ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

DESIGN AND ANALYSIS OF VIDEO COMPRESSION TECHNIQUE USING HEVC INTRA-FRAME CODING

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DOI: 10.5281/zenodo.817839

ABSTRACT

High Efficiency Video Coding (HEVC) is currently being prepared as the newest video coding standard of the ITU-T Video Coding Experts Group and the ISO/IEC Moving Picture Experts Group. The main goal of the HEVC standardization effort is to enable significantly improved compression performance relative to existing standards in the range of 50% bit-rate reduction for equal perceptual video quality. Intra-frame coding is essential in both still image and video coding. In the block-based coding scheme, the spatial redundancy can be removed by utilizing the correlation between the current pixel and its neighboring reconstructed pixels from the differential pulse code modulation (DPCM) in the early video coding standard H.261 to the angular intra prediction in the latest H.265/HEVC [1], different intra prediction schemes are employed. Almost without exception, linear filters are used in these prediction schemes. This paper provides an overview of the Intra-frame coding techniques of the HEVC standard.

KEYWORDS: High Efficiency Video Coding (HEVC), Intra- frame coding, angular intra prediction.

I. INTRODUCTION

Along with the development of multimedia and hardware technologies, the demand for high-resolution video services with better quality has been increasing. These days, the demand for ultrahigh definition (UHD) video services is emerging, and its resolution is higher than that of full high definition (FHD), by a factor of 4 or more. Based on the market demands, ISO/IEC Moving Picture Experts Group (MPEG) and ITU-T Video Coding Experts Group (VCEG) have organized Joint Collaborative Team on Video Coding (JCT-VC) and standardized High Efficiency Video Coding (HEVC), whose target coding efficiency was twice better than that of H.264/AVC [1]. In the near future, HEVC is expected to be employed for many video applications, such as video broadcasting and video communications.

Historically, MPEG-x and H.26x video compression standards employ the macro-block (MB) as one basic processing unit [2], and its size is 16 × 16. However, HEVC supports larger sizes of the basic processing unit, called coding tree unit (CTU), from 8 × 8 to 64 × 64. A CTU is split into multiple coding units (CU), in a quad tree fashion [1]. Along with the CU, the prediction unit (PU) and transform unit (TU) are defined, and their sizes and shapes are more diverse than the prior standard technologies [3]. On top of them, many advanced coding tools that improve prediction, transform, and loop filtering are employed to double the compression performance compared with H.264/AVC. However, the computation requirement of HEVC is known to be significantly higher than that of H.264/AVC because HEVC has more prediction modes, larger block size, longer interpolation filter, and so forth.

II. BLOCK-BASED VIDEO CODING

Block based video coding is one of the mostly used compression technique for video. In block based video coding, each video frame is split into coding blocks[3]. Each coding block is predicted, transformed. quantized and entropy encoded. Each frame is split into various coding blocks and then the blocks of first frame in a video frame sequence is intra predicted and encoded (prediction of image blocks within the frame) and the rest of the frames' blocks are either intra predicted or inter predicted (prediction between frames using Motion Estimation (ME) and motion compensation blocks). Nevertheless, in interprediction, in every frame the first block of slice (group of blocks) can be intra-coded and depends on the mode-decision algorithm.

The ME block predicts and estimates motion between frames and generate the Motion Vectors (MVs). The MVs are entropy encoded and also sent to motion compensation block. The motion compensation block uses these MVs to generate motion compensated frames. These motion compensated frames are subtracted from the original frames (current frames) to generate residual frame blocks. This residual information is transformed, quantized and then entropy encoded.

