A Study on Intra-Prediction Mode Deciding Algorithms of HEVC

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Abstract: Image Compression on digital images reduces the size of a file. It saves space while storing and time when transmitting it. Video compression uses modern coding techniques to reduce redundancy in video data. Most video compression algorithms and codecs combine spatial image compression and temporal motion compensation.High Efficiency Video Coding (HEVC), a successor to H.264, is the next generation video compression standard. It can achieve 50% bitrate saving compared with previous standard H.264/AVC. To enhance the coding efficiency of video frames, 35 intra prediction modes are used in Prediction Unit (PU) of HEVC to reduce spatial redundancy. The intra prediction unit of HEVC achieves higher compression ratio and image quality compared with previous standard. The best mode among these pre-defined intra prediction modes are selected by rate-distortion optimization (RDO) method for each blockand it involves large number of prediction directions at a cost of very high computational complexity. This paper reviews different intra prediction mode algorithms in order to reduce the computational complexity.

***KEYWORDS**–Video Compression, HEVC, Prediction Modes, Intra-Prediction, and RDO*

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I. Introduction

Compression is the basic process of reducing the size of data in order to save storage space and transmission band width. Compressionis removing different redundancies like spatial, temporal and encoding the information to suite for various applications. To compress data, it is necessary to recognize redundancies in data in the form of coding redundancy, inter- pixel redundancy, and psycho-visual redundancy.

Image compression/video coding is important in industrial imaging, commercial and academic applications. Image /video coding plays an important role in multimedia. [2]. The primary goal of most digital video coding standards has been to optimize coding efficiency. Coding efficiency is the ability to minimize the bit rate necessary for representation of video content to reach a given level of video quality. [3]

Recently, the requirements of ultra-high definition video contents have emerged along with the developments in multimedia services. Aiming to substantially improve the coding efficiency of the current H.264/AVC [1] standard, a Joint Collaborative Team on Video Coding (JCT-VC), the most recent joint video project of the ITU-T Video Coding Experts Group (VCEG) and the ISO/IEC Moving Picture Experts Group (MPEG) standardization organizations, was formed in 2010 to develop a new International Standard, named as High Efficiency Video Coding (HEVC). [4]

HEVC is widely used for many applications, including broadcast of high definition (HD) TV signals over satellite, cable, and terrestrial transmission systems, video content acquisition and editing systems, camcorders, security applications, Internet and mobile network video, Blu-ray Discs, real-time conversational applications such as video chat, video conferencing, and telepresence systems. Moreover, the traffic caused by video applications targeting mobile devices and tablet PCs and the transmission needs for video-on-demand services, are imposing severe challenges on today's networks. An increased desire for higher quality and resolutions is also arising in mobile applications.

This Paper focuses on different algorithms todecideon the intra prediction modes based on minimum RDO cost in HEVC. The rest of the paper is organised as follows: Section II describes

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about HEVC encoder and fast intra mode decision of HEVC Section III presents a brief literature review of the fast intra prediction algorithms for HEVC. Experimental results are analysed in Section IV to demonstrate the efficiency of the algorithms, while Section V concludes the work in this paper.

II Related Work

2. HEVC: A Review

The video coding layer of HEVC employs the same hybrid approach (inter-/intra - picture prediction and 2-D transform coding) used in all video compression standards since H.261. Fig. 1 depicts the block diagram of a hybrid video encoder, which could create a bit stream conforming to the HEVC standard.

