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A Survey on Coding Techniques and Intra Prediction Hardware Architecturefor HEVC Video Coder Standard

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***Abstract*—The most recent progressive video compression technology standard of International Telecommunication Union video coding group is High Efficiency Video Coding (HEVC), also known as ITU-T H.265 standard. This new video standard is more efficient compared to the previous AVC coders. The development process of HEVC is still undergoing to suit for real time video applications. For this new efficient algorithms and supporting hardware structures has been reported. This paper makes a systematic survey of these efficient algorithms and supporting hardware coders of the HEVC standard.**

***Index Terms*— HEVC,H.265,AVC coders.**

I. INTRODUCTION

Video compression and decompression algorithms are used to manipulate video signals in order to reduce the memory and bandwidth required without compromising on the video quality. Video codecs are essential for various embedded system applications involving video content data.Understanding of video codecs' processing and its storage demands is key to hardware selection and software optimization. This paper explores the working and characteristics of video codecs.

AVC is the previousstandard used in high end electronic devices for video compression and decompression. At present the most important development in video optimization area is the introduction of H.265/HEVC standardit has wide applications in area of video streaming services like broadcastingTVchannels, internetvideouploading and downloading and video Tele conferencing applications. The goal of thisnew standardization is to produce video compression specification that is capable of compression thrice as effective compared to previous H.264/AVC standard in terms of coding complexity and quality.

There are wide range of platforms that receive digital video. Embedded devices like TVs, personal computers, smartphones, tablets and each have different computational, display, and connectivity capabilities, thus video has to be transformed tomeet the specifications of recipient video platform. This conversion is achieved by a process called video transcoding. For transcoding the video content, compressed video signal is decoded and re-encoded in to the target compression format, but this process has high computation complexity. While transmitting video content in real-time ultrahigh-definition video, it is required toutilizethe information that is already available inthe compressed video bit-stream to reduce the

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conversion timeHowever, some of these techniques suffers problems in terms of design complexity, data dependency, external andinternal memory bandwidth, and on-chip memory size inrelation toprevious available standards.

This paper is categorized as follows. Section II emphasis on overall HEVC structure. Section III briefs various coding techniques reported in HEVC. The hardware architectures of HEVC encoding technology is described in detail in Section IV. Since writing an overview of a video technology is very vast as HEVC involves a significant amount of characterization, the reader is referred to [1] for any further details.

II. HEVC STANDARD STRUTURE

The basic structures of previous standard such as MPEG-2 Video and H.264 are similar to new HEVC standard. However, HEVC incorporates numerous additional improvements such as having more desirable partitioning, from large to small partition sizes.This in turnProvides remarkable flexibility in selecting prediction modes sizes and transform block sizes [2] and Implements high level complex interpolation and DE blocking filters.New video coder hashigh compression at the cost of increased processing power consumption.

Source video content consists of a series of video frames, and is encoded by a video encoder to generate a compressed video bit streams and further stored and sent.

A video decoder decompresses these bit streams to produce a sequence of decoded frames. Various steps involved (Fig 1) includes: Partitioning of each picture into multiple units Prediction of each unit by either inter/intra prediction methods, and subtracting the prediction by the unit transformation and further quantizing the residuals.

A video decoder (Fig 1) follows these steps:

i. Entropy decoding and extracting the elements of the coded sequence structures
ii. Inverting the transformation stage
iii. Prediction of each unit and summing the prediction to the output of the inverse transform

Reframing a decoded video still image

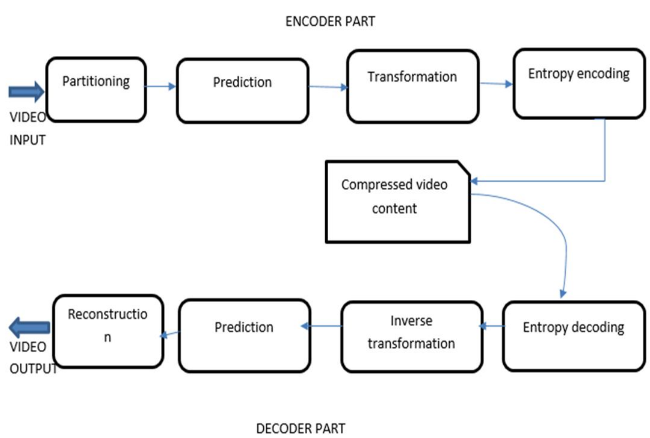

Fig. 1. Structureof Hevc Standard

The HEVC standard gives the compressed video sequence format and a method to decode a compressed sequence. The basic design of the encoder is not standardized. Each block is briefed below

A. Partitioning

HEVC supports high degree of flexible partitioning of a video sequence. Frame sequence is divided into rectangular and square regions called as Units. Each unit is predicted from previously encoded data. Beside the prediction method, transformation of entropy encoded unused residual is made. Encoded video frame is divided into a new types of blocks called Tiles and Slices, which are further divided into Coding Tree Units (CTUs). The CTU is the basic unit of coding which are similar to the Macroblocks used in previous standards. CTU has a maximum size of 64x64 pixels [3].