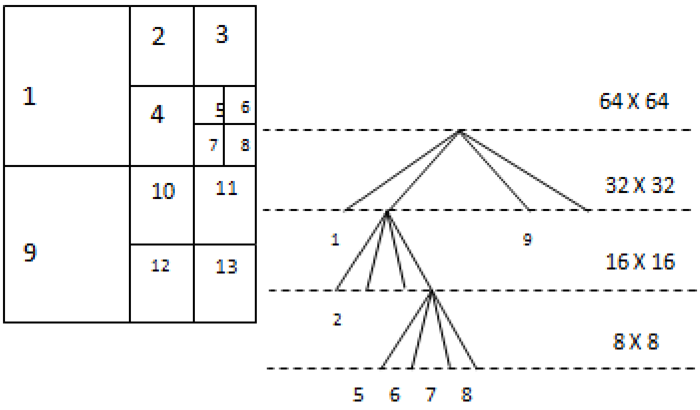


Fig.1 (a)Example of CTU (b) Quad tree structure of the CTU in (a)

III. INTRA-FRAME CODING

In MPEG-1 Standard, I-Picture is being coded by intra-frame coding. When encoding I-Picture, we only reduce the spatial redundancy in the picture without referencing other pictures. The coding process is much similar to JPEG Standard. So encoding I-Picture is less complex than P-frame and B-frame. Decoding I-Picture is inverse process of encoding process, so this section we only describe encoding process. Before we go further, we must know the basic coding unit is a block which is a 8 by 8 matrix. And a macroblock is consists of six block: 4 block of luminance (Y) , one block of Cb chrominance, and one block of Cr chrominance. Below Fig2 shows the macroblock structure:

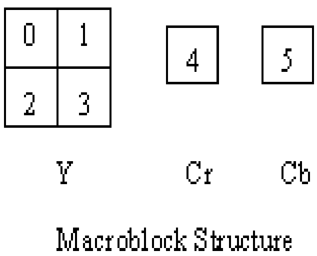


Fig 2:Macro block structure

Intra-prediction modes

The Intra-picture prediction uses the previously decoded boundary samples from spatially neighboring block in order to predict a new prediction block PB. So the first frame of a video sequence and the first picture at each clean random access point into a video sequence are coded using only intrapicture prediction [6]. Several improvements have been introduced in HEVC in the intra prediction module:

1) Due to the larger size of the pictures, the range of supported coding block sizes has been increased.
2) A plane mode that guarantees continuity at block boundaries is desired.
3) The number of directional orientations has been increased.
4) For intra mode coding, efficient coding techniques to transmit the mode for each block are needed due to the increased number of intra modes.
5) HEVC supports a large variety of block size, so it needs consistency across all block size.

HEVC employs 35 different intra modes to predict a PB:

1) 33 Angular modes,
2) Planar mode and
3) DC mode.

The table shows the mode name with their corresponding intra prediction mode index.

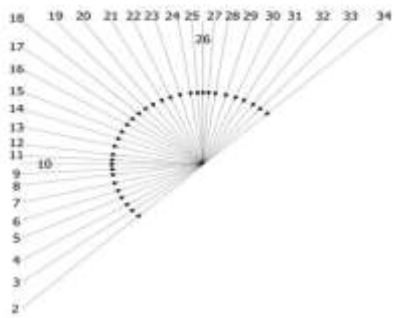


Fig3: Angular modes of Intra frame Prediction in HEVC

Intra-prediction is performed based on each PU from its neighboring reconstructed pixel samples in up to 35 different IPMs, including dc, planar, and 33 angular directions [Fig. 3], whereas H.264/AVC only allows nine IPMs at most .The prediction residual data derived from all PUs within a CU is then transformed and quantized in a group of pixels called TU.

Angular Mode

The angular prediction process is operating in the spatial domain. Comparing with previous standard H.264, this method has though improved significantly because of increased number of directional orientations and the bigger block sizes, providing a good compromise between encoding complexity and coding efficiency for typical video material [7]. The angular mode in HEVC supports 33 different directional orientations. In figure, Angular modes are indexed from 2 to 34. Directions may cover angles from near horizontal through near-diagonal to near-vertical. Each mode has associated a displacement parameter d, where the value of d indicates the numeric part which is the pixel's displacement expressed in 1/32 pixel fractions of accuracy, and H and V indicate the horizontal and vertical directionalities [7]. The modes 10 are 26 are known as pure horizontal prediction and pure vertical prediction.

