HEVC: Future Video Encoding Landscape

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ABSTRACT

This paper looks at the HEVC video coding standard: possible applications, video compression performance improvement, history, and technologies.

INTRODUCTION

HEVC is the most interesting and cutting-edge topic in the world of video compression right now. Around 20 years ago, digital video compression was something of a novelty and today it is ubiquitous. From TVs to cell phones, camcorders to PCs, most consumer electronic devices rely on video compression. It is because of advances in video compression technology that we are able to view hundreds of broadcast video channels over cable and satellite networks, and millions of hours of video over the Internet. And while most of us just assume that these improvements are a result of general-purpose improvements in consumer technology, these massive changes have really been driven by a technology called video compression, and HEVC is at the cutting edge of compression today.

In this paper we will examine what HEVC is and review the status of development of the standard. We will take a look at how past and current compression standards are extended by HEVC and will see which applications in particular may benefit from HEVC.

WHAT IS HEVC?

HEVC stands for High Efficiency Video Coding. It is currently a draft video compression standard that is intended to be a successor to the current state of the art: H.264/MPEG-4 AVC (Advanced Video Coding). It is under joint development by the ISO/IEC Moving Pictures Experts Group (MPEG) and ITU-T Video Coding Experts Group (VCEG). MPEG and VCEG have established a Joint Collaborative Team on Video Coding (JCT-VC) to develop the HEVC standard. HEVC is poised as a new generation video coding standard that promises to reduce the data rate needed for high quality video coding by 50% compared to the current state-of-the-art.

An uncompressed HD video signal consumes about 2 Gigabits per second of bandwidth. Back in the 80s, we were hoping to be able to compress this down to 130 megabits per second. These days, we routinely encode HD at 5 Mbps or even below, and HEVC is being designed to help us push that envelope even further.

While the primary goal for the standard is to improve video encoding by 50 percent or more, HEVC also includes a number of other significant improvements, including manageable complexity while making provisions for the development of affordable encoders and decoders. And while the standard is not yet ratified today, these goals should be achievable by the time the standard is finalized. As interest has grown in HEVC and more companies, groups and countries are becoming involved, a few more goals are being added, including support for interlaced video. While there is a definite trend away from interlaced video — after all, it is annoying to look at, hard to display on many devices, and most of the new consumer devices either do not support interlaced video or support it badly — we still have to be able to compress, store and transmit decades of legacy content efficiently.

Another more recent goal of HEVC is to support multi-view video coding or stereo 3D video as efficiently as possible, together with support of scalable video coding. The idea here is to enable the representation of a video stream, a sequence, or an image in multiple ways or multiple formats so that it can look good on an HDTV or a cell phone, with different resolutions and different frame or bitrates, all while retaining a high level of coding efficiency.

What is the status of the HEVC standard? Over the last few years, many groups have submitted technologies, software ideas and papers. The JCT has recently gone through a series of working drafts, culminating in a more formal Committee Draft. At this point the technology is nearly frozen, and the JCT is focused on making a high-quality, unambiguous specification with good software reference models that companies can easily build to. Over the rest of this year, there will be a lot of editing, cleanup, and closing of the last technical questions to produce a draft international standard with the goal of creating a final version in early 2013. After the final draft is reviewed or sent out for a vote, and when everyone comes back and votes ‘yes’, then this will become an official published International Standard.
THE EVOLUTIONARY PATH TO HEVC: BUILDING ON STANDARDS HISTORY

HEVC is the latest in a long line of low bitrate digital video standards. In this section, we briefly review past standards and see which key elements of technology they have brought to HEVC.

Going back to the 1980s, H.261 was one of the earliest video compression standards. It was targeted at video conferencing for ISDN networks, allowing point-to-point or multipoint video calls in multiples of 64 kbps, with sub-SD video quality. H.261 brought in motion compensation, which was a big leap forward as earlier standards were primarily designed for still frames or for very simple predictive coding. Put simply, motion compensation exploits the fact that often, in a video clip, the only difference between one frame and another is the result of either the camera moving or an object in the frame moving. This means that much of the information in one frame will be the same as the information used in the previous frame, possibly with spatial translation. Using motion compensation, almost the only information necessary to code each frame is the information needed to translate the previous frame into the next frame. So compression is just the use of mathematical techniques to find these redundancies and then represent the changes particularly efficiently so we can transmit high-quality video, using a lot fewer bits than we need for uncompressed video transmission. HEVC takes motion compensation to the next level by extending sets of tools such as multi-reference-frame motion compensation, multiple block size prediction, and high-accuracy motion compensation interpolation.

In the late 80s and early 90s, MPEG-1 targeted video on the PC, and offered a little bit less than SD quality. MPEG-1 introduced two fundamental new technologies: bi-directional motion compensation and half-pixel motion estimation. Bi-directional motion compensation is an extension to the basic motion compensation premise, using future pictures as well as past pictures.

MPEG-2, used in the broadcast and entertainment TV world, was a huge success, and enabled this industry to deliver hundreds of high quality channels over cable/satellite broadcast networks. It offered full SD quality at 4 Mbit, but the industry quickly realized that MPEG-2 could also enable HD. By using MPEG-2 compression, it became affordable to transmit HD to the home. MPEG-2, in addition to having tools for interface, really started to add a lot more adaptive coding: multiple patterns to scan transform coefficients, linear or nonlinear quantization, and changeable coefficient weighting matrices.

