JPEG2000-BASED SHAPE ADAPTIVE ALGORITHM FOR THE EFFICIENT CODING OF MULTIPLE REGIONS-OF-INTEREST

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ABSTRACT

The JPEG2000 standard supports two methods to code regions-of-interest (ROIs) in an image – the maxshift method and the scaling-based method. Compared to the maxshift method, the scaling-based method is preferable in many applications because it allows the non-ROI (background) region to be partially coded prior to coding all of the ROIs. This is accomplished by supporting arbitrary bitplane shift factors and by filling the most significant bitplanes of the non-ROI region with zeros after the ROI bitplanes have been shifted up in value. In both of these methods, the embedded block coding with optimum truncation (EBCOT) algorithm is then applied to code the wavelet coefficients. However, when multiple regions-of-interest need to be coded, the performance of the scaling-based method degrades significantly since the EBCOT coder is no longer able to efficiently code the non-ROI region, which is now less contiguous as compared to the single-ROI case. Also, the large header information that is required in JPEG2000 for each ROI degrades the coding performance. This paper presents an improved scaling-based method for the efficient coding of multiple, arbitrarily-shaped ROIs using a modified EBCOT algorithm. The proposed method utilizes the shape information of the different ROIs to generate a stripe mask, which is then used to optimize the coding performance. Coding results and comparisons with the JPEG2000 scaling-based method are presented to illustrate the improved performance of the proposed scheme.

1. INTRODUCTION

The JPEG2000 image compression standard [1] [2] is capable of supporting region-of-interest (ROI) coding, whereby certain regions within the image (ROIs) are coded with greater fidelity than the remainder of the image. In JPEG2000, ROI-based coding is supported by two different methods [3] [4]—the maxshift method and the scaling-based method. The maxshift method enables multiple ROIs of arbitrary shape to be coded, without having to send additional shape information to the decoder. However, maxshift requires that all ROIs be coded prior to any part of the non-ROI region. If the bit budget is insufficient, the non-ROI or background region will not be coded at all. This "all or nothing" approach can result in a complete loss of background information in the decoded image. On the other hand, the scaling-based method of JPEG2000 allows partial coding of the non-ROI region prior to full coding of the ROIs by supporting arbitrary bitplane shift factors. Unfortunately, the scaling-based method only allows ROIs to be rectangular or elliptical in shape, and the coding performance degrades dramatically as the number of ROIs increases. Since many applications require the coding and transmission of multiple ROIs within an image, this limitation is a serious drawback of JPEG2000.

In the scaling-based method, the most significant bitplanes (MSBs) of the non-ROI region are filled with zeros after the ROI bitplanes have been shifted up in level (Fig. 1). The EBCOT algorithm is then applied to code the wavelet coefficients. If there is only one ROI region, the EBCOT coder will efficiently code the non-ROI coefficients, which are coded as zeros. But if multiple ROIs exist, the coding performance of the scaling-based method degrades dramatically since the ROIs tend to be scattered throughout the image, thus resulting in a non-contiguous background region. In this paper, we present a modified EBCOT algorithm that efficiently codes an arbitrary number of ROIs, each with arbitrary shape, while supporting an arbitrary bitplane scale factor.

Other ROI coding methods have been proposed in the literature. In [5] and [6], for example, ROI coding for the SPIHT and Quadtree coders are discussed, respectively. In [7] [8], a bitplane-by-bitplane shift method is proposed, which has the option of shifting the ROI bitplanes by a scale factor, followed by the alternating transmission of the non-ROI and ROI bitplanes. In [9], a similar method has been proposed, which differs from the method of [7] [8] in the way the ROI and non-ROI bitplanes are arranged. In [10], a new approach to the maxshift method is given, which shifts the ROI bitplanes by arbitrary values. The ROI bitplanes overlapping with the non-ROI bitplanes are replaced with zeros, which results in the loss of a significant amount of ROI information for smaller shift values.

This paper is organized as follows. Section 2 gives a brief overview of the ROI coding methods that are incorporated in the JPEG2000 standard. In Section 3, our proposed ROI coding method is described. Coding results are presented in Section 4, and a conclusion is given in Section 5.

2. OVERVIEW OF JPEG2000 ROI CODING METHODS

JPEG2000 [1] is a wavelet-based bitplane coding method. In this algorithm, the original image samples are shifted in level (if they are unsigned pixel values) such that they form a symmetric distribution of the discrete wavelet transform (DWT) coefficients for the low-low (LL) sub-band. If lossy compression is chosen, the transformed coefficients are quantized. The ROI bitplanes of the quantized coefficients are shifted up in value according to the applied ROI coding method. The bitplanes are coded from the most significant bitplane (MSB) to the least significant bitplane (LSB) using the embedded block coding with optimal truncation (EBCOT) al-

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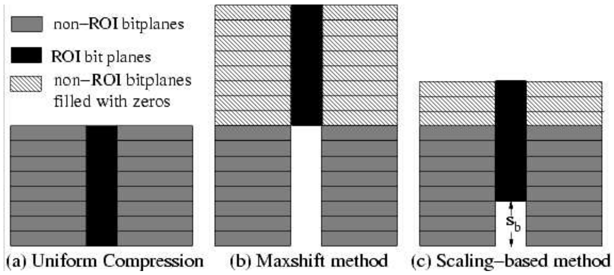

Fig. 1. (a) Uniform compression, (b) bitplane shifts for the maxshift method, and (c) bitplane shifts for the scaling-based method.

