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Fast intra-encoding algorithm for High Efficiency Video Coding

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ABSTRACT

The emerging High Efficiency Video Coding (HEVC) standard provides equivalent subjective quality with about 50% bit rate reduction compared to the H.264/AVC High profile. However, the improvement of coding efficiency is obtained at the expense of increased computational complexity. This paper presents a fast intra-encoding algorithm for HEVC, which is composed of the following four techniques. Firstly, an early termination technique for coding unit (CU) depth decision is proposed based on the depth of neighboring CUs and the comparison results of rate distortion (RD) costs between the parent CU and part of its child CUs. Secondly, the correlation of intra-prediction modes between neighboring PUs is exploited to accelerate the intra-prediction mode decision for HEVC intra-coding and the impact of the number of mode candidates after the rough mode decision (RMD) process in HM is studied in our work. Thirdly, the TU depth range is restricted based on the probability of each TU depth and one redundant process is removed in the TU depth selection process based on the analysis of the HEVC reference software. Finally, the probability of each case for the intra-transform skip mode is studied to accelerate the intra-transform skip mode decision. Experimental results show that the proposed algorithm can provide about 50% time savings with only 0.5% BD-rate loss on average when compared to HM 11.0 for the Main profile all-intra-configuration. Parts of these techniques have been adopted into the HEVC reference software.

1. Introduction

The High Efficiency Video Coding (HEVC) standard [1] developed by the Joint Collaborative Team on Video Coding (JCT-VC) achieves equivalent subjective quality with about 50% bit rate reduction when compared to the H.264/AVC High profile [2,3]. Specifically, the bitrate decrement of HEVC intra-coding over H.264/AVC is about 25% on average [4]. HEVC adopts a similar block-based hybrid video coding framework as H.264/AVC [5,6], but provides a highly flexible hierarchy of unit representation, which includes three units: coding unit (CU), prediction unit (PU) and transform unit (TU) [7]. CU is the basic unit used for inter/intra-coding, which allows recursive splitting into four equally sized CUs. The recursive splitting of CU is content adaptive, which is one of the biggest differences compared to H.264/AVC. PU is the basic unit used in a prediction process, whereas TU is the basic unit for transform and quantization processes. Both the sizes of PU and TU cannot exceed the size of CU.

Because of the recursive splitting, encoder needs to exhaust all combinations of all the possible sizes of CU, PU, and TU to select the optimal solution, which is very time consuming. In addition, an intra 4×4 TU has to decide whether to skip transform or not [8].

Recently, some works on reducing the complexity of the intra-encoding process have been proposed [9–18].

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Instead of using a fixed CU depth range for each CU, a current CU depth range is adaptively determined depending on the previously encoded slices and neighboring CUs [9,10]. Meanwhile, the comparison of rate-distortion (RD) costs between the two neighboring CU depths is exploited to early terminate the splitting of CU in quad-tree structure [11]. At each CU depth, the early CU splitting and pruning methods are performed based on low-complexity RD costs and full RD costs [12]. Furthermore, a novel complexity control method by selectively constraining the depth of CU is proposed in order to not exceed a predefined complexity target for the HEVC encoder [13,14]. To reduce the complexity of intra-mode decision, a fast intra-mode decision [15] was adopted into HM1.0. It includes two steps. In the first step, all intra-prediction modes are involved in a rough mode decision (RMD) process to select the N best candidate modes in terms of the minimum sum of absolute values of Hadamard transformed coefficients and the mode bits. In the second step, the rate-distortion-optimization (RDO) process is only applied to the selected N best candidate modes. However, the correlation of the intra-prediction modes among the spatially neighboring CUs is not considered in the intra-mode decision. To further accelerate the intra-mode decision process, a fast intra-prediction mode decision exploring the correlation of intra-prediction modes between neighboring CUs is proposed [16]. To speed up the selection of the best TU depth in transform unit structure, the TU depth selection process is only applied to the best intra-prediction mode instead of all intra-prediction modes [17]. However, the statistical distribution of TU depth is not used in the TU depth selection process. For fast intra-transform skip mode decision, Francois et al. propose to disable the intra-transform skip mode for 4 × 4 chroma TUs when the 8 × 8 luma TU is not split into four 4 × 4 TUs or none of the four 4 × 4 luma TUs uses the intra-transform skip mode [18]. However, the complexity of intra-transform skip mode decision for 4 × 4 luma TUs should also be reduced.

