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Fast intra prediction method by adaptive number of candidate modes for RDO in HEVC

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ABSTRACT

The intra prediction of high efficiency video coding (HEVC) selects the candidate modes through rough mode decision (RMD) among 35 modes for intra coding. The fixed number of candidate modes after the RMD might be inefficient, because the rate-distortion optimization (RDO) process using candidate modes still takes about 35% of total encoding time.

In this letter, we propose an efficient method to reduce the number of candidate modes adaptively by adjusting the threshold for Hadamard cost (HC). The threshold is determined using the weight based on the standard deviation of gray level of pixels in prediction unit. The proposed method performs the RDO process using the reduced number of candidate modes having smaller HC than the threshold. Simulation results show that the proposed method gives about 16% complexity reduction with just 0.08% BD-rate increase compared with the original HEVC test model. The proposed method gives significant improvement of BD-PSNR and BD-rate with similar complexity reduction compared with the previous state-of-the-art method.

1. Introduction

High efficiency video coding (HEVC) standard aims significant improvement of coding efficiency compared with the H.264/AVC standard. The HEVC has the recursive quadtree structure for a variety of video resolutions, and can compress efficiently ultra-high-definition video. The encoding structure consists of coding unit (CU), prediction unit (PU), and transform unit (TU) [1,2].

The HEVC can go through recursive division process from 64×64 size to 8×8 size for each CU, and it determines the best size of CU. By the flexible size of CU, HEVC improves the prediction accuracy [10,11]. The HEVC intra prediction is performed using 64×64 to 4×4 sizes of PU and it provides 35 intra prediction modes. The intra prediction of HEVC is possible to predict PU in more flexible and accurate manner than H.264/AVC. However, the complexity of rate-distortion optimization (RDO) process increases significantly as the number of prediction modes increases. The HEVC test model (HM) [12] has combined rough mode decision (RMD) with most probable mode (MPM) to reduce the complexity to compute all the rate-distortion (RD) costs of 35 modes.

The RMD uses Hadamard transform for measuring distortion and selects the N candidate modes ordered by Hadamard cost (HC) among the 35 prediction modes for the current PU. In RDO process, the MPMs and the selected N candidate modes are compared for determining the best mode. Even though the RMD improves the efficiency of overall RDO computation, it still takes about 35 percent of total encoding time. The number of candidate modes is fixed to N (3 or 8) in the previous method, and it might be inefficient to perform the RDO process for all these modes.

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Recently, various algorithms have been proposed for the fast intra coding in HEVC. The prediction mode decision method based on edge information is proposed in [3] to reduce the complexity of intra prediction. However, the method in [3] requires overhead operations such as edge detection, histogram mapping, and threshold comparison, which increases overall complexity. Cho et al. [4] proposed the early CU splitting and pruning method based on statistics for fast CU size decision. However, the method in [4] might give worse compression performance because it depends on the fixed threshold. Cen et al. [5] proposed the fast coding unit depth decision scheme, which determines adaptively the CU depth through comparisons using spatial correlations. Cen's method [5] gives similar RD performance compared with the original HM in [12]. The method achieves 16% reduction of computational complexity, but it increases the BD-rate by 2.82%, which is rather large amount in the quality point of view.

At the micro-level of PU, the progressive rough mode search (pRMS) scheme was proposed to reduce the number of prediction modes and the early rate-distortion optimized quantization (RDOQ)-skip method for complexity reduction in [7]. At the macro-level, it also proposed the scheme of early CU split termination [7]. In this scheme, if the estimated RD cost is already larger than the RD cost of the current CU, early CU split is performed. The early RDOQ-skip method reduces the computational complexity, but it also gives relatively large amount of BD-rate increase.

Chen et al. [8] proposed a method for determining the CU/TU depth decisions and the number of candidate mode decisions based on HC for PU. For CU depth decisions, it accomplishes early termination and early splitting of CUs by identifying the mode with the least HC. For TU depth decisions, the TU partitions of the least HC mode is accelerated by simple copy for the remaining modes. For PU intra mode decisions, the prediction mode decision method reduces the number of candidate modes using the characteristics of image (complexity and gradient) and the ratio of HC. However, in the PU intra mode decisions, it may not be appropriate to decide the number of candidate modes for each PU size based on the global characteristics of an image since the local texture characteristics within PU for each case can be different.

Fast intra prediction mode and CU size decision method was proposed for fast intra coding in [9]. The CU size is determined using two linear support vector machines (SVMs) that employ depth difference and HC ratio (RD cost ratio) features. For intra prediction mode decision, the numbers of RMD modes and candidate modes are determined based on horizontal and vertical gradient information in PUs. However, this method still takes a fixed number of candidate modes in prediction mode decision.

2. Proposed method

In this letter, we propose the method to reduce the number of candidate modes adaptively in RDO process. The number of candidate modes after the RMD in the conventional method is set as $N = 3$ for PU sizes of 64×64, 32×32, and 16×16, and $N = 8$ for PU sizes of 8×8, and 4×4 [6,7]. The first candidate mode gives the smallest HC among the N candidates. The subsequent candidate modes are ordered by the corresponding HC. Let H_i represent the HC of i-th candidate mode, and $H_i < H_j$ for $i = 1, 2, \cdots, N$.

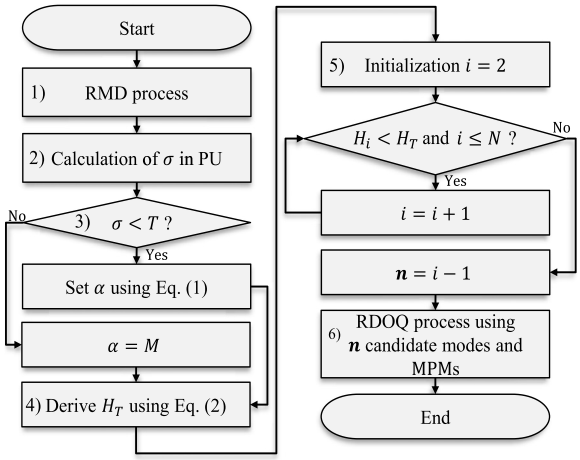

Fig. 1. Flowchart of the proposed method.

The proposed method determines the number of candidate modes adaptively by adjusting the threshold for HC. The threshold is determined using the weight based on standard deviation of gray level of pixels in PU, which gives information about the regional complexity of PU. The proposed method performs the RDO process using the MPMs and the reduced number of candidate modes, which have smaller HC than the adaptive threshold.

The proposed method is composed of six steps as shown in Fig. 1, which is described as follows.

1) The N (3 or 8) candidate modes are selected through the RMD process.
2) It calculates the standard deviation σ of gray level of pixels in PU.
3) In this step, the weight α is set adaptively based on σ. The weight α is set using Equation (1), if σ is smaller than T.

$$\alpha = M - \frac{T - \sigma}{T} \cdot R \tag{1}$$

In Equation (1), M is the maximum value for α, T is the threshold for σ, and R is the range of weight. If σ is larger than T, then α is set to M.
4) It calculates the threshold H_T for HC as equation (2)

$$H_T = \alpha \cdot H_1 \tag{2}$$

where H_1 is the HC of the first candidate, i.e., with the smallest HC.
5) It selects the candidate modes whose HC is smaller than H_T by comparing the HC sequentially from H_2 to H_N. If H_i is smaller than H_T, then i-th mode remains as the candidate mode. Otherwise, i-th mode and subsequent modes are removed from the candidate modes. After this step, n is the reduced number of candidate modes. The reduced number of candidate modes, n, for the RDO process in the proposed method