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A fast CU partition and mode decision algorithm for HEVC intra coding

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ABSTRACT

The latest video coding standard H.265/HEVC is a milestone because it can achieve up to 50 % coding performance improvement compared to the widely used H.264/AVC, owing to the newly introduced coding tools. However, these new techniques also introduce dramatic computational complexity increase. In order to release the computational burden while maintaining the coding efficiency, a two-part fast intra coding algorithm is proposed in this paper. First a CTU depth range prediction and two Bayesian decision rules are applied to accelerate the CU partition process. The depth search range of the current CTU is restricted by the neighboring CTUs on account of the spatial correlation. And one early split and one early termination strategies is presented based on the minimum Bayesian decision rule. Next, a three-step fast intra mode decision algorithm is performed to speed up the intra coding, both the depth information and the orientation information of the current CU are used to skip some unnecessary intra mode check, and the order of Most Probable Modes (MPM) is adjusted to further remove redundant calculation. As demonstrated in the experimental results, our proposed algorithm can reduce 52.9% encoding time on average with the cost of an negligible coding efficiency loss under the All-Intra configuration.

1. Introduction

High Efficiency Video Coding (HEVC) [1] is the state-of-the-art video coding standard developed by the Joint Collaborative Team on Video Coding (JCT-VC) in 2013. The HEVC shows a significant coding efficiency improvement compared with its predecessor H.264/AVC [2], it can achieve almost 50% bit rate saving under the same video quality. This tremendous coding efficiency benefits from many new coding tools, such as recursive quad-tree coding structure, refined prediction mode, large block transform, and advanced loop filter, etc.

Among all these new techniques, the recursive quad-tree coding structure is a strong feature of the HEVC for coding efficiency improving. The HEVC employs Coding Tree Unit (CTU) as the basic processing unit, to replace the macro block in previous H.264/AVC. Each CTU can be recursively split into several coding units (CU), which can be expressed in a quad-tree representation. The CU has a flexible size range, the Largest CU (LCU) has 64×64 pixels and the Smallest CU (SCU) is 8×8. Prediction Unit (PU) is the basic unit for prediction and its size varies from 64×64 to 4×4, it contains all the prediction information of a CU such as the best prediction mode, and motion vectors, and the indices of reference frames for inter-coded CUs. For intra coding, the SCU has two different types of PU size ($2N \times 2N$ and $N \times N$), other CU sizes only have one type of PU ($2N \times 2N$). Transform Unit (TU) is the basic unit for transformation and quantization, which has a flexible size range from 32×32 to 4×4. The optimal TU size is dependent on the feature of prediction residual, a bigger TU can better centralize the energy, while a smaller TU can keep more detail information of the texture. The quad-tree structure of CU, PU, and TU is shown in Fig. 1. This flexible hierarchy enables HEVC to choose a coding structure more adaptive to the video content. The complex regions can be described precisely by CUs with small size, while the homogeneous regions can be handled well by adopting large CU. More details about CTU partition can be found in [3]. Besides, up to 35 prediction modes (Planar, DC and 33 angular modes) are supported in HEVC intra coding, increased from 9 modes of its predecessor H.264/AVC. The fine-grained as well as flexible CTU lead to higher accuracy and smaller residuals, thus the video signal get a better compression and the coding efficiency is significantly improved.

However, this coding performance optimization is obtained at the cost of a high computational burden, which mainly comes from the necessity that the encoder have to find out the best CU partitions for all CU combinations. In HEVC intra coding, a recursively search in depth first order is performed for every CTU, and on each possible CU size, a complex Rate Distortion Optimization (RDO) [4] process is executed to obtain the best PU mode and TU structure. As we can see, these new tools introduced vast computational burden, making the complexity of

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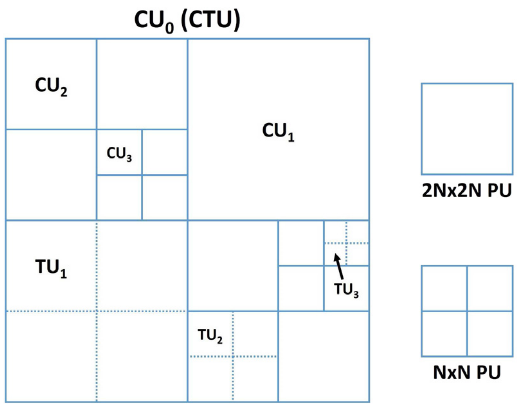

Fig. 1. The recursive quad-tree structure of CU, PU and TU in HEVC, where k indicates the depth for CU_k and TU_k.

HEVC increasing several times compared with H.264/AVC [5]. This intolerable computational complexity even makes the coding performance improvement not so welcome in some power-constrained and real time applications. Thus, it is important to develop fast coding algorithm to reduce the computational burden while maintaining the coding efficiency. In this paper, we proposed a fast CU partition and intra mode decision algorithm for HEVC, on the basis of our previous conference paper [6] with extensive advanced work.