Planner mode

This mode in HEVC is similar to the planar mode in H.264/MPEG-4 AVC, and is known as mode 0. In H.264/MPEG-4 AVC this method is a plane prediction mode for textured images, and may introduce discontinuities along the block boundaries. Conversely, in HEVC this mode was improved in order to preserve continuities along the block edges. The value of each sample of the PB is calculated assuming an amplitude surface with a horizontal and vertical smooth gradient derived from the boundaries samples of the neighboring blocks[8] .

DC mode

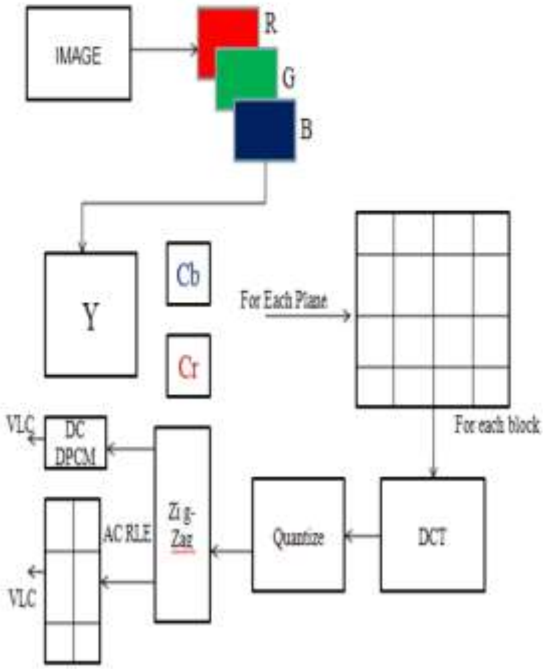
This mode is also similar to the DC mode in H.264/MPEG-4 AVC and is known as mode 1. It is efficient to predict plane areas of smoothly-varying content in the image, but gives a coarse prediction on the content of higher frequency components and as such it is not efficient for finely textured areas. The value of each sample of the PB is an average of the reference samples. As explained before, for this case the reference samples will be the boundary samples of the top and left neighboring blocks. So, all the samples of the PB are predicted with the same value [8].

I-Picture Encoding Process

(i) Decomposing image to three components in RGB space
(ii) Converting RGB to YCbCr
(iii) Dividing image into several macroblocks (each macroblock has 6 blocks , 4 for Y, 1 for Cb, 1 for Cr)

(iv) DCT transformation for each block.
(v) After DCT transform , Quantizing each coefficient.
(vi) Then use zig-zag scan to gather AC value.(vii) Use DPCM to encode the DC value, then use VLC to encode it.
(vii) Use RLE to encode the AC value, then use VLC to encode it.

I-Picture Encoding Flow Chart



IV. RELATED WORK

Development and evaluation of a fast partitioning decision algorithm. Being aware that the partitioning of the coding units is the most critical decision that the encoder has to take in terms of computational burden but also regarding the impact on quality, the second objective is the complexity reduction of the partitioning decision. With the aim of tackling this task with high efficiency, the use of the *Machine Learning* techniques [4], for the design of a decision tree was developed. Special efforts will be made in the training stage of the decision trees, selecting the optimal number and type of attributes, allowing a high precision classifier with the minimum computational cost. It required that the architecture of the proposed approach permit a scalable implementation with different decision nodes, achieving different levels of speed-up, and as a counterpart, different levels of performance reductions compared to the HEVC reference software.

Development and evaluation of a fast mode decision algorithm. With the aim of exploiting the strong correlation between the texture orientation of the image and the angular modes defined in HEVC, a fast mode decision algorithm[3], based on texture orientation will be proposed and developed. The proposal is based on the computation of the *Mean Directional Variance* (MDV) along a set of *co-lines*, and it will be highly efficient for the detection of the dominant gradient in all the range of coding unit sizes, from 64x64 to 4x4 pixels. The concept of *Sliding Window* for the improvement of the MDV algorithm, denoted as MDV-SW, was developed. The aim of the MDV-SW approach will be to achieve a significant speed-up of *intra-prediction* coding by reducing the number of modes to be evaluated, with a very low performance penalty.

