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A Survey on Fast Algorithms for High Efficiency Video Coding (HEVC) Standard

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Abstract: Recently, ITU-T VCEG and ISO/IEC MPEG have started a new joint standardization activity on video coding, called High Efficiency Video Coding (HEVC). The development process of HEVC is till now undergoing. Researchers around the world are trying to make this new coding standard as fast as possible. For this reason, different fast techniques based on HEVC have been reported. In this study, researchers have made a survey about these fast algorithms for the new coding standard.

Key words: HEVC, inter-mode decision, fast algorithm, H.264/AVC, prediction techniques, video

INTRODUCTION

Video compression is basically about the reduction and removal of redundant data from a raw video stream to make an efficient and effective video file which can be sent or stored easily. This process involves a set of algorithms which are applied to a raw video sequence to create a compressed stream that is suitable for transmission or storage. On the other hand, to play the compressed stream, an inverse set of algorithms are required in the decoder side to produce a video sequence which shows virtually the same content as the original one. The required time to compress, send, decompress and display a video stream is called latency. Generally, more advanced compression algorithm takes higher latency. Different video compression standards utilize different methods to remove or reduce the redundant data and hence, results differ in bit rate, quality and latency. Now days, to create a user friendly consumer electronics product is it very important to make the device as fast as possible. Moreover, from the user's point of view, it is better to have a real time performance device. Hence, the main challenge for the video codec algorithm developers in recent time is to make a suitable algorithm which gives fast (i.e., very low latency) as well as good performance in terms of quality, bit rate, etc.

Recently, ISO-IEC/MPEG and ITU-T/VCEG have formed the Joint Collaborative Team on Video Coding (JCT-VC) which aims to develop the next generation video coding standard, called High Efficiency Video Coding (HEVC). With a flexible coding architecture and respective tool extension from previous standard H.264/AVC, a promising compression performance can be expected. The major goal of the HEVC standard is to achieve significant improvements in coding efficiency compared to H.264/AVC, especially when operating on high resolution video content. Complexity of the HEVC standard is also carefully considered in the development process in order to make it possible to enable high resolution, high quality video applications in resource constrained devices such as tablets and mobile phones.

For the requirements of low computational complexity in mobile and real-time communication devices, a lot of early determination algorithms have been proposed in H.264 standard. In last couple of years, there are good amount of fast termination algorithms have been reported of HEVC. In this study, researchers are trying to make a survey on different fast algorithms that have been reported in literatures for HEVC. According to the observation, till now there is no such kind of survey paper present in this particular field. In this context, researchers have observed that there are four kinds of approaches are generally taken to make a fast algorithm in HEVC. These can be grouped as fast algorithms based on efficient prediction techniques, improved RD cost calculation technique, efficient filter design and finally improved transform technique.

EFFICIENT PREDICTION TECHNIQUES

There are good amount of papers have been reported in efficient prediction techniques. It can be said that this is one of the most effective technique to make a fast algorithm in HEVC. The fast encoder decision algorithm called FEN has been included in HM Software which can reduce the complexity greatly. The main idea of FEN is

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that the following CU calculation is skipped when the rate-distortion cost of current CU selects SKIP mode as the best mode is smaller than the average rate-distortion cost of previously encoded CUs as SKIP mode. The average rate-distortion of previously skipped CUs is multiplied by fixed weighting factor to increase the number of CUs which can be encoded as SKIP mode. The weighting factor of FEN is 1.5.

In (Kim *et al*., 2010) an adaptive coding unit has been proposed based on early SKIP detection technique. In this study, 3 tests have been performed to find the statistical characteristics of SKIP mode. From these tests it is found that current CU and neighboring CUs are highly correlated. Hence, in this study an adaptive weighting factor adjusting method is proposed using these correlations. The initial weighting factor of proposed method is fixed on 1 then the weighting factor is adjusted 1.0-2.0. The experimental result shows that the average coding time cab be reduced up to 54% using this technique. In natural pictures, neighboring blocks usually hold similar textures. Consequently, the optimal intra prediction of current block may have strong correlation with its neighboring blocks. Based on this consideration, in (Zhao *et al*., 2011) conditional probabilities has been estimated for the optimal intra direction of current block. From this calculation a Most Probable Mode (MPM) is defined from its neighboring blocks. From the statistic results, it is observed that the MPM of current block possesses a large ratio to be the best mode in current block in both test conditions and this ratio of MPM fluctuates only a little between different sequences.

It is shown that the large CU can be considered as very efficient for high resolution, slow motion or large QP video sequence (Leng *et al*., 2011). Larger CU can provide less side information and motion vectors. Apart from that it can also predict the smooth and slow motion part of sequence more accurately. So, there exists mode correlation among consecutive frames. In this study, the researchers have provided two key ideas: frame level and CU level in this context. About 45% encoding time saving can be possible using this technique. The researchers take the reference software HM 0.9 as a bench mark and developed their own system based on hierarchical block-based coding and a block-adaptive translational model in inter-frame coding (Peng *et al*., 2011). In (Van Wallendael *et al*., 2011) a low complexity intra mode prediction algorithm has been proposed which combines most probable mode flag signaling and intra mode signaling in one elegant solution. Using this algorithm, 33% bit rate reduction can be obtained. The algorithm takes neighboring intra modes into account to obtain a prioritization of the different modes. In most video coding, chroma samples prediction is performed after the luma samples are taken. The researchers have proposed a reversed prediction structure that would make luma predictions after the chroma samples were taken (Chen *et al*., 2011). In the conventional structure, the intra prediction has to calculate 341 (256+64+16+4+1) times for luma intra prediction when the maximum CU is set to 64×64 and the max allowed partition depth is 4. However, the proposed structure calculates only 85 (64+16+4+1) times in chroma samples. Experiment results show that the proposed algorithm can achieve approximately 30% time savings in average with 0.03, 0.05 BD-PSNR losses in chroma components and unnoticeable increments in bit rate.

