A New JPEG2000 Region-of-Interest Image Coding Method: Partial Significant Bitplanes Shift

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***Abstract*— In this letter, we propose a new ROI coding method called Partial Significant Bitplanes Shift (PSBShift) that combines the advantages of the two standard ROI coding methods defined in JPEG2000. The PSBShift method not only supports arbitrarily shaped ROI coding without coding the shape, but also enables the flexible adjustment of compression quality in ROI and background. Additionally, the new method can efficiently code multiple ROIs with different degrees of interest in an image.**

***Index Terms*— Image coding, JPEG2000, region-of-interest coding**

I Introduction

Region of Interest (ROI) image coding is a new feature in JPEG2000, which allows ROIs to be coded with better quality than the rest of an image, i.e., background(BG) [1], [2]. Two kinds of ROI coding methods are included in the standard: the maximum shift (Maxshift) method [1] and the generic scaling based method [2]. As illustrated in Fig. I(b) and Fig. I(c), these two methods place ROI associated bits in the higher bitplanes by down-shifting the bits of BG coefficients from Most Significant Bitplane (MSB) to Least Significant Bitplane (LSB), so that ROI coefficients can be coded firstly in the following embedded bitplane coding [3], [4], [5]. As any scaling value is supported, the generic scaling based method allows fine control on the relative importance between ROI and BG. However, it needs to code ROI shapes, and the current standard restricts ROI shapes to be rectangle and ellipse [2]. On the other hand, in the generic scaling based method, the different wavelet subbands must have the same ROI definition, which is not desired in some applications [6]. The Maxshift method may be considered as a particular case of the generic scaling based method when the scaling value is so large that there is no overlapping between BG and ROI bitplanes, i.e., the scaling value, s, must satisfy (1):

$$s \geq \max(M_b), \tag{1}$$

where M_b is the nominal maximum number of magnitude bitplanes in subband b, and $\max(M_b)$ is the largest magnitude for any coefficients [1]. Therefore, ROI shape is implicit for the decoder in the Maxshift method, and arbitrarily shaped ROI coding can be supported. Moreover, it can flexibly treat wavelet subbands differently [4]. The major limitation of the Maxshift method is that it cannot flexibly control the relative importance between ROIs and BG by adjusting the scaling values. It means that for the wavelet subbands where the distinction between ROI and BG is applied, no information about BG coefficients can be received until ROI coefficients are fully decoded [6].

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Considering the limitations of two standard ROI coding methods, some authors proposed several improved methods for JPEG2000 ROI image coding. A Maxshift-like method with low scaling values was proposed in [5] to take the advantages of two standard methods. It is implemented by removing all the overlapping bitplanes between ROI and BG coefficients and relatively modifying the quantization steps of coefficients. However, this modification would bring the reduction of final ROI and BG qualities. In [6], Wang *et al.* proposed a bitplane-by-bitplane shift (BbBShift) method, which shifts the bitplanes on a bitplane-by-bitplane basis instead of shifting them all at once in standard methods. This new method supports arbitrarily shaped ROI coding without coding shapes, and can finer control ROI and BG quality than the Maxshift method. While, it is not compatible with the current JPEG2000 ROI coding definitions and a new mode is needed. Moreover, it is difficult for the BbBShift method to code multiple ROIs with different priority during encoding/transmission of one image [6]. In this letter, a new and flexible scaling based method called Partial Significant Bitplanes Shift is proposed, which can combine the advantages of the two standard methods and efficiently compress multiple ROIs with different degrees of interest.

II Partial Significant Bitplanes Shift

The proposed method is mainly based on the facts that at low bit rates, ROI in an image is desired to sustain higher quality than BG, while at the high bit rates, both ROI and BG can be coded with high quality and the difference between them is not very noticeable. So we can just isolate a certain number bitplanes of ROI in the most significant bitplanes to adjust the importance between ROI and BG. That means we only need to shift part of the most significant bitplanes of ROI coefficients instead of shifting the whole bitplanes as the standard methods do. Thereby we name this method as Partial Significant Bitplanes Shift (PSBShift). An illustration of the PSBShift method is shown in Fig. I(d) (where $s = 6$). The whole bitplanes of ROI coefficients are divided into two parts: *the most significant bitplanes* and *the residual significant bitplanes*. The number of the most significant bitplanes is the same as the scaling value s, and the number of the residual significant bitplanes N_{lsbs} is represented as:

$$N_{lsbs} = \begin{cases} M_b - s & \text{if } s \leq M_b; \\ 0 & \text{if } s > M_b. \end{cases} \tag{2}$$