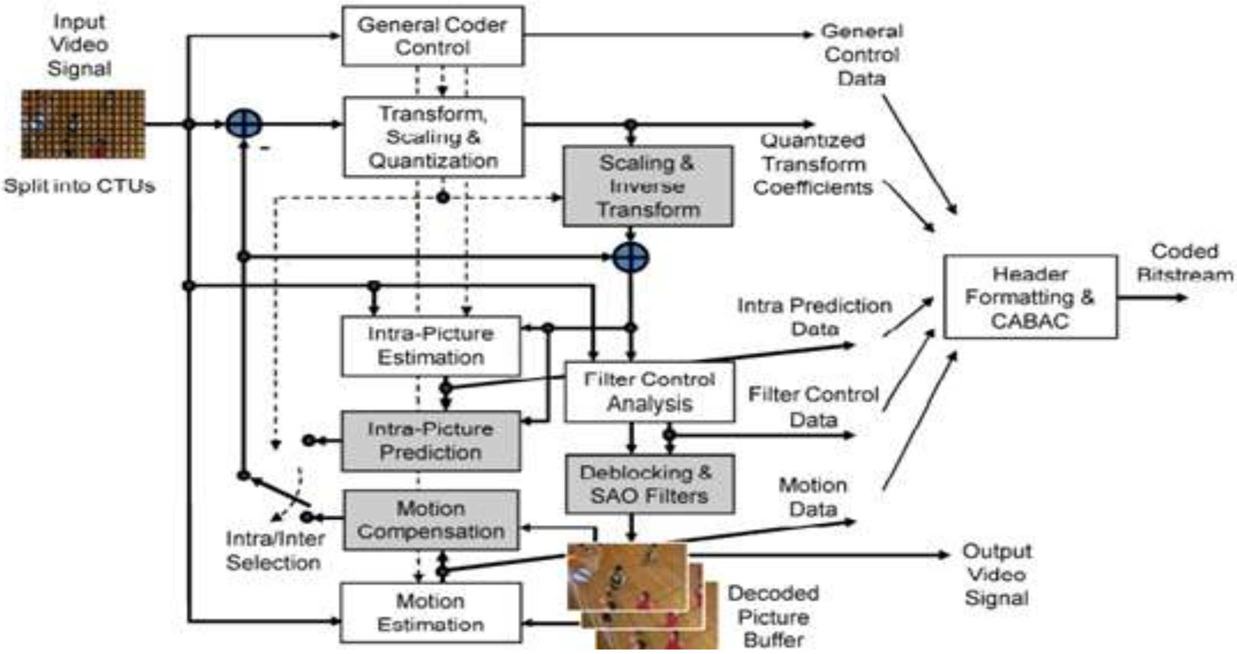

Figure 1: Block diagram of HEVC encoder.

An encoding algorithm producing an HEVC complaint bit stream would typically proceed as follows:

Video pictures are firstly divided into slices and slices are split into sequences of largest coding units (LCU). HEVC employs a content-adaptive quad tree structure with three block concepts: coding unit (CU), prediction unit (PU) and transform unit (TU), which enables the efficient use of large and multiple sizes of coding, prediction and transform blocks. CU is the elementary unit of region splitting used for inter/intra prediction; its size can range from 8×8 to 64×64 in the test model of HEVC (HM).

The CU concept allows for recursive splitting into four equal blocks, as shown in Fig. 2. PU is the elementary unit for prediction and is defined after the last depth level of CU splitting. For intra prediction, two PU sizes are supported at each depth level: 2 N×2 N and N×N. The types of PU are 64×64, 32×32, 16×16, 8×8 and 4×4. TU is the unit for transform and quantisation. [5]

The first picture of a video is coded using only intra picture prediction that uses some prediction of data spatially from region-to-region within the same picture, but has no dependence on other pictures.

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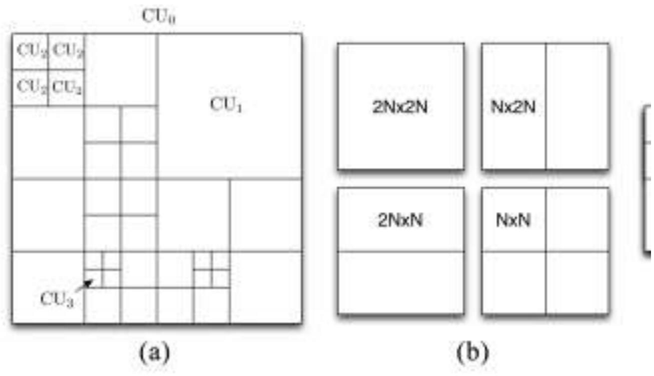

Figure 2: Illustration of recursive CU structure in HEVC

Intrapicture prediction supports 33 directional modes compared to eight such modes in H.264/MPEG-4 AVC, plus planar (surface fitting) and DC (flat) prediction modes.Therefore, the search modes of intra prediction in HEVC are considerably larger than those of H.264/AVC. For example, intra prediction in H.264/AVC generates 2,872,320 prediction blocks in one frame with FHD (1920×1088) resolution when each prediction block is divided by 4×4 block. In contrast, intra prediction in HEVC generates 22,848,000 modes, i.e., about 8 times larger than H.264/AVC.There are several effective approaches present in intra prediction to reduce the complexity.

