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Algorithm and Architecture Design of High Efficiency Video Coding (HEVC) Standard

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Abstract- This paper deals with the latest H.265/HEVC video coding standard. The main goal of the HEVC standardization effort is to facilitate significantly improved compression performance relative to existing standard H.264/AVC. HEVC offer 50% bit-rate reduction for equal video quality compared to H.264/AVC. The objective of this paper is to provide the technical features and characteristics of the HEVC standard, particularly focusing on the key features of hybrid coding tools and also provide theoretical analysis, summaries of the technological advancements, and compares its performance with the H.264/ MPEG-4 AVC standard.

Keywords- Advanced Video Coding (AVC), H.264, High Efficiency Video Coding, HEVC, video quality.

I. INTRODUCTION

HEVC (High Efficiency Video Coding) is a recently video coding standard of the ITU-T VCEG and the ISO/IEC Moving Picture Experts Group. It is the most efficient codec for UHD video. In comparison to AVC, HEVC offers about twice the data compression ratio at the same level of video quality, or largely improved video quality at the same bit-rate. HEVC was designed to target many applications such as mobile TV, home cinema, and especially ultrahigh definition television. HEVC supports next-generation of display technologies offering higher resolutions, frame rates, and progressed picture quality in terms of noise level, color gamut, and dynamic range.

However HEVC contains many additional improvements such as:

• Flexible partitioning, from large to small partition sizes.

• Improved variable block size segmentation.

• Increased “intra” prediction and motion region merging.

• Improved compensation filtering and new filtering step called Sample-adaptive offset filtering.

• Features to support efficient parallel processing.

With H.265/HEVC, it is possible to store or transmit video more comfortably than with earlier technologies. This means: At the equivalent picture size and quality, an HEVC video sequence should utilize less storage or transmission capacity than the H.264 video sequence. At the same storage or transmission bandwidth, the quality and resolution of an HEVC video sequence should be greater than the corresponding AVC video sequence. H.265 has many big advantages over H.264, including better compression, delicate image and bandwidth saving. The technical content of HEVC was settled on January 25, 2013, while the specification was approved as a standard on April 13, 2013. Last year, Apple applied next-generation H.265 technology to its new iPhone6 and large iPhone6 Plus for FaceTime over cellular. Some of the key differences between H.264/AVC and H.265/HEVC are listed below in table1:

Table 1. H.264 vs H.265

Category	**H.264/AVC**	**H.265/HEVC**
Name	MPEG 4 Part 10 AVC (Introduced in 2004)	MPEG-H, HEVC, Part 2 (Approved in Jan 2013)
Application Area	-Blue-ray discs -On-line video streaming -Broadcast of HDTV signals over satellite	-Professional H.265 Encoder/Decoder -Next generation HDTV, Satellite TV
Specification	-Support upto 4K (4,096x2,304) -Support upto 59.94 fps	-Support upto 8K UHDTV (8192x4320) -Support upto 300 fps
Bitrate	-40-50% bitrate reduction compared to MPEG-2	-40-50% bitrate reduction compared to AVC
Progression	Successor to MPEG-2	Successor to AVC
Block Structure	Macro Blocks structure with maximum size of 16x16	CTU Supporting large Block structure of 64x64
Intra prediction directional modes	9 directional modes for intra prediction	35 directional modes for intra prediction

This paper highlight the latest developments and analysis of HEVC related technologies and coding tools. Paper is organized as follows. Section II highlights some key features of the HEVC coding design. The HEVC coding technology is described in Section III. Since writing an overview of a technology HEVC involves a significant amount of summarization, the reader is referred to [1] for any details. The history of the HEVC standardization effort is discussed in Section IV.

II. HEVC CODING DESIGN AND FEATURE HIGHLITS

The HEVC standard is designed to achieve multiple goals, including coding efficiency, ease of transport system integration and data loss resilience, as well as implementability using parallel processing architectures. The following subsections briefly describe the key elements of the design by which these goals are achieved.

