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Universal intra coding for arbitrary RGB color filter arrays in HEVC

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ABSTRACT

Compressing mosaic video sequences is necessary for storage and transmission over the internet. However, mosaic video sequences with different red–green–blue (RGB) color filter arrays (CFAs) require different compression schemes. We propose a two-stage universal intra coding scheme for compressing mosaic video sequences with arbitrary RGB-CFAs in high efficiency video coding (HEVC). Based on the associated mosaic structure, the proposed scheme first demosaics the neighboring reference pixels and then predicts the color value of the target pixel using the color values of the identical color components in the demosaiced reference pixels. Experimental results demonstrate that the proposed universal intra coding scheme achieves substantial improvement on bitrate while preserving the quality of the reconstructed video sequences.

1. Introduction

With the advance in multimedia technology, digital cameras become increasingly ubiquitous. For the consideration of cost, most consumer digital cameras are equipped with a light sensor and a red–green–blue (RGB) color filter array (CFA) structure to capture color information [18]. The structures of color filters in the RGB-CFA are usually designed by the camera manufacturers and referred to as the mosaic structures. Ten commonly used types of the RGB-CFAs [16] are shown in Fig. 1 and the Bayer CFA [1] is the most well-known structure among them. The camera with specific RGB-CFA structure produces mosaic video sequences by selecting only one of the RGB color components for each pixel in the image frame. To reconstruct a full color video sequence, the missing color components of each pixel in the image frame are estimated by the demosaicing process, which has been extensively studied in [5,6,10,13–17,19,20,22–24].

In addition to the demosaicing process, another important issue for mosaic video sequences is video compression, which is necessary for storage saving and transmission over the internet. Compression schemes for mosaic video sequences can be divided into two categories: structure conversion based and color recovering based schemes. The former converts the CFA structure into three distinct color planes for compression and the latter recovers the full RGB colors for compression. Structure conversion based compression schemes are often applied to compress mosaic video sequences with the Bayer CFA structure since the Bayer CFA is easier to convert than other CFA structures and has 2:1:1 (G:B:R) color component composition which is similar to the 4:2:2 sampling format for the encoder. Gastaldi et al. [9] presented the first mosaic video coders for compressing the sequences with the Bayer CFA under the MPEG-2 environment [26], where each mosaic image frame is decomposed into three distinct rectangular color planes which are individually compressed to increase the compression ratio. Since H.264/AVC video coders [25] usually achieves better compression performance than MPEG-2 video coders, Doutre et al. [7] incorporated the structure conversion technique in [12] with the prediction schemes in H.264/AVC to tackle the mosaic video sequences with the Bayer CFA structure. Doutre and Nasiopoulos [8] further modified, according to the Bayer CFA structure, the intra prediction scheme in H.264/AVC to enhance the quality of the reconstructed video sequence. However, due to the requirement of specific sampling format by an encoder and the difficulty in converting irregular CFA patterns, the structure conversion based compression schemes cannot be used directly to compress mosaic video sequences with non-Bayer CFAs.

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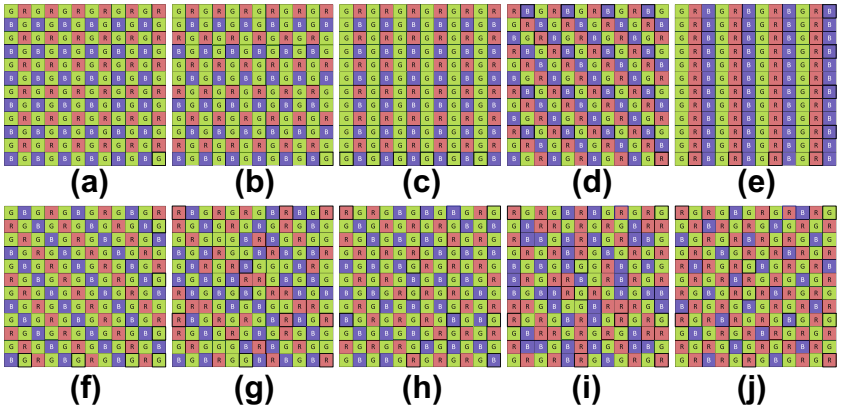

Fig. 1. Ten typical RGB-CFAs: (a) Bayer CFA, (b) Lukac and Plataniotis CFA, (c) Yamanaka CFA, (d) diagonal stripe CFA, (e) vertical stripe CFA, (f) modified Bayer CFA, (g) HVS-based CFA, (h) type I pseudo-random CFA, (i) type II pseudo-random CFA and (j) type III pseudo-random CFA.