A Coding Tree Unit is further segregated into square regions known as Coding Units (CUs) using quad tree structures (Fig 2).Each CU is estimated using Inter/Intra prediction method and transformed using one or more Transform Units

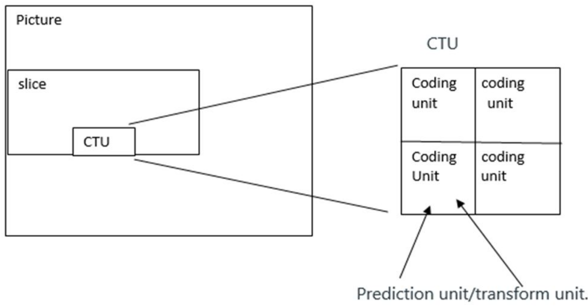

Fig. 2. Codingtreeunitssamples [4]

B. *Prediction stage*

Video frames are coded using Intra/ Inter prediction method. Figure 3 shows a sequence of coded video frames and coded pictures. Initial picture is coded using spatial prediction methodonregions of the same image. Succeeding pictures are predicted from various available

One or more reference pictures, using Inter prediction for each Prediction Unit .The prediction sources for each picture are indicated by arrows.

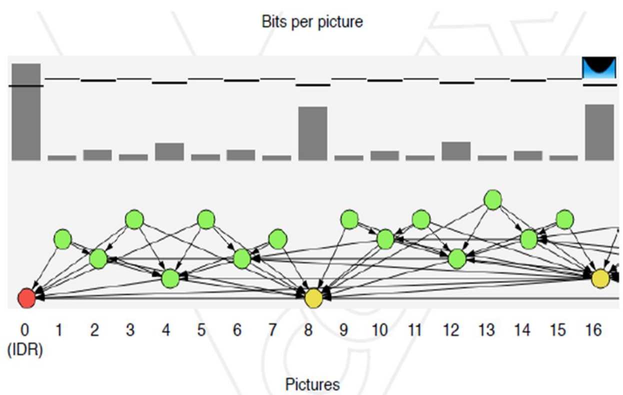

Fig 3: Sequence Of Coded Structure [3]

Each Coding Unit (CU) is partitioned into one or more individual Prediction Units (PUs), each of which is predicted using Intra/Inter prediction method.

C. Intra Prediction Method

EveryPU is predicted from adjacent image data within the picture itself, using DC mode prediction planar prediction or directional prediction. DC mode prediction indicates ameanvalue for the PU, planar prediction indicates a plane surface to the PU or directional prediction involves extrapolation nearbyadjacent data...

Inter prediction: Each and every individual PU is predicted from image data of a reference picture using motion compensated prediction.

D. Transformation

HEVC supports four different transform sizes of 4x4, 8x8, 16x16 and 32x32.The transformation has integer transforms based on the discrete-cosine-transform [4]. Further the transform used for intra prediction of size 4x4 is based on the discrete sine transform.The basis matrix uses coefficients involving 7 bit storage memory, so it is considered to be more precise than previous coding standard AVC. High accuracy and large sizes of the transforms results in increasing HEVC performance higher than H.264.

The residual signal of a Coding Unit has more transform units. The CU is splited using the same quad-tree method analysisand the CTB dividing with the smallest allowable block of size 4x4 considered to be the smallest TU. For example a 16x16 Coding unit contains three 8x8 TUs and four 4x4 TUs.

Since there is no availability of 64x64 transform, a 64x64 CU must be divided at least once into four 32x32 Tus. Further there is no 2x2 Chroma TU size.Becauseof the smallest CU is of size 8x8, there are four 4x4 luma TUs in 8x8 region TUs, and region thus consists of four luma 4x4's and two Chroma.

4x4s Like the Coding units in a CTB, TUs within a CU are also traversed in Z-order [5]. If a TU has size of 4x4, the encoder will rise a transform skip flag at which the transform is detoured all together, and the transmitted coefficients are really just spatial residual samples.