Video Coding Layer

The video coding layer of H.265/HEVC employs the same hybrid approach used in all video compression standards since H.261. Fig. 1 depicts the block diagram of a hybrid video encoder, which could create a bitstream conforming to the HEVC standard.

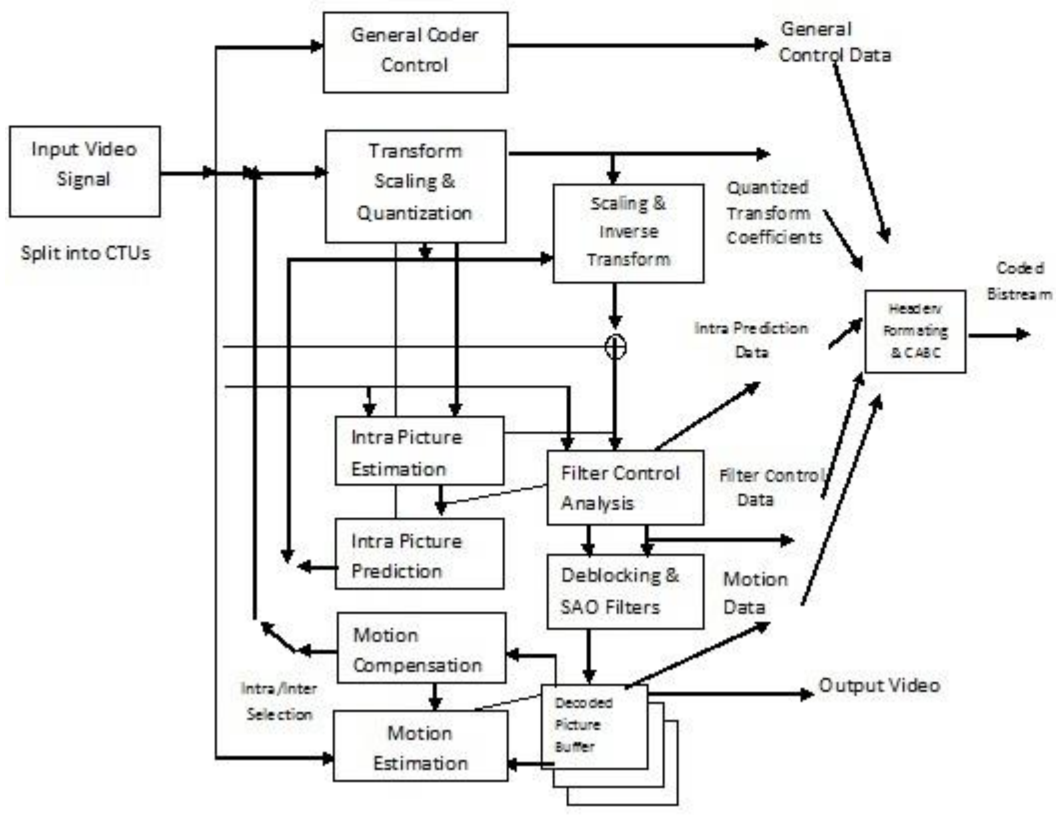

Figure 1. HEVC Video Encoder

An algorithm producing an HEVC compliant bitstream would proceed as follows. Each and every picture is split into regions of block-shaped, with the exact block partitioning being conveyed to the decoder. The first picture is coded using only intrapicture prediction of a video sequence. For all remaining pictures of a sequence or between random access points, interpicture predictive coding modes are used for most blocks. The encoding process for interpicture prediction consists of electing motion data comprising the selected reference picture and motion vector (MV) to be applied to the samples of each block. The encoder and decoder generate identical interpicture prediction signals by applying motion compensation using the motion vector and mode decision data, which are transmitted as side information. The residual signal of the intrapicture/interpicture prediction, which is the difference between its prediction and the original block, is transformed by a linear spatial transform. The transform coefficients with the prediction information are then scaled, entropy coded, quantized and transmitted.

