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Review

Complexity-based intra frame rate control by jointing inter-frame correlation for high efficiency video coding ☆,☆☆

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ABSTRACT

Rate control is of great significance for the High Efficiency Video Coding (HEVC). Due to the high efficiency and low complexity, the R-lambda model has been applied to the HEVC as the default rate control algorithm. However, the video content complexity, which can help improve the code efficiency and rate control performance, is not fully considered in the R-lambda model. To address this problem, an intra-frame rate control algorithm, which aims to provide improved and smooth video quality, is developed in this paper by jointly taking into consideration the frame-level content complexity between the encoded intra frames and the encoded inter frame, as well as the CTU-level complexity among different CTUs in texture–different regions for intra-frame. Firstly, in order to improve the rate control efficiency, this paper introduces a new prediction measure of content complexity for CTUs of intra-frame by jointly considering the inter-frame correlations between encoding intra frame and previous encoded inter frames as well as correlations between encoding intra frame and previous encoded intra frame. Secondly, a frame-level complexity-based bit-allocation-balancing method, by jointly considering the inter-frame correlation between intra frame and previous encoded inter frame, is brought up so that the smoothness of the visual quality can be improved between adjacent inter- and intra-frames. Thirdly, a new region-division and complexity-based CTU-level bit allocation method is developed to improve the objective quality and to reduce PSNR fluctuation among CTUs in intra-frame. In the end, related model parameters are updated during the encoding process to increase rate control accuracy. As a result, as can be seen from the extensive experimental results that compared with the state-of-the-art schemes, the video quality can be significantly improved. More specifically, up to 10.5% and on average 5.2% BD-Rate reduction was achieved compared to HM16.0 and up to 2.7% and an average of 2.0% BD-Rate reduction was achieved compared to state-of-the-art algorithm. Besides, a superior performance in enhancing the smoothness of quality can be achieved, which outperforms the state-of-the-art algorithms in term of flicker measurement, frame and CTU-wise PSNR, as well as buffer fullness.

Contents

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1. Introduction

High Efficiency Video Coding (HEVC) is the latest video coding standard developed by JCT-VC (Joint Collaborative Team on Video Coding). Compared with former standards of video coding, the coding efficiency can be dramatically improved with HEVC.

Due to the various advanced encoding tools employed in HEVC, the compression performance can be improved to a great extent and half of the bit rate can be saved when compared with the H.264 for the same perceptual video quality. In addition, rate control (RC) is of great significance for the transmission of high-quality video data through the communication channel and it is aimed at achieving the best video quality under certain restrictions like bandwidth, delay of decoding, buffer capacity as well as content complexity.

Intra-frame coding means that the diverse kinds of techniques in lossless and lossy compression are carried out relative to the information that is included in the current frame only, rather than to any other frames in the video sequence. Due to the significant improvement of the motion compensated prediction (MCP) in HEVC, inter frames are higher compared with the intra frames. In this way, the channel bandwidth occupied by the HEVC's intra frame bits is more than those of the H.264/AVC in a compressed video stream. Moreover, the intra frame rate control is of greater importance in HEVC than in H.264/AVC, which may cause the buffer overflow and frame-skip. Thus, the intra frame rate control of HEVC is not only one of the most hot research point but also the valuable key point.

The majority of studies on the H.264 rate control technology pay attention to P-frames, and there are fewer researches on intra-frame rate control [2–16]. Nevertheless, some deficiencies exist in those schemes: (1) incorrect estimation of QP: The estimation of intra-frame QP is conducted based on bits per pixel (bpp) only. (2) Insufficient ability of buffer control: Buffer overflow tends to occur sometimes and frame skipping is also likely to be caused, especially under the condition of a low bit rate. (3) Inexact frame-level rate control: a very large deviation is shown between the target bits of a frame and the generated encoding bits of it. There are at least the following two reasons causing the above problems. One is that those algorithms don't give full consideration to the complexity of frames. The other is that a unified model is adopted while allocating bit for macro block (MB) of diverse content characteristics.

The rate models in HEVC mainly include three categories, namely, quadratic model (URQ) [17], ρ-domain model [18] as well as R-lambda model [19,20]. A rate control scheme [17] was applied to HEVC, while the same quadratic rate quantization model was also adopted, in which the MAD estimation was seen as the complexity measurement. Nevertheless, several restrictions are presented in the proposed rate control scheme to obtain accurate results of rate control, which is caused by its inaccurate rate-quantization model. In [18], the rate control schemes based on ρ-domain is proposed by adopting the percentage of zero-quantized coefficients. Regardless of their rate models' higher accuracy, mapping ρ to the sizes of quantization step is of great difficulty. λ-domain RC that has been integrated into the HEVC Ref. software has been proposed by Li et al. [19,20] for more accurate rate estimation. In comparison with the quadratic and ρ-domain models, the overall bit rate which includes not only the transform coefficient bits but also the overhead bits is considered in the R-lambda model.

It should be pointed out that the R-λ model only considers the target bit but ignores the complexity characteristics. More specifically, the value of the current intra frame is directly set as the QP of each CTU in frame level [19]. Thus, the content complexity has been considered to improve R-λ model. And the most representative methods [21–30] will be analyzed and summarized in the next. Wang and Karczewicz [21] proposed to use summation of absolute transformed differences (SATD) to measure the complexity of an intra-frame. And some modifications have been made in the intra frame rate control through enabling bit allocation and QP computing at CTU level. However, if intra period is excessively long, it will be unable to avoid the reduction of coding efficiency. Zhou and Tian [25] proposed a rate control scheme for HEVC based on the proposed novel R-D model and a PID buffer feedback controller. A rate control method based on frame and content is proposed for the intra frame coding of HEVC [26]. However, above two methods are proposed for all intra coding structure (AI), and not suitable for other coding structure. Li and Xu [29] proposed a novel weight-based R-λ rate control scheme to improve the perceived visual quality of compressed conversational video, based on the weights of face regions and facial features learned from eye-tracking data. However, it failed therein to take account the content complexity in frame level rate control, which usually causes bit fluctuation. Wang and Ngan [27] presented a novel rate control framework based on the Lagrange multiplier in high-efficiency video coding. This method can get ideal result for inter frame, and is especially suitable for the application of inter frame. However, it does not consider the application of intra frames, which restricts the range of application. What's more, the method does not discuss the difference of different types of frames in HEVC, and cannot maintain the stability of the quality of different types of frames. Zhou etc. [30] proposed a content-adaptive model coefficients estimation scheme for multi-dimensional rate control.

In short, the existing HEVC rate control methods have considered the content complexity of intra frame to a certain extent. However, the considerations are not adequate. In the meantime, the relationship between complexity and the different types of frames didn't discuss. We will carry out further