Signal Processing: Image Communication 55 (2017) 121–129

Contents lists available at ScienceDirect

Signal Processing: Image Communication

journal homepage: www.elsevier.com/locate/image

Fast intra coding unit decision for high efficiency video coding based on statistical information

Dokyung Lee, Jechang Jeong*

Department of Electronics and Computer Engineering, Hanyang University, Seoul 133-791, Republic of Korea

ARTICLE INFO

Keywords:
High-efficiency video coding (HEVC)
Fast coding unit size decision
Online learning algorithm
Bayes decision
Quadratic discriminant analysis (QDA)
Video compression

ABSTRACT

The latest video coding compression standard is known as high–efficiency video coding (HEVC). It supports high-resolution video sequences and has better coding performance than the previous standard H.264/AVC. A quad-tree based coding unit (CU) partitioning process is one of the most efficient technologies used in an HEVC encoder. A coding tree unit (typically 64×64) can be split into smaller CUs based on rate-distortion optimization, allowing various types of video content to be adaptively compressed. In addition, intra prediction of the HEVC standard supports 35 prediction modes (planar, DC, and 33 angular modes) to improve coding efficiency. However, the computational complexity of HEVC encoder becomes a critical problem when implement with an encoder. Thus, a fast CU size decision algorithm for intra prediction of an HEVC encoder is proposed in this study. We utilize image complexity and an adaptive depth prediction for early split CU decision making. In addition, the Bayesian decision rule and quadratic discriminant analysis are used for early termination of the CU partitioning process. Experimental results show that our proposed algorithm considerably reduces encoding time by approximately 55.47% with only a small BD-BR loss (1.01%) compared to the HEVC reference software HM 16.0.

1. Introduction

To meet the increasing demand of ultra-high definition video content, the Joint Collaborative Team on Video Coding (JCT-VC), which consists of ISO/IEC JTC 1/SC 29/WG 11 MPEG and ITU-T Q6/16 VCEG, has developed high-efficiency video coding (HEVC) [1]. HEVC is a state-of-the-art international video coding standard and adopts many novel coding tools to compress various types of video content. Using quad-tree-based block partitioning, 35 modes for intra prediction, sample-adaptive offset, discrete-cosine-transform-based interpolation filter for motion compensation, and advanced motion vector prediction, HEVC improves coding efficiency considerably compared to H.264/AVC, which is the former video coding standard [2]. HEVC achieves 21.9% BD-rate reduction in all intra (AI) configuration and 37.1% BD-rate reduction for random access (RA) configuration [3] and with better visual quality.

In HEVC, a coding unit (CU) is the basic unit of the encoding and decoding processes; it has flexible sizes (from 64×64 to 8×8), which can be used to adapt to various video resolutions. The coding tree unit (CTU), which is the largest CU (typically 64×64), can be divided into four 32×32 CUs using quad-tree partitioning, and these 32×32 CUs can be further split into smaller CUs until they reach the size of 8×8. The optimal size of a CU is determined after rate-distortion (RD) costs of entire depth levels have been calculated. Prediction unit (PU) and transform unit (TU) are basic units of prediction and transform procedures, respectively. The PU of intra prediction is usually the same size as CU. However, it can be further split into 4×4 when a current CU is the smallest CU. Using the flexibility of unit size, the HEVC encoder can adaptively compress video sequences from 8K (7680×4320) to WQVGA (416×240). CU partitioning results of HEVC test model (HM) 16.0 [4] are shown in Fig. 1. We can observe that CUs in complex regions (e.g., building structures, terraces, and edges) are split into small sizes (8×8 or 16×16), whereas flat areas (e.g., rivers, roads, and parasols) have larger CUs.

1.1. Intra prediction of HEVC encoder

For HEVC intra prediction, 35 intra prediction modes, including planar, DC, and 33 angular modes, are defined [5]. This enables an HEVC encoder to identify the best prediction direction more precisely than previous coding standards. In addition, new technologies exist for improving intra prediction efficiency. These include mode-dependent intra sample smoothing and filtering of block boundary pixels. Mode-dependent intra sample smoothing is used to remove quantization

* Corresponding author.
E-mail addresses: dky1006@gmail.com (D. Lee), jjeong@hanyang.ac.kr (J. Jeong).

http://dx.doi.org/10.1016/j.image.2017.03.019
Received 9 August 2016; Received in revised form 24 March 2017; Accepted 24 March 2017
Available online 02 April 2017
0923-5965/

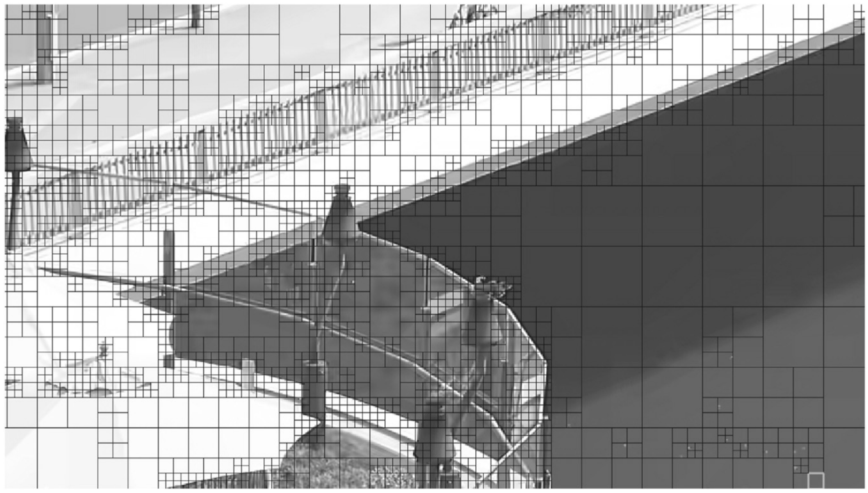

Fig. 1. CU partitioning results of the first frame of the *BQTerrace* sequence (QP =27 and AI configuration is used).