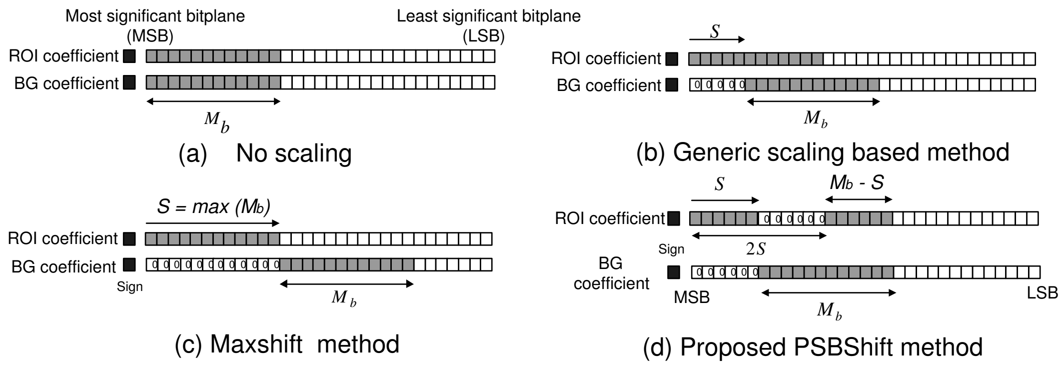


Fig. 1. Standard ROI coding methods and the proposed PSBShift method, where Bitplanes are represented by the gray blocks and the black block represents the sign of coefficients.

At the encoder, the most significant bitplanes of ROI coefficients are not shifted while the residual significant bitplanes of ROI coefficients are down-shifted towards LSB with BG coefficients. At the decoder, ROI coefficients can be identified in the same way as Maxshift. All bits lower than the s^{th} bitplane are scaled up s bitplanes, and combined with the bits higher than the s^{th} bitplane. It is a little different from the Maxshift decoding method, in which no combination operation is included. Since the bits above the s^{th} bitplane of BG coefficients are all zeros, this modified decoder can also handle the standard codestream generated by the Maxshift method.

II-A PSBShift ROI Coding

The PSBShift method can code ROI in an image with higher or the same quality as BG. As shown in Fig. I(d), if the encoded bitstream is truncated or the encoding/decoding process is terminated before $2s$ most significant bitplanes are coded/decoded, ROI will have higher quality than BG. After $2s$ most significant bitplanes are coded/decoded (when bitplanes of ROI and BG are overlapping), ROI and BG will be coded with the same quality. The scaling value s controls the relative quality between ROI and BG. For example, we apply the different scaling values ($s = 0, 5, 7, 9, 11, 13$) to the "Barbara" image (720×576, 8bpp) coded in the revertible coding mode, where a rectangular ROI has been defined on face region. Fig. 2 illustrates ROI and BG distortion reduction with the increase of bit rate. When s is small, e.g., $s = 5$, the quality of ROI and BG has no much difference (Fig. 2(b)). With the increase of the scaling value, e.g., $s > 6$ (Fig. 2(c)-(e)), ROI can be coded with higher quality than BG within a large range of bit rates. When all bitplanes are decoded, the lossless decoding is reached. If $s \geq \max(M_b)$ (here $\max(M_b) = 12$), the result is the same as the Maxshift method, as shown in Fig. 2(f). Therefore, the PSBShift method can also generalize the Maxshift method in a way that is different from the generic scaling based method. Compared with the generic scaling based method, which only supports rectangle and ellipse ROI shapes [2], the PSBShift method can code arbitrarily shaped ROI without coding the shape. The new method can also allow different ROI definitions in different wavelet subbands as the Maxshift method does. Different from the Maxshift method, the PSBShift method can also flexibly adjust the relative importance between ROI and BG by using different scaling values. This flexibility may lead to improved quality of ROI coding, which depends on the applications. For example, Fig. 3 shows "Barbara" image, which is coded reversibly (ROI/BG distinction is applied in all subbands) and decoded at 0.5bpp using the Maxshift method ($s = 12$) and the PSBShift method ($s = 10$), respectively. It can be observed that without visual difference at ROI, the PSBShift method provides better quality at BG than the Maxshift method. If ROI needs to have higher quality than BG, the larger scaling value can be used and the results would be closer to the Maxshift method. Therefore, the PSBShift method may lead to an efficient and flexible ROI coding that can be tailored for different applications.