Generally, the bi-prediction is effective when the video has scene changes, camera panning, zoom-in/out and very fast scenes. It is shown that the RD costs of forward and backward prediction are increasing when bi-prediction is the best prediction mode from observation (Kim *et al*., 2012). This study presents a kind of the bi-prediction skipping computational complexity of bi-prediction efficiently. Their assumption is that if the bi-prediction is selected by the best prediction mode, the RD costs of blocks which are included in each list (forward and backward) can be larger than the average RD cost of earlier blocks which is coded by forward and backward prediction. The consuming time for bi-prediction is almost 20% of total encoding time. The proposed method can reduce nearly half of total bi-prediction time with negligible loss of quality. In (Lee *et al*., 2011) another efficient bi-prediction algorithm has been proposed based on the Overlapped Block Motion Compensation (OBMC). It views the received motion data as a source of information about the motion field and forms a better prediction of a pixel's intensity based on its own and nearby block MVs.

On the other hand, the prediction mode in HEVC can be divided into three categories: inter, skip and merge. When a PU is coded in either skip or merge mode, no motion information is transmitted except the index of the selected candidate. The residual signal is also omitted for skip. Based on this observation, three novel techniques have been proposed by Lin *et al*. (2011) for efficient merging of the candidate block. However, these three proposed coding tools were adopted in HEVC and integrated in HM-3.0 onwards. In (Teng *et al*., 2011) a fast algorithm for residual quad-tree mode decision has been proposed based on merge and split decision process. Experimental results show that it gives 42-55% encoding time reduction.

IMPROVED RD COST CALCULATION

Apart from fast mode decision algorithms, researchers are trying to improve the rate distortion calculation technique. In this context by Lee and Kim

(2011) a mixture of Laplacian-based RD cost calculation scheme has been proposed. In this study, it is shown and analyzed that the inter-predicted residues exhibits different statistical characteristics for the CU blocks in different depth levels. The experimental results show that based on the mixture Laplacian distribution, the proposed rate and distortion models are capable of better estimating the actual rates and distortions than the one based on the single Laplacian distribution.

In order to reduce the total Rate Distortion (RD) cost, in (Zou *et al*., 2011) a set of transform pairs that can minimize the total RD cost has been proposed. The proposed transforms are trained offline using several video sequences. The transforms are achieved by matrix multiplication. The proposed scheme provides a set of rate distortion optimized transforms which achieves 2.0% bit rate saving and 3.2% bit rate in Intra HE and Intra LoCo setting. The number of full R-D checks for Intra prediction mode decision is reduced (Tan *et al*., 2011). The Residual Quad Tree (RQT) checking is always done for all Intra prediction modes that undergo R-D checks. That is, less Intra-prediction modes are tested but for each of the mode tested, a thorough search for the optimal transform tree is carried out.

EFFICIENT FILTER DESIGN

The video codec under development still relies on transform domain quantization and includes the same in-loop deblocking filter adopted in the H.264/AVC standard to reduce quantization blocking artifacts. This deblocking filter provides two offsets to vary the amount of filtering for each image area. In (Naccari *et al*., 2011) a perceptual optimization technique has been proposed of these offsets based on a quality metric able to quantify the blocking artifacts impact on the perceived video quality. The implementation complexity of Adaptive Loop Filtering (ALF) for luma at the decoder is analyzed by Budagavi *et al*. (2011). Implementation complexity analysis involves not only analysis of computations but also analysis of memory bandwidth and memory size. These filters reduce memory bandwidth and size requirements by 25 and 50%, respectively with minimal impact on coding efficiency. Sample Adaptive Offset, namely SAO has been proposed by Fu *et al*. (2011) to reduce the distortion between reconstructed pixels and original pixels. The proposed SAO can achieve 1.3, 2.2, 1.8 and 3.0% bit rate reductions. The encoding time is roughly unchanged and the decoding time is increased by 1-3%.

IMPROVED TRANSFORM TECHNIQUE

Applying mode-dependent separable transforms is an effective method for improving transform coding of intra prediction residuals. In (Yeo *et al*., 2011) an orthogonal 4-point integer Discrete Sign Transform (DST) has been proposed that has a multiplier-less implementation consisting of only add and bit-shifts. These properties make the proposed implementation suitable for low complexity architecture. Experimental results show that the proposed implementation matches the coding performance of fixed-point arithmetic implementation of the integer Odd type-3 Discrete Sine Transform (ODST-3) and approaches closely the performance of fixed-point arithmetic implementation of trained KLTs. The new transform coding techniques in the HEVC Test Model has been described including the Residual Quad Tree (RQT) approach and coded block pattern signaling (Winken *et al*., 2011). Experimental results showing the advantage of using larger block size transforms, especially for high resolution video material are presented.

CONCLUSION

In this study, several different fast algorithms for HECV have been surveyed. Researchers observed that there are four major groups present where the researchers are trying to make the new coding standard as fast as possible. Researchers believe that this survey may be beneficial for the researchers to have a proper motivation and direction to make a fast algorithm using HEVC coding standard.

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