HEVC reference software adopts a Hadamard transform-based rough mode decision (RMD) to choose fewer candidates (out of 35 modes). [6]The selected intra picture prediction modes are encoded by deriving most probable modes (e.g., prediction directions) based on those of previously decoded neighbouring PBs.The rate distortion optimisation (RDO) process to find the mode with the least rate distortion (RD) cost in all of the possible depth levels (CU sizes) and intra prediction modes is then applied. The R-D cost of sub-CUs and sub-TUs is predicted by the Hadamard costs. The predicted cost is then compared with the R-D cost in the upper level to decide whether the CU split is necessary. The RD cost function (J_{RDO}) used in HM is evaluated as follows:

$$J_{RDO} = SSE + \lambda \times B \quad (1)$$

where SSE is the sum of square error of current CU and the matching blocks, λ is the Lagrange multiplier and B specifies the bit cost to be considered for mode decision, which depends on each decision case. [5]

For all remaining pictures of a sequence or between random access points, inter-picture temporally predictive coding modes are typically used for most blocks. The encoding process for inter-picture prediction consists of choosing motion data comprising the selected reference picture and motion vector (MV) to be applied for predicting the samples of each block.

The encoder and decoder generate identical inter-picture prediction signals by applying motion compensation (MC) using the MV and mode decision data, which are transmitted as side information.

The residual signal of the intra- or inter-picture prediction, which is the difference between the original block and its prediction, is transformed by a linear spatial transform.

The transform coefficients are then scaled, quantized, entropy coded, and transmitted together with the prediction information. [3]

2.1 Intra-Prediction Modes

The Intra-picture prediction uses the previously decoded boundary samples from spatially neighbouring 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:

- Due to the larger size of the pictures, the range of supported coding block sizes has been increased.
- A planar mode that guarantees continuity at block boundaries is desired.

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- The number of directional orientations has been increased.
- For intra mode coding, efficient coding techniques to transmit the mode for each block are needed due to the increased number of intra modes.
- 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 encoding complexity of HEVC becomes extremely larger than that of H.264/AVC because of newly introduced coding tools. Especially, intra prediction introduces 35 prediction modes including directional modes, while H.264/AVC has 9 intra prediction modes. Coupled with a recursive quad-tree partitioning, the increased modes of intra prediction in HEVC face the serious difficulties in the encoding complexity. There are many proposals to solve the complexity problem of intra prediction in H.264/AVC [7]

III Review on Intra Prediction modes

Sangkwon et.al [7] proposes anEdge-Based Fast Mode Decision Algorithm for Intra Prediction in HEVC where they adopted the correlation between a local edge and intra prediction mode. First, the candidate modes are characterized for the given edge direction with the edge map built with Sobel edge operator and edge histogram. Parameters are utilized to determine the edge direction in an image block, i.e. vertical, horizontal, 45-degree, 135-degree direction. With the edge map, the range of coding unit (CU) sizes has been determined in terms of the uniqueness of the edge direction in the image block. If the sole edge direction exists in the given blocks on a quad-tree structure, those blocks were merged into a single block. As a result, unnecessary rate-distortion optimization processes can be removed so as to minimize the computational complexity in intra prediction.

Jiang et.al [8] proposeda gradient based fast mode decision algorithm to reduce the computational complexity of HEVC.In this paper prior to intra prediction, gradient directions are calculated and a gradient-mode histogram is generated for each coding unit. Based on the distribution of the histogram, only a small part of the candidate modes are chosen for the RMD and the RDO processes. As compared to the default encoding scheme in HEVC test model HM 4.0, experimental results show that the fast intra mode decision scheme provides almost 20% time savings in all intra low complexity cases on average with negligible loss of coding efficiency.

Chen et.al [9] proposes a Pixel Gradient Statistics (PGS) and Mode Refinement (MR) based fast mode decision algorithm in which PGS uses pixel gradient information to assist prediction mode selection after Rough Mode Decision (RMD).In Jiang et.al [2], it reduced time and only aimed at RMD part. RDO had more calculation than RMD. The RDO part use similar theory of Jiang’s and saves time.In this algorithm PGS use pixel gradient information to assist prediction mode selection after Rough Mode Decision (RMD). MR utilized neighbouring mode information to select most probable mode (MPM). Thus the proposed algorithm reduced the huge calculating time and save the efficiency as much as possible.