The encoder duplicates the decoder processing loop so that both will develop identical predictions for subsequent data. Therefore, the quantized transform coefficients are created by inverse scaling and are then inverse transformed to duplex the decoded approximation of the residual signal. The residual is then combined to the prediction, and the result of that addition may then be fed into 1 or 2 loop filters to stable out artifacts induced by quantization and block-wise processing. For the prediction of subsequent pictures a decoded picture buffer stored the final picture representation. In general, the order of encoding/decoding processing of pictures differs from the order in which they arrive from the source; constraining a distinction between the output order and the decoding order for a decoder.

The video coding layer of H.265/HEVC employs the same hybrid approach used in all video compression standards since H.261. The various features involved in hybrid video coding using HEVC are highlighted as follows:

- Coding Tree Unit: HEVC is not using fixed macro block size as earlier standards any more. Instead of macro block, the term Coding Tree Unit (CTU or CU) is used. Coding Tree Unit consists of luma Coding Tree Block (CTB), chroma CTBs and syntax. For luma component, the size of CTB can be 16x16, 32x32 or even 64x64. These CTBs further divided into smaller blocks called Coding Blocks. These blocks do not have same size with in the CTB and the encoder determined their size and position according to the image content.

- Entropy Coding: Context Adaptive Binary Arithmetic Coding (CABAC) is used for entropy coding. This is similar to the CABAC scheme in AVC. CABAC is the only entropy encoder method that is allowed in HEVC. While there are two entropy encoder methods allowed by AVC. CABAC and the entropy coding of transform coefficients in HEVC were designed for a higher throughput then AVC, while maintain higher compression efficiency for larger transform block size relative to simple extensions.

- Intra Prediction: HEVC specifies 33 directional modes for intra prediction compared to the 8 directional mode for intra prediction specified by H.264/AVC. HEVC also specifies DC intra prediction and planar prediction modes. The intra prediction modes use data from neighboring prediction blocks that have been previously decoded from within the same picture.

- Motion Vector Prediction: HEVC allows for two MV modes which are Advanced Motion Vector Prediction (AMVP) and merge mode. AMVP uses data from the reference picture and can also use data from adjacent prediction blocks. The merge mode allows for the MVs to be inherited from neighboring prediction blocks.

- Deblocking filter: it is similar to the one used by AVC but with a simpler design and better support for parallel processing. In HEVC the DBF only applies to an 8x8 sample grid while the AVC the DBF applies to a 4x4 sample grid.
- Sample adaptive offset: The SAO filter is applied after the DBF and is designed to allow for better reconstruction of the original signal amplitudes by applying offsets stored in a look up table in the bit stream.

III. HEVC VIDEO CODING TECHNIQUE:

The HEVC design follows the classic block-based hybrid video coding approach (as depicted in Fig. 2). The basic source-coding algorithm is a hybrid of interpicture prediction to exploit temporal statistical dependences, intrapicture prediction to exploit spatial statistical dependences, and transform coding of the prediction residual signals to further exploit spatial statistical dependences. There is no single coding element in the HEVC design that provides the majority of its significant improvement in compression efficiency in relation to prior video coding standards. It is, rather, a plurality of smaller improvements that add up to the significant gain.

HEVC Encoding/Decoding Algorithm:

1. Read the video clip
2. Encoding
   - 2.1 Assign the pattern which you want to convert
   - 2.2 Convert the color format from RGB to YCbCr
   - 2.3 Start encoding the block
     - 2.3.1 Define the size of the CTU as 64x64
     - 2.3.2 Encode each and every CTU or CU
       - 2.3.2.1 Divide the CTU in to CTB and may be further divided in to CB
       - 2.3.2.2 Entropy Coding is being done on each and every CU
       - 2.3.2.3 Calculate the motion vector using logarithmic search and the CU of size 4:2:1
       - 2.3.2.4 Apply MV to each 16x16 block Decode this CU
3. Decoding
   - 3.1 Decode the block
   - 3.2 Cache the previous block

3.3 Convert the color format from YCbCr to RGB

3.4 Make sure that the block is in 16 bit range

3.5 Store the block

As we choose HEVC encoder for video compression. The above algorithm of HEVC shows how the video file is encoded and decode for video compression. First read the video clip, after reading the video clip encoding is done. In encoding first assign the pattern which you want to convert. Then convert the format fron RGB to YCbCr.