II-B Multiple ROI Coding

Multiple ROI coding requires multiple ROIs to be coded with different quality according to their priorities in an image. The generic scaling based method can support multiple ROI coding. But it needs to code ROI shape and restrict it. The Maxshift method may support multiple ROI coding, while it would significantly reduce the compression efficiency by largely increasing the dynamic range of wavelet coefficients [4]. The PSBShift method can support efficient multiple ROI coding by scaling the different numbers of most significant bitplanes for different ROIs, as illustrated in Fig. 4. For example, "Bike" image (2048×2560, 8bpp) with three defined ROIs, i.e., ROI-1, ROI-2, and ROI-3, shown in Fig. 5(a), is compressed reversibly. The priority order of these ROIs is ROI-1>ROI-2>ROI-3. The upshifted numbers of the most significant bitplanes should be chosen as $s_1 > s_2 > s_3$, e.g., $s_1 = 10, s_2 = 8, s_3 = 6$. The scaling value stored in the codestream is $s = \max(s_1, s_2, s_3) = 10$. Fig. 5(b)(c) show the reconstructed quality (PSNR) of three ROIs and BG. It can be found that at the low bit rates (e.g., bpp<0.9), all ROIs have higher quality than BG. ROI-1 has the highest quality while ROI-3 has the lowest quality among three ROIs. When the bit rate increases, the BG quality increase quickly and may be better than the quality of ROI-3 and even better than ROI-2. This is because the upshifted numbers of the most significant bitplanes of ROI-3 and ROI-2 are not large enough. At last,