Zhang et.al [10]proposes an adaptive fast mode decision for intra prediction for the emerging HEVC standard. By utilizing the blocks’ texture characteristics from rough mode decision and by further simplification of RQT splitting process, they adaptively reduce the number of uncorrelated directions taking part of in Rate-Distortion optimization (RDO), which results in a reduction of intra encoder complexity. Experiment results show that the proposed scheme has almost negligible loss while reducing encoding complexity based on HM-4.0.

Min et.al [11] proposed a fast algorithm to reduce the coding complexity, based on the statistical cost and corner detection algorithmfor intra coding in HEVC. The paper discuss the gradient homogeneity in a block, represented by the corner detection response. A block can be categorized as corner, edge and flat area by the corner response. If corner points exist in a block, it is considered to be have multiple strong gradients in a block. Therefore, the intra coding in the current depth can be skipped and the block is decided to be split into smaller size. Otherwise, the edge and flat block is considered to can be predicted by only one directional angle. If its RD cost is small one among the statistical costs derived from the training block, the searching of best intra coding of the block is terminated at the current depth. The time saving of the proposed method in this paper is over 62% on average and up to nearly 80%, while the increased BD-rate is about 3.42%.

IV Experimental Analysis

The algorithms was implemented on the HEVC test model (HM).Table I gives the comparison results between the Sangkwon et.al [7] andZhang et.al [10] algorithms in terms of BD-Rate (BDR) (%) and Time-Saving (TS) (%), Table 2 gives the comparison between Jiang et.al [8] andChen et.al [9] algorithms.

Table 1: Performance Comparison

	Sangkwon algorithm		Zhang algorithm	
Sequences	BDR	TS(ΔT)	BDR	TS(ΔT)
Class A (2560 X 1600)	2.20%	-59.90%	0.70%	-20%
Class B (1920 X 1080)	1.60%	-67.50%	1.20%	-21.00%
Class C (832X 480)	2.50%	-52.90%	1.00%	-21.00%
Class D (416X 240)	2.40%	-46.50%	0.80%	-21.00%
Class E (1280 X 720)	3.60%	-56.90%	1.50%	-19.00%

Table I reports the experimental results of Zhang's work[10] and the Sangkwon algorithm[7] compared in terms of the relative bit-rate calculated by Bjontegaard delta bit-rate (BD-BR) and the encoding time in CPU; ΔTime represents the encoding time reduction. As shown in Table I, the proposed algorithm reduces the total encoding time by 20.5% at the cost of 0.94% BD-BR increase on average.

Table 2: Performance Comparison

		Jiang's algorithm		Chen's algorithm	
Sequences		BDR	TS(ΔT)	BDR	TS(ΔT)
Class A 2560 X1600	Traffic	0.5	20.35	0.57	28.41
	PeopleOnStreet	0.6	20.38	0.41	29.11

Class B 1920 X 1080	Cactus	0.77	20.28	0.53	29.21
	BasketballDrive	1.16	19.88	0.61	27.85
Class C 832X 480	RaceHorses	0.65	20.15	0.8	28.08
	BasketballDrill	0.79	19.55	0.4	32.27
	BQMall	0.77	19.22	0.12	27.82
Class D 416X 240	BQMall	0.84	19.22	0.53	28.74
	BasketballPass	0.99	19.2	0.63	27.23
	RaceHorses	1.06	20.43	0.63	26.49
Class E 1280 X 720	Vidyo1	0.92	20.33	0.76	28.76
	Vidyo3	0.85	19.87	0.46	27.31
	Vidyo4	0.74	20.16	0.38	28.54

From the experimental analysis we have found that proposed fast intra mode decision methods give the state-of-the-art performance in terms of the trade-off between the coding efficiency and the encoding complexity.

V. Conclusion

In this paperwepresented the different intra-prediction mode deciding algorithmof HEVC Standard. Many fast prediction algorithms are studied to review how they help to reduce the number of prediction modes which in turn reduce the computational complexity.Experimental results show that the reviewed algorithms could save encoding time with BD-rate gain and BD-PSNR loss.The future work would be to find an algorithm for predicting intra-prediction modes that can speed up the coding efficiency of HEVC intra coding with the increase in a BD-Rateand decrease in BD-PSNR.

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