errors in neighboring reference samples of a current PU. This method uses two types of filters: strong (bi-linear) and weak. In addition, rough mode decision (RMD) is a fast encoder algorithm that can choose limited candidates for the full RD calculation process, which requires a large amount of computation power [6,7].

The procedure for HM encoder intra prediction is shown in Fig. 2. First, the reference samples are collected in a reference buffer. Reference sample padding is performed if some samples are not available. RMD is a search process that finds 3, 3, 3, 8, and 8 candidates of 64×64, 32×32, 16×16, 8×8, and 4×4 PUs, respectively, for full RD calculation. The candidates are determined based on the following equation:

$$J_{SATD} = \text{SATD} + \lambda_{pred} {*} B_{mode} \quad (1)$$

Here, *SATD* denotes an absolute sum of Hadamard-transformed residual signal, λ_{pred} is a Lagrangian multiplier, and B_{mode} represents required bits for encoded prediction mode. Prediction modes that have small J_{SATD} are included in the candidates. In a single-depth residual quad-tree (RQT) process, the best intra mode among the candidates is determined based on the full RD cost. This is calculated by:

$$J_{Full} = D + \lambda {*} B. \quad (2)$$

Here, D is a distortion in terms of sum of the squared error (SSE) between an original frame and a reconstructed frame. λ denotes the Lagrangian multiplier, and *B* represents encoded bits for a prediction mode and residual data. Eq. (2) is used to calculate both the best mode for one TU depth and the optimal TU depth.

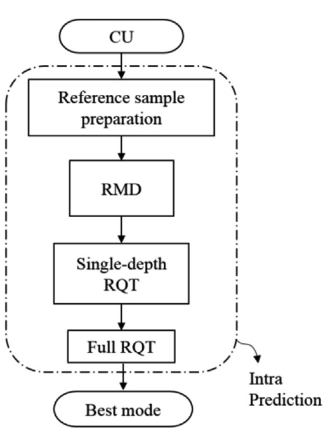

Fig. 2. Flowchart of the HEVC intra prediction.

1.2. Related works

Although HEVC improves coding efficiency compared to previous video coding standards, the complexity of an HEVC encoder is generally high because of the recursive coding structure and additional prediction modes. Many studies investigating fast algorithms for reducing the computational burden of HEVC encoder have been conducted.

Because the angular modes of intra prediction and edges of an image have similarities, a fast mode decision algorithms with an edge detection were proposed in [8–13]. Jiang et al. [8] introduced a gradient-based fast mode decision algorithm. They employed an amplitude and an angle of a gradient vector calculated by a Sobel operator. Yan et al. [9] proposed a group-based fast algorithm for intra mode decision. They used statistical data from the RMD of the intra prediction and their experimental results showed that the algorithm achieves approximately 24% time saving with a 1.3% Bjontegaard Delta bit rate (BD-BR) increase. In [10,11], Silva et al. calculated dominant edge strength from PU texture to reduce encoding time. They achieved time savings as much as 34.9% by employing the fast intra mode decision algorithm in [11]. Chen et al. [12] incorporated an edge detector and a kernel density estimation into a histogram generation. They successfully reduced complexity of intra prediction by approximately 25%, with only a small BD-BR increase. In [13], Jamali et al. introduced an improved edge detector based on a Sobel operator and binary classification to reduce the number of candidates of the RD cost calculation.

Recently, several studies [14–24] have been conducted to reduce the complexity of the CU partitioning process. Comprehensive fast algorithms related to intra prediction of HM were proposed by L. Zhao et al. in [14]. Algorithms about early termination of CU encoding, fast intra-prediction mode decision, TU depth selection and transform skip mode decision were introduced to save intra encoding time. Shen et al. [15,17] proposed fast algorithms using depth prediction, RD cost and motion vectors. In [15], they defined a new depth search range for CU splitting and proposed an early termination method based on information related to motion homogeneity, RD costs, and skip mode checking. They predicted that a current CU's depth level refers to depths of neighboring CUs and defined five types of tree blocks to adjust the depth search range. Shen et al. also proposed a CU size decision algorithm for intra coding that employs a high correlation of intra modes, neighboring CU depth levels, and RD costs in [17]. Cho and Kim introduced an algorithm for early splitting and pruning of the quad-tree CU partitioning process for intra coding [16]. They adaptively determined RD cost thresholds using the Bayesian decision rule with an online update phase. Min and Cheung [18] calculated global and local edge complexities to reduce the encoding time. They defined thresholds