A. Sampled Representation of Pictures

For representing color video signals, HEVC typically uses a tristimulus YCbCr color space with 4:2:0 sampling. This separates a color representation into three components called Y, Cb, and Cr. The Y component is also called luma, and represents brightness. The two chroma components Cb and Cr represent the extent to which the color deviates from gray toward blue and red, respectively.

B. Division of the Picture into Coding Tree Units

A picture is partitioned into coding tree units (CTUs), which each contain luma CTBs and chroma CTBs. A luma CTB covers a rectangular picture area of L×L samples of the luma component and the corresponding chroma CTBs cover each L/2×L/2 samples of each of the two chroma components. The value of L may be equal to 16, 32, or 64 as determined by an encoded syntax element specified in the SPS.

C. Division of the CTB into CBs

The blocks specified as luma and chroma CTBs can be directly used as CBs or can be further partitioned into multiple CBs. Partitioning is achieved using tree structures. The tree partitioning in HEVC is generally applied simultaneously to both luma and chroma, although exceptions apply when certain minimum sizes are reached for chroma. The CTU contains a quadtree syntax that allows for splitting the CBs to a selected appropriate size based on the signal characteristics of the region that is covered by the CTB. The quadtree splitting process can be iterated until the size for a luma CB reaches a minimum allowed luma CB size that is selected by the encoder using syntax in the SPS and is always 8×8 or larger (in units of luma samples).

D. Entropy Coding

Context Adaptive Binary Arithmetic Coding (CABAC) is used for entropy coding. This is similar to the CABAC scheme in AVC. CABAC is the only entropy encoder method that is allowed in HEVC. CABAC and the entropy coding of transform coefficients in HEVC were designed for a higher throughput then AVC, while maintain higher compression efficiency for larger transform block size relative to simple extensions.

E. Motion Vector Prediction

HEVC allows for two MV modes which are Advanced Motion Vector Prediction (AMVP) and merge mode. AMVP uses data from the reference picture and can also use data from adjacent prediction blocks. The merge mode allows for the MVs to be inherited from neighboring prediction blocks.

IV. APPLICATIONS

Regarding the compression HEVC offers technical and commercial benefits to existing applications and usage scenarios, including extended-range uses with enhanced precision and color format support, scalable video coding and 3-D/Stereo/multiview video coding. Moreover multiscreen applications or over-the-top (OTT) Services can also benefits from HEVC by improving the overall quality of video to mobile devices. HEVC enabling better picture quality at lower bitrates [10], it will offer sports fans, for instance, a better viewing experience on mobile devices. Last but not least, a 4K application for which HEVC was originally designed.

V. CONCLUSION

The HEVC standard has been developed and standardized by both the ITU-T VCEG and ISO/IEC MPEG organizations. HEVC represents a number of advances in video coding technology. Its video coding layer design is based on conventional block-based motion compensated hybrid video coding concepts, but with some important differences relative to prior standards. When used well together, the features of the new design provide approximately a 50% bit-rate savings for equivalent perceptual quality relative to the performance of prior standards (especially for a high-resolution video). For more details on compression performance, please refer to [23]. Implementation complexity analysis is outside the scope of this paper; however, the decoder implementation complexity of HEVC overall is not a major burden (e.g., relative to H.264/MPEG-4 AVC) using modern processing technology, and encoder complexity is also manageable. For more details on implementation complexity, please refer to [24].

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