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Study and Comparison of H.265/HEVC Video Coding Architectures

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Abstract— The paper has been written with the sole aim to aware about the newly advanced H.265video coding standards. The H.265 or the HEVC encoding standards provide improved video withmuch better efficiency of compression.
Keywords—HEVC; H.265Compression; Video; DCT

1. Introduction:

The general representation of the image in a computer is like a vector of pixels. A pixel isan abbreviation of picture element. Thus we can infer that a picture is generated by pictureelements or pixels just like a molecule is made up of atoms. When we talk aboutresolution of a picture, we are actually talking about the pixels it has. For ex: A 200 X 200image can be seen as a square of side 200. Each pixel has representation in terms of bits,suppose if there are 4 bits for each pixel then the size of a 200 X 200 image with 4bitpixel would be 200*200*4 => 160000 bits or approximately 20kB.

This was for an image and HEVC is a coding standard for videos, so what is a video?We can say that video is a sequence of images and hence each frame of a video is animage and therefore if can compress those images we can eventually compress the video.The frame rate is the number of frames passing per second in a video thus more is theframe rate, smoother the video is.The video compression involves spatial image compensation and temporal motioncompensation. Video Compression is needed mainly due to less channel capacity hencetransferring along channels becomes too inefficient hence compression saves both timeand space with the cost of computational complexity. Thus it fastens the file transferprocess and also reduces space on disk.

If we look at internet traffic, it is mainly due to the video streaming. Approximately80% of the internet traffic is due to videos and 20% is due to other data. In such a scenariowhere videos are dominating the traffic over internet we need to find more efficient videocoding standard which is faster, saves bandwidth and is cost and quality efficient.

Fig. 1. Video and data Traffic over Internet

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2. H.265 Terminology:

The basics of H.264 are worth noting before we move on for the features of HEVC, as

HEVC (standardized in 2013) is ultimately a better version of H.264.In the past we had the MPEG standard in DVDs in 1996 for video coding and now wehave moved to H.265 with the technological advancements. Every standard promises tofulfill the same or even better quality with a lower cost and bandwidth. There are twomain methods in video compression, one is the Interframe and another is the Intraframe.

In the Interframe method we basically compare the previous and future frames with thecurrent one and we only encode what is changed, for example in a 5sec movie clip whilethe actor is reciting a poem, only his facing expressions or his gestures change while thebackground is the same, then there we only have to encode the actor and not thebackground, so the background data could be saved in many frames.

On the other hand in Intraframe, we look for the similarity in the adjacent pixelswithin a frame.We initialize with an I-frame which is likely to be stored as a JPEG thenwe divide it into small 16 X 16 pixels which were called Macroblocks previously. Thenwe move on to the next frame and compare its macroblock with the I frame, if someblocks are roughly same then we will give this block the status of Predicted frame or theP-frame (this was interframe). Next we will give the completely new pixel values for thepixels which have changed only for this frame, and this way we have intracoded theintercoded block.

In the recent H.265 instead of a 16 X 16 macroblock we have a 64 X 64 Coding TreeUnit. Now this is a significant difference because in H.264 standard in 2003 the 1080pwas the greatest milestone achieved but now we have achieved 4k and therefore moreefficient video coding is needed and this is made possible with larger coding tree units.Now the second improvement is in the Intraframe compression. In HEVC we havemore prediction direction as compared with previous standards and this enables moreprecise compression with more options in various directions for the pixels values.

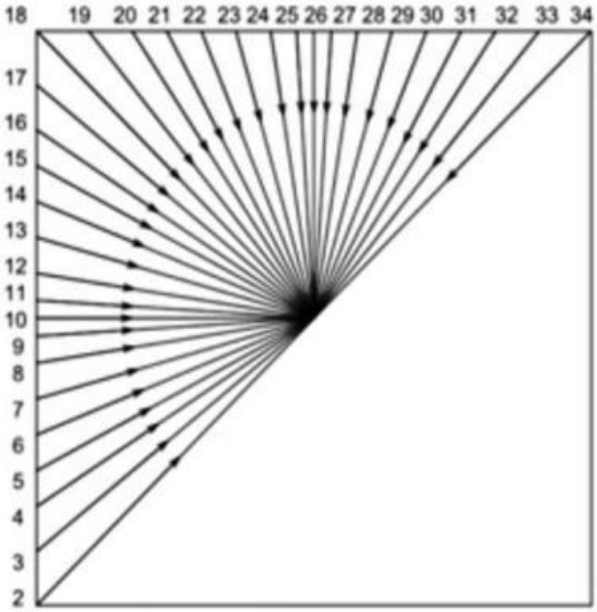

Fig. 2. Angle definitions of angular intra prediction in HEVC for 2 to 34 modes andthe associated displacepent parameter *H.265/HEVC Video Coding*