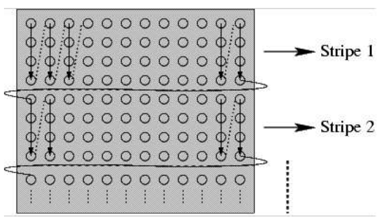

Fig. 2. Stripe scan within a codeblock in JPEG2000.

gorithm [11]. The EBCOT algorithm has three coding passes—the significance propagation pass, the magnitude refinement pass, and the cleanup pass. The significance propagation pass codes the significance of each sample based upon the significance of the neighboring eight pixels. The sign coding primitive is applied to code the sign information when a sample is coded for the first time as a non-zero bitplane coefficient. The magnitude refinement pass codes only those samples that have already become significant. The cleanup pass will code the remaining coefficients that are not coded during the first two passes. The output symbols from each pass are entropy coded using context-based arithmetic coding. After all bitplanes are coded, the post-compression rate-distortion optimization (PCRD-opt) algorithm is applied to determine the contribution of each coding block to the final bit stream.

As stated earlier, JPEG2000 supports two ROI coding methods, as shown in Fig. 1. The maxshift method, which is given in part-I of JPEG2000 [1], shifts the ROI bitplanes above the non-ROI (background) bitplanes. This method can support ROIs of arbitrary shape, since there is no need to send the shape information to the decoder. However, to ensure that there is no ambiguity between ROI and non-ROI bitplanes, all ROI bitplanes are shifted above the non-ROI bitplanes. Hence, the decoder needs to decode all the ROI regions before decoding any of the non-ROI region. Also, the decoder must support higher-precision arithmetic to decode all of the bitplanes.

Part-II of the JPEG2000 [2] standard supports the scaling-based method with rectangular and circular ROIs. At the encoder, the ROI bitplanes can be shifted up with an arbitrary scale factor, s_b, where s_b ranges from 1 to the maximum number of bitplanes. The shape information and the scale factor are sent to the decoder, where the ROI bitplanes are shifted down before decoding.

In both methods, after the ROIs have been shifted up in value, the most significant bitplanes associated with the non-ROI region are filled with zeros, as shown in Fig. 1.

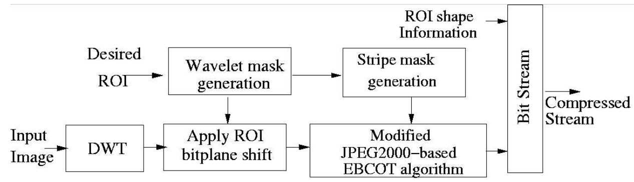

Fig. 3. Proposed embedded multiple region-of-interest coding method.

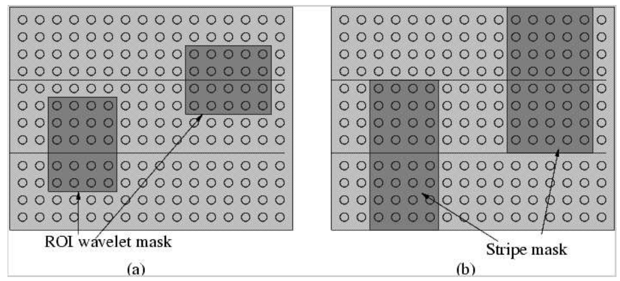

Fig. 4. a) Wavelet mask and b) Stripe mask within a Codeblock.

3. PROPOSED ROI CODING METHOD FOR JPEG2000 WITH MODIFIED EBCOT ALGORITHM

The block diagram of the proposed coding method is shown in Fig. 3. The proposed method facilitates the efficient coding of multiple, arbitrarily-shaped regions-of-interest, with any bitplane scaling factor, s_b, where the shape information of each ROI is embedded within the bit stream. The encoding steps for the proposed method are as follows:

- Generation of a wavelet mask from the ROI shape information;
- Bitplane shifting of the multiple ROIs by the desired scaling factor, s_b;
- Generation of a stripe mask from the wavelet mask;
- Coding of the bitplanes with a modified EBCOT algorithm that makes use of the generated stripe mask to more efficiently code the multiple ROIs and non-ROI region.

A reduced size custom header [12] was implemented in the proposed method. Additional details pertaining to the aforementioned steps are presented in Sections 3.1 – 3.4.

3.1. Wavelet mask generation

The spatial-domain shape information of the multiple regions-of-interest is used to generate a corresponding wavelet-domain ROI mask using a method similar to the one used in JPEG2000 [1], which specifies which wavelet coefficients correspond to regions of interest, and which correspond to the background region.