There is a possibility that encoder will signal a "transform skip" flagfor a TU having size of 4x4unit. During this the transform is detoured all together, and the transmitted coefficients are considered as spatial residual samples

E. Entropy Coding

HEVC uses a context-adaptive binary arithmetic coding (CABAC) algorithm that is fundamentally similar to CABAC in H.264/MPEG-4.CABAC is mainly used in H.265 coder standard. CABAC and the entropy coding of transform coefficients provide higher throughput than H.264/MPEG-4 standard, while maintaining higher compression efficiency for larger transform block sizes[6]. CABAC bypass-mode is improved in terms of its design to increase throughput. Another major improvement with HEVC is that the dependencies in the coded data is varied randomly to increase the throughput. Context modelling in HEVC assists CABAC to select a context that increases efficiency when compared with H.264.

III. HEVC CODING TECHNIQUES

This paper analyses HEVC coding mechanism and discusses the motivation leading to the selection of this specific design. Fig 4 shows the basic difference of inter and intraprediction methods.

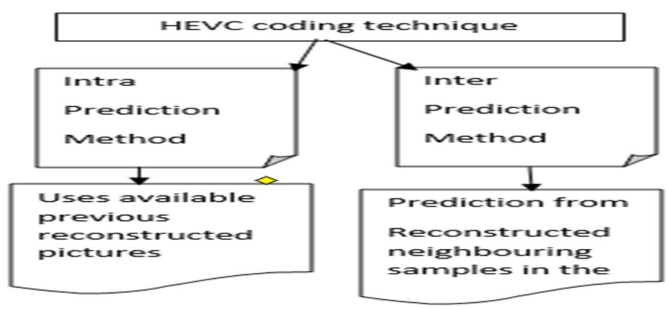

Fig 4: Basiccoding technique

A. Inter-Prediction Mode

For all pictures of a sequence and random access point's inter-picture prediction may be used, to make use of temporally-predictive coding modes which predicts a new prediction blocks (PB), employing image data from one or two reference pictures before or after the current picture, and using motion related compensated prediction.

The initial process for encoding is thatthe inter-picture prediction method selects motiondata reference picture along with motion vector (MV).This is further applied for predicting the samples of each block. Motion vectors have maximum of quarter-sample resolution with lumacomponent. The encoder and decoder generates similar inter prediction signals by applying motion compensation using motion vector and mode decision data, that are transmitted as side information.

1).***Partitioning:***HEVC has high PB block partition structure for interpicture-prediction than for intrapicture-prediction. When the prediction mode is indicated as inter-prediction, the luma and Chroma Coding blocks are divided into one or two, or four prediction blocks (PBs). When the Coding block is divided in one (NxN), the resulting Prediction block is the same size as the corresponding CB [7]. When a CB is split into two PBs, various types of this splitting are possible.

The cases are, M×M/2 (CB is divided into two equal-size PBs vertically), M/2×M (CB is divided into two equal-size PBs horizontally), M/4(L)xM, M/4(R)xM, MxM/4(U), MxM/4(D). These last four modes are termed asymmetric motion partitions. The division of four equally-sized PBs (M/2xM/2) is supported when the CB size is equal to the smallest allowed CB size (8x8 samples); in this case each PB is equal to a quadrant of the CB.

Each inter-coded Partion block is assigned with one or more motion vectors and reference picture indices [3]; these reference indices pointing into a reference picture list. Similar to H.264/ MPEG-4 AVC, HEVC has two reference picture, list 0 and list 1.

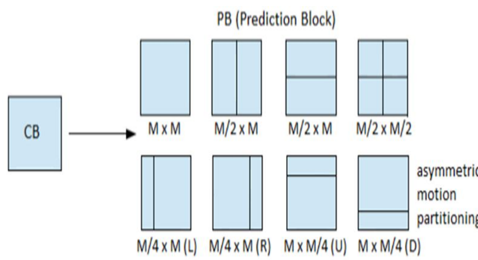

Fig 5:PB for inter prediction block

*2. Fractional Sample Interpolation**:** The* horizontal and vertical components of a motion vector indicate the location of the prediction in the reference picture. These components identify a block region in the reference picture, needed to obtain the prediction samples of the PB for an inter-picture predicted CB [11].

In the case of luma samples HEVC has motion vector values with units of one quarter distance between twoadjacent luma samples. Samples at fractional locations are interpolated using the content available at integer prediction locations.

In order to obtain these samples, HEVC makes use of an eight-tap filter for the half-sample positions and two possible seven-tap filters for the quarter sample positions. In Figure 6 the position labelled with capital letters, Ai,j, represent integer locations at the free luma samples and the other positions which are labelled with small case letters represent non-integer sample locations, that is needed to be generated by interpolation.