Actually we can further breakdown our CTUs to Coding Units or Coding Blocks(CBs) which can have 8 X 8 pixels and these CUs can be further partitioned in

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different.PredictionBlocks.(PBs).

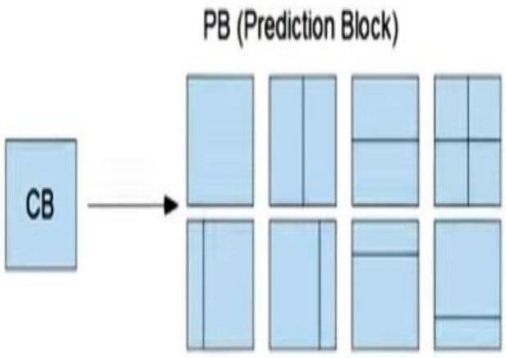

Fig.3. Breaking of CTU into CBs and PUs

The motive behind the prediction block is to mathematically generate pixel valuesinstead of storing them and this gives an edge for compression by reducing the size ofeach frame consecutively. For instance look at the below PU of 4 X 4 surrounded by twogroups of pixels A and B now we can use various Intraframe prediction models which theHEVC standard offers.

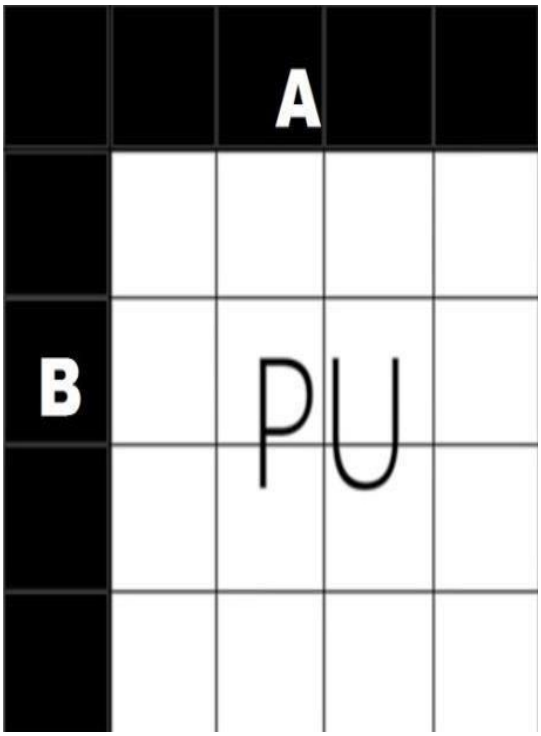

Fig.4.PU of 4x4 surrounded by two group of pixels

There are different prediction models for different categories for example if we just want the background of a single color then we can opt out DC type or if we want a patternto be continued then we can choose Angular. Previously there were only nine predictionmodes and thus quality deterioration was more critical but now in H.265/HEVC we have35 prediction modes which is more than 3 times as it was in H.264. This therefore giveshighly intra-compressed frames with better quality.

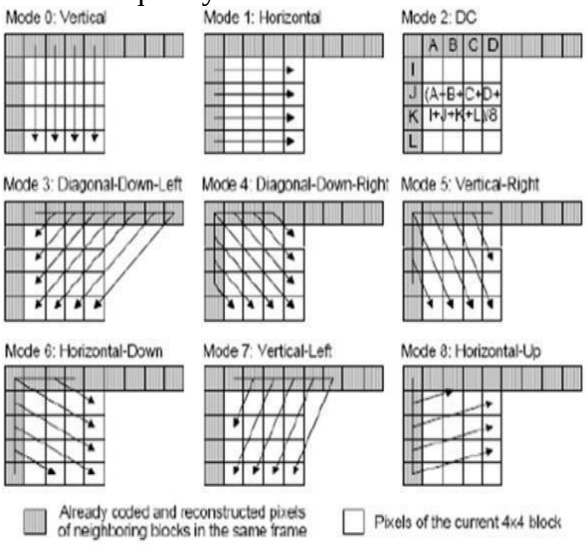

Fig.5: Prediction of modes of HEVC

The main points which demarcate HEVC from H.264 are:

The macroblocks are renamed as Coding Tree Units (similar in structure), the
previous macroblocks were having size range 16 X 16 but the new CTUs have a size range of 64 X 64. The larger range of size for HEVC provides more clarity and smoothness.The 35 prediction modes in H.265, as compared with only 9 modes in H.264.

3. The Algorithm:

Starting from the very basic process of a video codec wehave the following

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flow diagram:

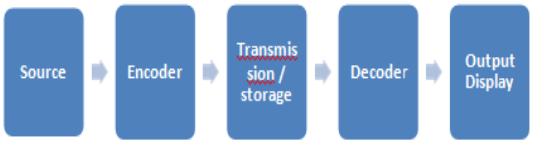

Fig.6. Video CODEC

It is worth noting that Encoder and Decoder together constitute a "Codec". Each process in encoding has a counter part in decoding.The previous H.264/AVC gave ~2X better compression than MPEG and the recent H.265/HEVC is also ~2X better than H.264, thus with each passing standard the compression rate is increasing hence in turn size is reducing, with a better picture quality. Size (H.265) ~ 0.5 Size (H.264).There is a kind of trade-off in video coding:

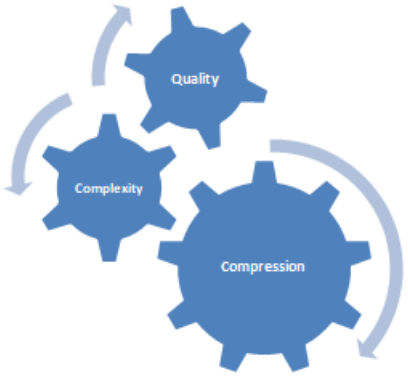

Fig.7.Vieo Coding trade-offs

So, we can achieve a better compression rate with a better picture quality by increasingComputational Complexity. Starting with the detailed algorithm of H.265 video codecthere are some terms which we have already seen in the introduction itself, therefore thealgorithm can be seen more effectively. Before moving on to thecomplex algorithm lets grasp some more insights:

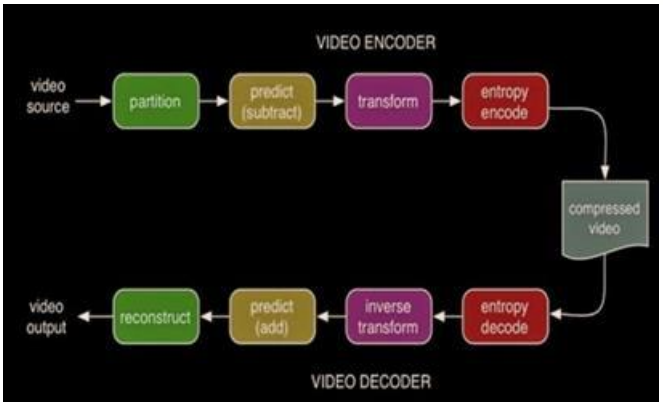

Fig.8:H.265 Video CODEC

H.265/HEVC Video Coding

3.1. Partitioning:

It refers for breaking up the video frame into small units. A frame or picture can be broken down into slices and each slice is made up of several CTUs. These CTUs can be further broken down into coding units. A video codec processes one CTU at a time.For ex: Take up a frame of a video and now take a macroblock or CTU from it, eachCTU will have a luma (brightness) component and red and blue color differentiatingcomponents which are CUs. The brightness component is stored at a higher resolution and the color components are stored at a lower resolution as the human eye is more sensitive towards brightness than colours.

