for the four codecs is shown for the test sequence "Tempete". For this sequence (chosen as an example) and for all other sequences from the test set, H.264 significantly outperforms the other codecs.

Tempete CIF 15 Hz

On the following chart, the bit-rate savings relative to the H.262 (MPEG-2) video coding standard are plotted against the PSNR objective quality of the luminance* component for H.263 HLP and H.264 MP. H.264 MP significantly outperforms the other standards.

Tempete CIF 15 Hz
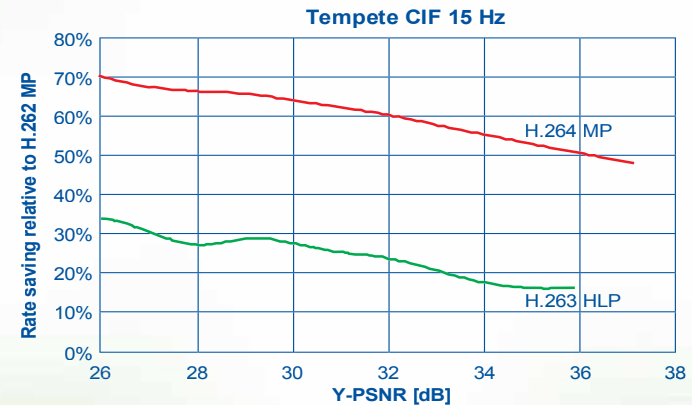
The luminance component of the video signal represents the gray-shade brightness component of the image, and is the most perceptually important part of a colour image.

For more information: **www.itu.int/ITU-T/studygroups/com16**