The rest of the paper is organized as follows. Section 2 introduces the default fast mode decision algorithm in HEVC intra coding and presents a brief review of the relative works. Section 3 introduces the framework of the proposed algorithm and describes the fast CU size decision and fast intra mode decision scheme in detail, respectively. Section 4 demonstrates and analyzes the experimental results, and the conclusion is given in Section 5.

2. Background and related work

2.1. Review of HEVC intra coding

In order to cut down the computational burden of encoder, the HEVC test model reference software [7] employs a three-step fast mode decision technique to accelerate the intra coding process, which is shown in Fig. 2. First, Rough Mode Decision (RMD) [8] is executed to generate a set of candidate modes (for convenience we use $\boldsymbol{C}$ to indicate this set) from all 35 prediction modes. The candidate set $\boldsymbol{C}$ is built according to J_{SATD}, which is computed as follow:

$$J_{SATD} = SATD + \lambda \cdot B \tag{1}$$

where *SATD* is the Sum of Absolute Transform Difference between the original pixels and the predicted pixels, λ is the Lagrangian multiplier, and B is the necessary bits to encode the prediction mode. To some extent, the *SATD* can reflect the intensity of residual in the frequency domain, and its performance is similar with the Discrete Cosine Transformation (DCT) [9], thus the J_{SATD} can be regarded as an approximation of the Rate-Distortion (RD) cost. Then after the calculation of J_{SATD}, a number of prediction modes with small J_{SATD} are selected to form the candidate set $\boldsymbol{C}$. Eight modes are selected for PUs with size of 4×4 and 8×8, and three modes for PUs with larger size. In the second step, the Most Probable Modes (MPM) [10] is performed. They motivation of MPM is that in a frame, the neighboring blocks often hold a strong correlation, and have a high probability to choose the same or similar prediction mode as the best mode. The encoder generates a MPM list contains 3 modes based on the best mode of the already coded neighboring PUs, and the MPM will be added to the candidate set $\boldsymbol{C}$ if they are not included yet. Finally, the RDO process is applied to decide

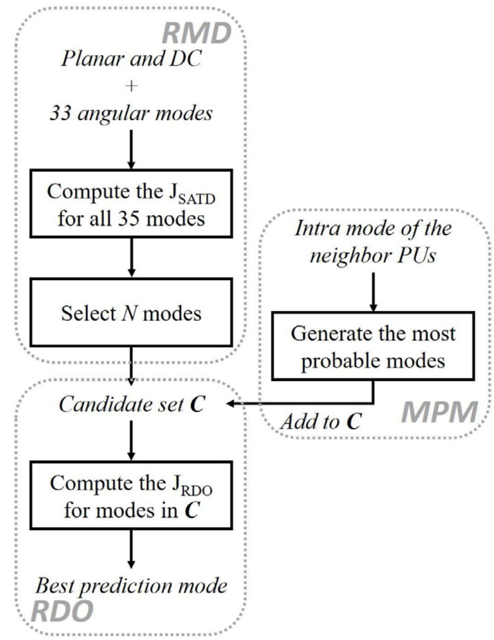

Fig. 2. The three-step fast mode decision technique in the HEVC test model reference software.

the best prediction mode. The RDO process can be describe as finding a mode to minimize the distortion with a given rate constriction, the RD cost J_{RDO} is calculated as follow:

$$J_{RDO} = SSE + \lambda \cdot R_{total} \tag{2}$$

where *SSE* means the Sum of Squared Errors between the original pixels and the reconstructed pixels, it can express the distortion caused by compression. R_{total} is the total number of bits used to code the mode. The J_{RDO} can reflect the overall performance of a mode by synthetically considering how the quality loss and bit rate impact the coding efficiency. By comparing the J_{RDO}, the mode with the lowest J_{RDO} will be chosen as the best prediction mode for current CU.

Because this three-step fast mode decision technique is applied, the number of modes need be check in RDO process is reduced from 35 to 3˜11, which can cut down some computational burden of the encoder. But the complexity is still high, since the RMD process have to traverse all 35 intra modes, and this intra prediction process need to be performed on all possible CU depth. Thus there is still some room for improvement in terms of computational complexity reduction.

2.2. Relative work

Recently, there have been a lot of works on reducing the computational complexity of HEVC intra coding. Most of the fast algorithm focus on optimizing the CU partition process or accelerating the intra mode decision process, and a number of algorithms combine two or more techniques to develop a hybrid algorithm. In this sub-section, some relative works will be briefly reviewed in different categories.

CU partition optimization. Min and Cheung [11] proposed a fast CU decision algorithm based on edge complexity. The global and local edges in different direction are utilized to decide the partition of a CU. Zhang et al. [12] introduced a two-stage algorithm. First the Hadamard cost of sub-CUs are used to represent the complexity of a CU, thus some compound CUs can be early split. In the second stage, an estimated RD cost is employed to make a early pruned decision. Lu et al. [13] proposed a hierarchical CU size decision algorithm, they used an adaptive threshold to classify the homogeneity of the video content