3.2. Prediction:

The prediction is made with respect to the current frame and a very less residual is left on comparing the original and the predicted frame. There are two kinds of prediction one is the Interframe and the other is the Intraframe compression as we have already seen. We cut down the undesired information stored by mathematically preceding it based on various prediction modes Inframe: N x N, 2N x 2N

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Inframe: N x N, 2N x 2N, dN x N, N x dN There are in total eight methods for partitioning an interceded coding unit and two main methods are merge and advanced motion vector prediction. On the other hand there are 35 modes of interceded in which 33 are uniquely patterned one is planar and one is DC which predicyts the PB by filling in the average of surrounding pixel values.

3.3 Transform + Quantize:

As we have studied about the Fourier transform, Laplace transform and Z transform the basic idea of transforming a compressed video after prediction is also the same. The image's or frame's blocks are converted to frequency domain representation followed by quantization step where removal of unnecessary small values takes place. These two steps reduce the size considerably by converting into frequency domain and further quantizing it to discrete integers.

3.4 Entropy Encoding:

This concept is derived from the concept of Information Theory used in Digital Communication Systems. Entropy Encoding is done in order to convert the quantized block values to binary form. This is done by assigning binary values to a series of information and thus each specification takes its corresponding binary value. This is also referred as CABAC which stands for Context Adaptive Binary Arithmetic Coding which is a sophisticating and complex content management scheme. After this step the memory requirement is reduced and therefore better compression is achieved leading to improve the resulting in speed of transmission.If all these steps are done precisely then after decoding you can get a video very muchsimilar to the source.A decoder simply does the similar steps in reverse manner to give theoutput very much similar to the source input but highly compressed in nature. A video fileof size in GBs can be easily compressed to a file of size in KBs, even the changes in thecompressed version are non noticeable.

Summarizing all this, we have portioned the frames into various blocks, then we predicted the blocks after that we transformed the image values to frequency domain representation followed by quantization and at the end entropy encoded for good transmission speed with much less memory requirement. Furthermore we can see a more detailed H.265 coding standard where we have separately shown all the inter frame predicted filters.

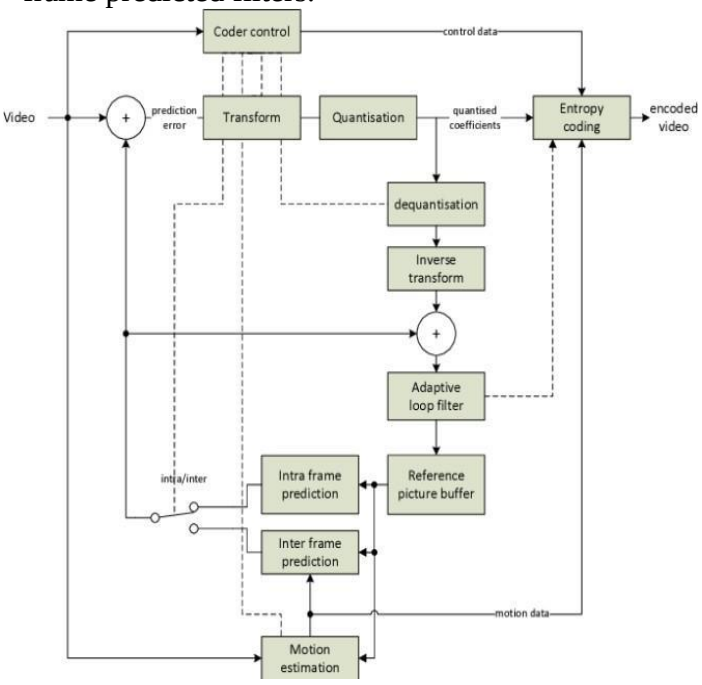

Fig.9.Block diagram of HEVC

4. Advantages and Disadvantages of an HEVC codec:

We can infer from all the above analysis that H.265 offers a much higher
compression with almost 2x better quality as compared to H.264/AVC.

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- All this is obtained in HEVC at a half bit rate.

- It has the ability to deliver high quality crisper video content such as 3D, 4K and even 8K.

- The only disadvantage is the computation complexitywhich is higher in H.265

and this can be thought of as the cost of achieving better compression with better picture quality.

5. Acknowledgment:

I want to gratefully acknowledge Associate Prof. TVK Hanumantha Rao, NIT Warangal, for encouraging me to write about the H.265Video Compression Standard.

6. References:

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