In this paper, to further relieve the computation load of the encoder, a fast intra-encoding algorithm is proposed, which is composed of four techniques. Firstly, an early termination technique for coding unit (CU) depth decision is proposed based on the depth of neighboring CUs and the comparison results of rate distortion (RD) costs between the parent CU and part of its child CUs. Secondly, the correlation of intra-prediction modes between neighboring PUs is exploited to accelerate the intra-prediction mode decision for HEVC intra-coding and the impact of the number of mode candidates after the rough mode decision (RMD) process in HM is studied in our work. Thirdly, the TU depth range is restricted based on the probability of each TU depth and one redundant process is removed in the TU depth selection process based on the analysis of the HM software. Finally, the probability of each case for the intra-transform skip mode is studied to accelerate the intra-transform skip mode decision.

The rest of this paper is organized as follows. Section 2 presents an overview of intra-encoding in HEVC. Section 3 gives a detailed description of the proposed fast intra-encoding algorithm. Experimental results are provided in Section 4. Section 5 concludes this paper.

2. Overview of intra-encoding in HEVC

This section reviews the intra-encoding process of HEVC from the following four aspects: coding tree unit (CTU) and coding unit (CU) structure, intra-prediction, transform unit structure, and intra-transform skip mode.

2.1. Coding tree unit and coding unit structure

A picture is composed of a sequence of coding tree units (CTUs). The CTU concept is similar to the macroblock in H.264/AVC [5]. The coding unit (CU) is the basic unit used for inter/intra-coding, which is the leaf node of the CTU. The largest coding unit and the smallest coding unit in a CTU is specified by 64 × 64 and 8 × 8 in the Main profile respectively. One example of recursive splitting for CTU is illustrated in Fig. 1.

2.2. Intra-prediction

As shown in Fig. 2, for intra-coded CU, there are two partition types of prediction unit (PU): Part_2N × 2N and Part_N × N, where the CU size is equal to 2N × 2N and the partition type Part_N × N is only allowed for the smallest CU. The size of PU ranges from 4 × 4 to 64 × 64 and each PU has 35 intra-prediction modes, where intra-prediction mode 0 refers to the planar intra-prediction, mode 1 to DC prediction, and modes 2–34 to angular prediction modes with angles of +/− [0, 2, 5, 9, 13, 17, 21, 26, 32]/32 [4]. Fig. 3 further illustrates the 35 intra-prediction modes. When compared to the 9 intra-prediction modes in H.264/AVC, the 35 intra-prediction modes in HEVC are more adequate to model accurately different directional structures as well as homogeneous regions with gradually changing sample values. The number of intra-prediction

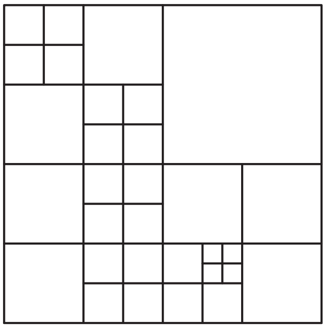

Fig. 1. Example of CTU structure.

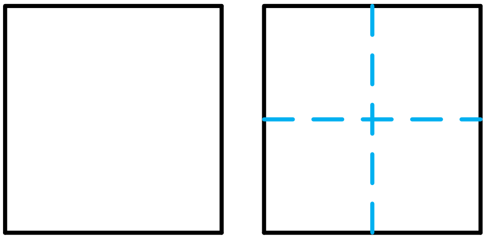

Fig. 2. Part_2N × 2N (left) and Part_N × N (right).