Combination of both proposals in a full fast intra-prediction algorithm. the integration of both fast decision approaches in a unified architecture, called *Fast Partitioning and Mode Decision* (FPMD)[5], is proposed. The performance evaluation of the combined proposal will allow knowing the best performance that can be achieved by speeding up both decisions. The analysis of the results will also show the mutual inference that exist between the wrong classification decisions of both algorithms in terms of bit rate penalty and quality degradation. That

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

is, how a wrong mode decision affects the overall encoding performance when a wrong partitioning decision is taken, or vice versa, how a wrong partitioning decision affects the encoding performance when a wrong mode decision is taken.

Fast Coding Unit Size Decision Algorithm for Intra Coding in HEVC : the fast CU size decision algorithm for intra coding to early terminate the recursive CU splitting process before further checking the RD cost with being split into sub- CUs. If the RD cost computed for one CU is small enough, that is, below a pre-set threshold, then the current CU is selected as the best CU with the optimal size, and the encoding process proceeds to the next LCU. This early termination process is applied to each CU with different sizes by using different threshold values. The threshold values play a critical role to control the tradeoff between complexity reduction and RD degradation.

Fast Mode Selection for HEVC Intra-Frame Coding With Entropy Coding Refinement Based on a Transparent Composite Model: To reduce the mode decision complexity in HEVC intra-frame coding, while maintaining its RD performance, in this paper, we first formulate the mode decision problem in intra-frame coding as a Bayesian decision problem based on the newly proposed transparent composite model (TCM) for discrete cosine transform coefficients, and then present an outlier-based fast intra-mode decision (OIMD) algorithm. The OIMD algorithm reduces the complexity using outliers identified by TCM to make a fast coding unit split/non split decision and reduce the number of IPMs to be compared. To further take advantage of the outlier information furnished by TCM, we also refine entropy coding in HEVC by encoding the outlier information first, and then the actual mode decision conditionally given the outlier information. Specifically, both CU split flags and IPMs are conditionally encoded given the outlier information in the CABAC refinement. The OIMD algorithm can work with and without the CABAC refinement. From the analysis the following findings in comparison with HM-15.0

1) When applied alone, our developed OIMD algorithm reduces, on average, the ET by 50% with a 0.7% increase in the Bjontegaard distortion (BD) rate [3].
2) When applied in conjunction with the proposed CABAC refinement, it reduces, on average, both the ET by 50% and the BD-rate by 0.15%.

***Edges based Intra-prediction in High Efficiency Video Coding (HEVC) Standard*.** According to the standard features and process, the first important step in intra-frame prediction process is the quad tree block decomposition which is in action with respect to a predefined threshold and the amount of details in different area of and image. In this method, fist a fixed block sizes of from 32x32 to 4x4 has been used and then canny edge detection algorithm is used for variable block size partition at each instance of intra-frame prediction to be able to evaluate the flexibility of HEVC intra-frame prediction with 35 modes in total and 33 different angular modes and further perform a comparison between H.264 and H.265 standards. For variable block size canny edge detection method is used because it detects edge with low error rate, which means that the detection should accurately catch as many edges shown in the image as possible. Among all edge detection method this method gives best result[9].

V. CONCLUSION

Although high valued results have been reached in terms of complexity reduction and efficiency performance, there exist several issues that are still open to further research. The algorithms mentioned can be considered as a starting point for the development of new approaches in *intra-prediction* coding. These should consider new factors that have not been addressed, such as the use of perceptual models for the selection of the optimal partitioning and angular modes, or the adaptation of the algorithm to future hardware architectures. Some new research lines to be addressed are Use of directional information as attributes for the CTU partitioning decision Detection of optimal non-angular mode , Training of combined partitioning and mode decision**.**

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CITE AN ARTICLE

Reddy, K. S., Srikanth, B., & Reddy, C. L. (2017). DESIGN AND ANALYSIS OF VIDEO COMPRESSION TECHNIQUE USING HEVC INTRA-FRAME CODING. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY*, *6*(6), 477-482. doi:10.5281/zenodo.817839