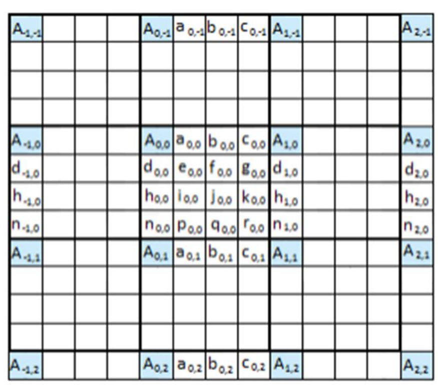

Fig 6: Integer and fractional positions

B. Intra-Prediction Mode

The Intra-picture prediction uses the previously decoded boundary samples from spatially neighbouring block in order to predict a new prediction block PB. Thestarting framein particular sequence of sample video and the first pictures sample video sequence having an access point are encoded using only intra picture prediction [6].

Several changes are made in the intra prediction module: 1), the range of coding block sizes is increased because of the larger size of the pictures. 2) A continuity of plane mode block boundaries is expected. 3) The quantity of orientations in a specific directions are increased. 4) In intra mode coding mode, efficient coding techniques are used to transmit the mode for each block

There are 35 intra modes in HEVC to predict a Partition block, out of which 33 are mode consisting of Angular values andone mode of planar value and remaining one DC mode. The table below indicates different types of intra mode with intra prediction mode indexes [9].

TABLE: INTRA PREDCTION MODE

Intra prediction mode types	**Mode index value**
Planar mode type	Mode 0
DC mode type	Mode 1
Angular mode type	Mode 2 to 34

*1) PB partitioning:*The Coding block can be divided into size of NxN or N/2xN/2. The first one means that the CB is not split, so the PB has the similar size as that of CB. It is possible to use it in all CUs. The second partitioning means that the CB is divided into four equally-sized PBs. This can be used in the smallest 8x8 CUs. A flag is used to select type of partitioning in CU. Each resulting PB has its own intra prediction mode [12]. The prediction blocks size varies from 4x4to64x64.

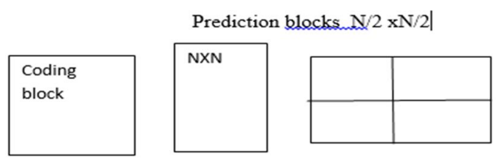

Figure 7: Prediction Block for Intra Prediction.

IV. INTRA PREDICTION HARDWARE ARCHITETURES

This paper focuses on finding optimal hardware architectures for different MPEG-HEVC application fields having minimal resource utilization. To reach this goal of providing the highest power efficiency, apure intra prediction hardwired core processors are needed.

HEVC intraprediction modes of size 4x4 and 8x8 have similar equations. There is similarity in equations between 4x4/8x8 luminance prediction modes. The identical equations for prediction to all luminance prediction mode size of 4x4 and 8x8 is calculated at once and resulting value is used for the corresponding intra 4x4 and 8x8 prediction modes[10]

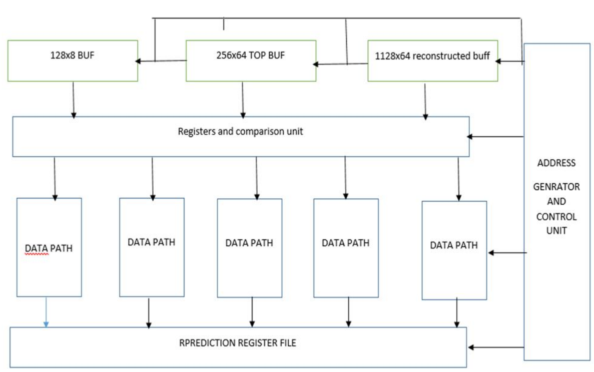

Fig 8:H.265 Prediction hardware architecture

Five parallel datapaths are presentinPrediction hardware architecture and aidsincalculation of all 4x4 and 8x8 intra prediction modes.One 8x8 and four 4x4 PU calculation takes 160 clock cycle as showninfig 9.

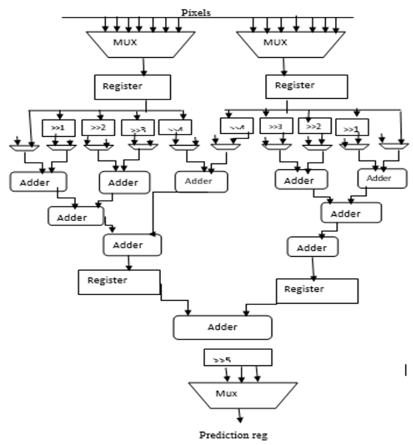

Fig 9:H.265 Prediction-DataPatharchitecture.

V. CONCLUSION

HEVC or H.264 standard is a advanced video compressing technologyintroduced by the IEC-MPEGin collaboration with ITU-T Video Coding Experts Group .HEVC codec formatis based on the general structure of existing coding standards but with an improved additional encoder design.Presently HEVC has a 25% bit rate reduction and a 50% reduction on the complexity of the process of encoding and decoding.

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