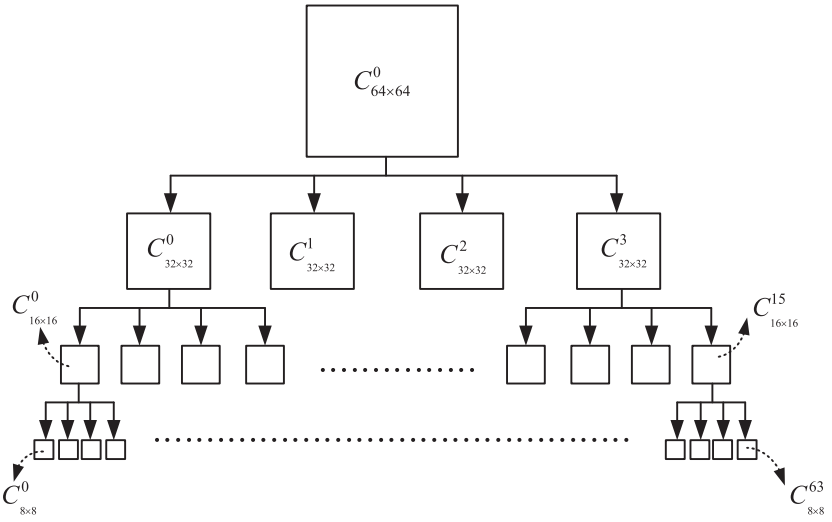

Fig. 2. The quadtree structure for coding units.

Instead of converting the structure, demosaicing the mosaic video sequence prior to compressing is another approach. Prior to compression, Chen et al. [4] first recovered the full RGB colors for a mosaic video sequence with the Bayer CFA structure and then adjusted the chroma subsampling strategy in H.264/AVC to improve the quality of the reconstructed mosaic video sequences. Yang et al. [21] proposed a universal compression scheme for mosaic video sequences with arbitrary RGB-CFAs in H.264/AVC, which, prior to compression, basically combines and modifies the universal demosaicing method by Lukac and Plataniotis [15] and the subsampling method by Chen et al. [4]. The color recovering based compression schemes avoid the difficulty of structure conversion but suffer from the color deviations from color domain transformation [27]. Consequently, the reconstructed video sequence using color recovering based compression schemes may have poor compression performance.

As the resolution of video sequences increases, the H.264/AVC standard can no longer deliver satisfied compression results. A high efficiency video coding [3], abbreviated as HEVC, is developed to improve the compression efficiency for high resolution video sequences. When compressing mosaic video sequences using the HEVC standard, one natural approach is to adapt the compression schemes in H.264/AVC to the HEVC standard. However, the structure conversion based compression schemes cannot be applied in HEVC since the sampling format required for structure conversion is not supported in HEVC and the color recovering compression schemes still suffer from problem caused by color domain transformation in HEVC. Thus, developing a universal compression scheme in HEVC for mosaic video sequences with arbitrary RGB-CFAs is important, leading to main motivation of this research.

In this paper, we propose a two-stage universal intra coding scheme in HEVC for compressing mosaic video sequences with arbitrary RGB-CFAs. In the first stage, the proposed scheme demosaics, according to the associated mosaic structure, the pixels in the reference row and column. Based on the associated mosaic structure, the second stage predicts the color value for a mosaiced pixel with a specific color component using the demosaiced reference pixels with the identical color component. The proposed scheme is universal since no structure conversion is involved and a demosaicing scheme for arbitrary CFA structure is available. Furthermore, the proposed scheme avoids the quality degradation in the reconstructed video sequences since no color domain transformation is required. Experimental results on ten typical RGB-CFAs demonstrate that the proposed universal intra coding scheme can achieve substantial bitrate reduction and quality improvement over the existing intra coding schemes. To the best of our knowledge, the proposed scheme is the first universal intra coding scheme designed specifically for mosaic video sequences with arbitrary RGB-CFAs in HEVC.