H.263 featured a number of cutting-edge technologies beyond what MPEG-2 already had. It was very successful in the video conferencing world and enabled applications with bitrates lower than 64 kbps, with much better quality than was possible with H.261. H.263 also introduced much more sophisticated motion vector prediction, and had the first in-loop de-blocking filter – a filter applied in the motion compensation prediction loop, to improve visual quality and prediction performance by minimizing the visual impact of block-boundary artifacts generated by compression.

MPEG-4 Part 2 introduced interesting technologies such as synthetic graphics combined with video, object coding, and non-rectangular image coding, which found applications on the PC but not widespread success beyond that. MPEG-4 did however add refinement to motion estimation with quarter pixel precision.

The H.264/AVC standard, which again was developed jointly by the ITU and MPEG, enabled a 50 percent bit reduction relative to MPEG-2. This enabled broadcast SD at very low bitrates and even broadcast HD at shockingly low bitrates for the time. H.264/AVC added quite a lot of new tools, including sophisticated intra prediction (whereby a prediction block is formed based on previously encoded and reconstructed blocks within the same frame), a better de-blocking filter, new transforms, improved motion compensation interpolation, multiple motion estimation references, weighted prediction, and Context-Adaptive Arithmetic Coding (CABAC).

What is fascinating when we review the history of digital video standards is that during all these years, as the world has gone from a very simple digital video compression standard to something very sophisticated, all the standards still fundamentally use the same core technology: they still use block-based spatial transforms, block-based motion compensation, predictive coding of pixels, prediction to code motion vectors efficiently, and quantization and some form of entropy coding. Across all those standards, and now with HEVC, we retain the same basic structure.
HOW DOES HEVC IMPROVE ON PREVIOUS STANDARDS?

This section reviews in more detail how HEVC builds upon what has been done before. In spite of a lot of interest over the years in technologies such as fractals, matching pursuits, 3D transforms, etc., we have basically retained the same coding building blocks all the way through. HEVC utilizes all of the technologies we have talked about in existing standards, and improves or extends them.

Compared to previous standards and in particular H.264/AVC, HEVC achieves improved coding efficiency by introducing additional tools to exploit spatial and temporal correlations. Specifically, HEVC incorporates improved motion compensated filtering, multiple coding block sizes, and expanded loop filters including de-blocking and sample adaptive offset.

Some of the key improvements in HEVC are due to the use of larger block sizes, which makes it particularly well suited for 4K by 2K “Ultra HD.” If we are coding large images, the larger block sizes enable more efficient coding, especially for regions with few changes in the picture content.

In HEVC, improved intra-frame prediction enables better prediction of pixels by exploiting redundancy within the current frame. The proposed tools offer more prediction directions than AVC, and a more sophisticated way of predicting and coding the intra mode selected.

The advances in HEVC require higher computational complexity in the decoder (which is estimated to be 2 to 3 times more complex than H.264). This makes sense, however. HEVC is being designed to perform well for years into the future, as improvements in semiconductor technology enable more sophisticated encoders.

APPLICATIONS FOR HEVC

The potential for HEVC spans a wide gamut of applications, including home and digital cinema, surveillance, broadcast, videoconferencing, mobile streaming, video storage and playback and VoD.

We believe HEVC will make a significant impact with next-generation HDTV displays and content capture systems which feature progressive scanned video and display resolutions up to Ultra HDTV (3840×2160). HEVC will enable efficient high-quality delivery of Ultra HD video using today’s networks.

Another application for HEVC with significant potential is fixed point contribution, i.e. news gathering, live events, sports, concerts, etc., where bandwidth is typically restricted. While these applications do well today with MPEG-2, JPEG2000, and H.264/AVC, they are likely to take off with HEVC. If we replace today’s MPEG-2 or AVC equipment with HEVC equipment, we will be able to drop the bitrate, allowing content carriers to broadcast these types of events at higher quality on more channels, and save costs.

Possibly the biggest future application for HEVC is over-the-top video delivery. HEVC will enable OTT delivery of true HD, over today’s constrained networks. While there is a lot of over-the-top Internet delivery of video today, most available services are near HD and not full 1080p resolution, and the quality is not quite good enough for large displays. The service is still hugely popular and operators, content owners and consumer electronic manufacturers are scrambling to find ways to carry more content. This is a source of worry for Internet providers, who see that video is becoming as much as 95 percent of their traffic. Coupled with HEVC encoding of video for mobile devices, HEVC will enable true ‘multiscreen homes’ with lower costs and more video devices.

The arrival of HEVC will help bring compression technology to a level that is able to meet the demands of upcoming mobile and 4K television services (running at bitrates comparable to today’s HDTV data rates). It will enable future business services that are currently impeded by today’s video compression technology.
CONCLUSION

HEVC promises increased efficiency plus adaptation to all present and future video applications currently envisioned, from mobile phones to Ultra HDTV. The new standard will have the same revolutionary impact as former video compression standards that helped bring video to all aspects of our daily lives.

ABOUT THE AUTHOR

Paul Haskell is Vice President, R&D at Harmonic Inc., where he has worked for 14 years. He and his group research technologies and develop products in the areas of video compression, transcoding, preprocessing and analysis. Paul’s team is active in several standards activities, including MPEG, DVB, and the JCT-VC. Paul received his B.S. and Ph.D. degrees from the University of California, Berkeley in Electrical Engineering and Computer Science. He holds more than 10 granted and filed patents.