An Extension of JPEG XT with JPEG2000

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***Abstract*--A new two-layer coding scheme based on JPEG 2000 is proposed for HDR images, where coded data consist of two layers: the base-layer for tone mapped LDR version of an HDR image and the enhancement layer. The paper considers the coding scheme as an extended version of the JPEG XT Profile A. JPEG coders used in JPEG XT are replaced with JPEG 2000 ones. Compared to normative JPEG XT coding, the proposed scheme has the following properties, (1) high compression efficiency, (2) over-eight-bits LDR images, (3) flexible bitrate control, etc. We demonstrate the effectiveness of the proposed scheme by experimental results.**

I. INTRODUCTION

High dynamic range (HDR) images, which have over eight bits as their bit-depth for each color channel, are now becoming popular in digital photography applications such as digital still cameras, digital video cameras, and displays[1]. Meanwhile, some methods to compress HDR images have been reported[2] -[5]. Since the legacy JPEG, which is known as the most widely used digital photography format, only supports eight bits per color channel, the legacy JPEG can not be used to compress HDR images. To resolve this problem, a new standard referred to as JPEG XT[6][7] is primarily designed to provide coded data containing HDR and wide color gamut content while simultaneously providing eight-bits-per-pixel low dynamic range(LDR) images. JPEG XT coded data consist of two layers to reconstruct images with various quality: base layer and enhancement layer. The legacy JPEG decoder can understand the base-layer of JPEG XT coded data because it has the same codestream syntax as the legacy JPEG. On the other hand, JPEG XT decoder can reconstruct HDR images using the enhancement layer with the base layer. The two-layer coding scheme enables to store both an original HDR image and the tone mapped LDR image as one codestream. However, the legacy JPEG codec used in the JPEG XT codec has some issues such as low compression performance, block artifacts, mosquito noise and so on. As a result, the JPEG XT standard has the same issues as the JPEG standard.

To improve the issues, a new two-layer coding scheme based on JPEG2000 are proposed. In the proposed scheme, JPEG coders used in JPEG XT coders are replaced with JPEG 2000 ones. The JPEG 2000 fast mode encoder[8] that bypasses MQ-coder is used for the residual layer, while the JPEG 2000 standard encoder is used for the base layer, because the residual data are not suitable for MQ-coder. Compared to the normative JPEG XT encoder, the proposed ones enable to have the following advantages, due to the difference between the JPEG standard and the JPEG 2000 one:

1. It provides high compression efficiency.
2. It utilizes rich JPEG 2000 functionalities (SNR scalability, the resolution scalability, error robustness, etc.).
3. Total bitrate can be freely controlled.

Finally, the experimental results are shown to demonstrate the effectiveness of the proposed scheme in terms of the coding performance.

II. JPEG XT

Three profiles have been proposed for JPEG XT Part 7 floating point coding[9]. This paper focuses on only Profile A, and uses a JPEG XT demo implementation[10].

In the JPEG XT Profile A, the input HDR image is first tonemapped from the original HDR image to the LDR image, which is coded by the legacy JPEG encoder as a base layer. At the end of encoding process, the codestreams encoded by the legacy JPEG encoder of the base layer and enhancement layer are composed into the JPEG XT codestream. The encoded residual data is referred to as a residual layer. The phrase "residual layer" is used to describe an enhancement layer in the following part of this paper. A residual layer is multiplexed into a base layer using the APP_{11} marker of the standard JPEG file format.

There are two parameters for the quantization of a tonemapped LDR image and the residual data. Parameter q controls the quality of tonemapped LDR image. That is, this q is exactly equal to the quality factor of the legacy JPEG. On the other hand, parameter Q is able to control the quality of residual images. The Q is transformed into a constant in a certain manner, and the constant is multiplied by the quantization matrix. For both q and Q, the larger the value, the better the quality of decoded images, and the range of values is from 1 to 100.

III. PROPOSED STRUCTURE

The block diagram of the proposed structure, which is an extended version of JPEG XT Profile A, is illustrated in Fig. 1. In the proposed structure, the legacy JPEG encoders in the LDR and residual layers are replaced with JPEG 2000 encoders.