The wavelet mask is also generated at the decoder using the ROI shape information that has been embedded within the bit stream.

3.2. ROI bitplane shifting

Once the wavelet mask has been generated for all sub-bands, the wavelet coefficients that correspond to regions of interest are scaled up by s_b with respect to the non-ROI region. The scaling factor can be chosen depending upon the bit budget for the ROI and non-ROI regions as in [2].

3.3. Stripe mask generation

In JPEG2000, stripes are formed from four rows of a codeblock as shown in Fig. 2. During the bitplane coding passes, the codeblock of wavelet coefficients is scanned in stripes (Fig. 2). The proposed method generates a stripe mask from the wavelet-domain ROI mask as follows: if any one of the wavelet coefficients in a column of a stripe belongs to the ROI, then that entire column of that stripe is included in the generated stripe mask. The stripe mask is then used during the significance-propagation and cleanup passes of the modified EBCOT algorithm, as described in Section 3.4.

3.4. Modified JPEG2000-based EBCOT coding

The scaled-up DWT coefficients of the source image are input to a modified JPEG2000-based EBCOT coding algorithm as shown in Fig. 3. In the proposed algorithm, the significance-propagation and cleanup passes are modified to efficiently utilize the generated stripe mask (Section 3.3).

In the significance propagation pass of JPEG2000, whenever a coefficient has a significant neighborhood and the sample is insignificant, its significance event is coded. In the standard scaling-based method of JPEG2000, even a zero non-ROI coefficient must be coded if one of its eight closest neighbors is significant. Alternatively, in the proposed multiple ROI coding method, the significance propagation pass is modified to code only the coefficients that are located within the generated stripe mask. All coefficients that are outside the stripe mask are forced to remain insignificant when coding the most significant s_b bitplanes. Thus, whenever a coefficient is not included within the ROI stripe mask, then its significance event is not coded for the most significant s_b bitplanes. This modified process increases the coding efficiency of the algorithm, while simultaneously decreasing the computational complexity.

In addition, during the cleanup pass, the standard scaling-based method codes all non-ROI coefficients that are not coded during the significance and magnitude-refinement passes. In the proposed method, for the most significant s_b bitplanes, the cleanup pass is modified to code only those coefficients that are within the stripe mask, with all other coefficients not being coded.

The magnitude refinement pass is not modified since it only refines the sample values at each bitplane once a sample becomes significant.

4. RESULTS

To illustrate the performance of the proposed method, multiple regions-of-interest in different images were coded using both the proposed shape-adaptive multiple ROI coding method and the JPEG2000 scaling-based method. Note that the proposed method uses a custom header as described in [12]. Although rectangular shapes were chosen to facilitate a direct comparison with JPEG2000, our proposed method can accommodate ROIs of arbitrary shape [12]. Coding results are presented in Figs. 6 and 7 for the 1024×976 "AirField1" and 1024×1024 "Airfield2" images, respectively. For comparison, the original images are shown in Fig. 5. The presented PSNR results were computed over the observed regions-of-interest. Figs. 6 and 7 show the reconstructed "Airfield1" and "Airfield2" images with multiple ROIs at overall bit rates of 0.004 bits/pixel (bpp) and 0.005 bpp, respectively. An ROI scale factor of s_b = 5 was selected for both images. Figs. 6a and 7a show the spatial domain ROI regions. It can be seen that the proposed method results in dramatically better visual quality, even at very high compression ratios as compared to the JPEG2000 scaling-based method. In addition, the proposed method results in a much higher PSNR over the desired ROIs than the JPEG2000 scaling-based method. Also note that our proposed method provides more background information than JPEG2000.

5. CONCLUSION

This paper presents a novel algorithm for efficiently coding imagery with multiple, arbitrarily-shaped regions-of-interest. In the proposed method, a modified stripe mask is generated from the ROI wavelet mask, and is used in the significance propagation and cleanup passes of a modified EBCOT algorithm. As demonstrated, the proposed method significantly improves the coding performance as compared to the scaling-based method of JPEG2000 when multiple regions-of-interest are present.

6. REFERENCES

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(a) Original "Airfield1" Image

(b) Original "Airfield2" Image

Fig. 5. Original 1024×976 "Airfield1" and 1024×1024 "Airfield2" images.

(a) Spatial domain ROI mask

(b) JPEG2000 scaling-based method, ROI PSNR = 17.2694 dB

(c) Proposed method, ROI PSNR = 20.9401 dB

Fig. 6. Reconstructed "Airfield1" image at a bit rate of 0.004 bpp and a scale factor of s_b = 5.

(a) Spatial domain ROI mask

(b) JPEG2000 scaling-based method, ROI PSNR = 16.6777 dB

(c) Proposed method, ROI PSNR = 18.8821 dB

Fig. 7. Reconstructed "Airfield2" image at a bit rate of 0.005 bpp and a scale factor of s_b = 5.