In the normative JPEG XT, the two scaling processes are used to generate 8bpp integer images before the residual encoder. In contrast, the proposed structure uses two lossless index transformation processes to map half-float data to 16 bit integers, because JPEG 2000 can treat up to 16bpp integer

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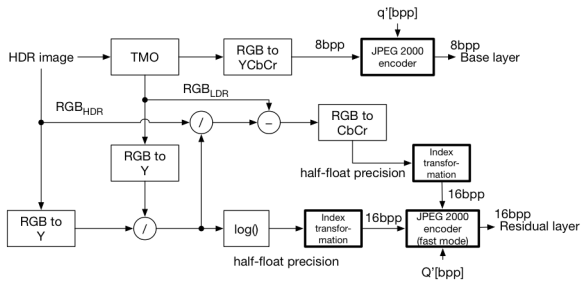

Fig. 1. Block diagram of the proposed scheme (Profile A)

images. The index transformation generates an integer-numbered indexed image from a half-precision float image so that any ordinary image compression technique for fixed-point numbered images can compress the half-precision float image. This transformation first interprets 16-bit integers instead of floating-point numbers. Then, the interpreted image is transformed to an indexed image, where indices are given according to the pixel values represented as floating-point numbers to preserve the characteristic of half precision float images. The obtained 16bpp integer image is not suitable for the arithmetic encoder, so that it is encoded by the JPEG 2000 fast mode encoder without MQ-coder.

IV. Experimental Results and Discussion

To confirm the effectiveness of the proposed scheme, some experiments regarding the quality of decoded images are carried out. In this paper, HDR-VDP 2.2 is used to evaluate the quality of HDR images, which is highly correlated with subjective scores[11][12]. In the experiments, HDR images `McKeesPub' and `Memorial' are encoded by the reference software available from the JPEG committee under the condition $q = Q$ $(q = 10; 20; 30; 40; 50; 60; 70; 80; 90)$. The modified software is also used to evaluate the proposed scheme.

A. Evaluation (HDR images quality)

In order to satisfy the same requirements as JPEG XT, q' and Q', which are the bitrates of the base layer and the residual layer of the proposed scheme respectively are given by

$$q' = Q' = \frac{1}{2} \cdot \frac{\text{File size of JPEG XT}}{\text{The number of pixels}} [bpp].$$

Note that the proposed scheme can directly offer coded data with a target file size due to the functionality of one pass rate control, although the normative JPEG XT can not.

Figure 2 shows the quality of decoded HDR images for the proposed scheme and JPEG XT. The horizontal axis denotes the total bitrates, and the vertical axis denotes HDR-VDP-Q values between the original HDR image and the decoded one. A higher HDR-VDP-Q value indicates higher quality. It is shown that the proposed structures provide better quality than the normative encoders for almost total bitrates. The proposed ones particularly give strongly better performances than JPEG XT at low bitrates.

B. Evaluation (LDR images quality)

The LDR images are obtained from each bitstream as an output signal (base layer signal) of the legacy JPEG decoder / JPEG 2000 decoder. We have confirmed that the proposed structure provides better PSNR performances than the normative encoders in the LDR domain, as well as in the HDR one.

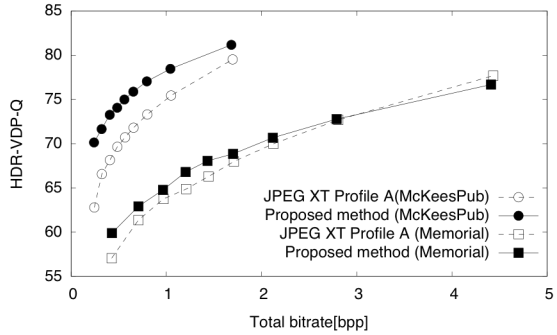

Fig. 2. Coding performance of JPEG XT and the proposed coding. ($q = Q, q' = Q'$)

V. Conclusion

A new HDR image coding scheme with two layers has been proposed. JPEG XT Profile A has been extended by replacing JPEG coders with JPEG 2000 ones, to improve some disadvantages of JPEG coding used in the normative JPEG XT coders. In addition, JPEG 2000 fast mode is used for the residual layer coding. In some experiments, it has been confirmed that the proposed scheme provides better coding performances than the normative JPEG XT coders, and the difference between two proposed ones.

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