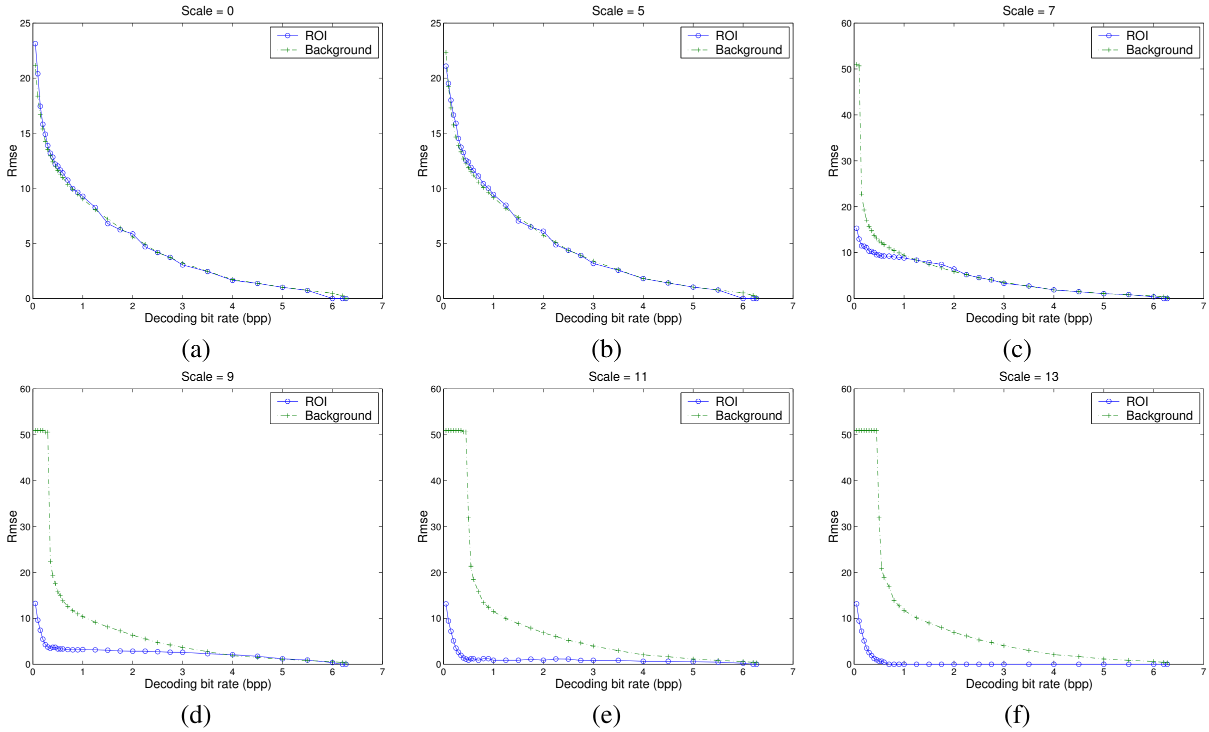


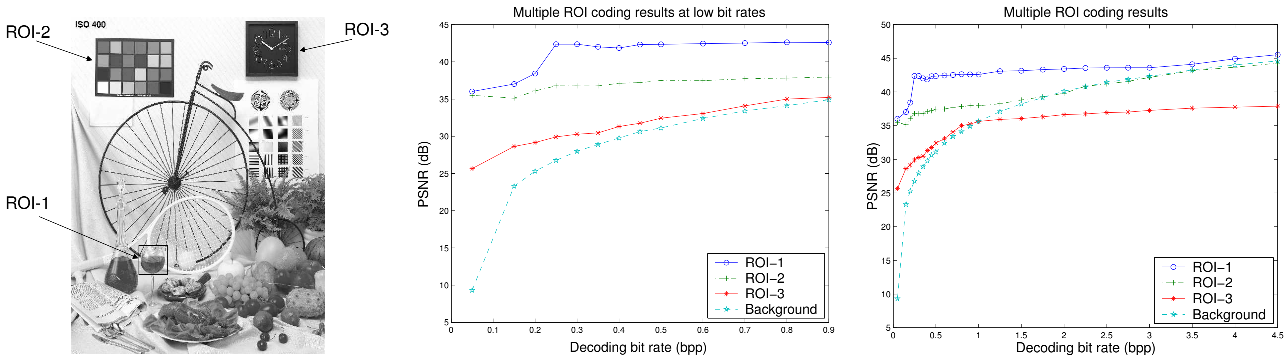
Fig. 2. The distortion reduction of ROI and BG with respect to the increase of bit rates at different scaling values, i.e., $s = 0, 5, 7, 9, 11, 13$.

Fig. 3. "Barbara" coded at 0.5bpp using the Maxshift method (left, $s = 12$) and the PSBShift method (right, $s = 10$). The ROI is at the face region and 1/14 of the image size.

three ROIs and BG can reach the lossless quality at the same time when all the bitplanes are decoded. Hence, the PSBShift method can support multiple ROI coding in a certain range of bit rates, depending on the number of upshifted bitplanes for each ROI.

II-C Complexity and Compatibility

Since it is not necessary for the PSBShift method to code ROI shapes, its complexity is less while coding efficiency is better than the generic scaling based method, when the same scaling value is used. Compared with the Maxshift method, a little more complicated procedure need to be included in the decoder of the PSBShift method in order to shift back and reconstruct the original bitplanes. If the point of lossless coding is reached, the bit rate produced by the PSBShift method is less or approximately same as the Maxshift method, depending on the scaling value used and ROI sizes. Experiments on twelve images (8bpp, images of size 512×512 up to 2560×2048, rectangular ROI shape) show that, compared with the Maxshift method, PSBShift spends approximately $0 \sim 3.34\%$ (depending on the scaling value used) less bits for ROI size $1/20$ of the image size, and for ROI size $1/5$ of the image size, the PSBShift method costs $0.86 \sim 3.94\%$ less bits if $s < 8$, while $0 \sim 1.46\%$ more bits if $s > 8$. The



(a) "Bike" with three ROIs. (b) Bit rates from 0 to 0.9bpp (c) Bit rates from 0 to 4.5 bpp.

Fig. 5. "Bike" image and its results of Multiple ROI coding.

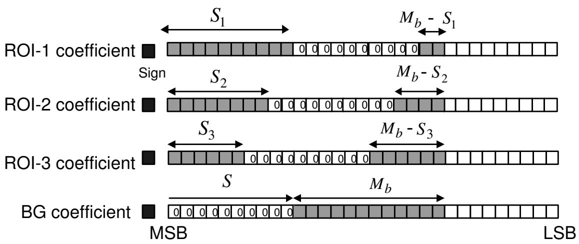


Fig. 4. PSBShift method for Multiple ROI coding.

slightly increased bit rate is due to the reason that the PSBShift method affects the following entropy coding by reordering the bitplanes. It is still true that the PSBShift method codes no more bitplanes than the Maxshift method. Moreover, the codestream generated by the PSBShift method has the same syntax format as the current JPEG2000. While it still needs a minor modification of the JPEG2000 Part I decoder as described above, the modified decoder can also handle the codestream produced by the Maxshift method.

III Conclusions

In this letter, we have proposed a so-called PSBShift JPEG2000 ROI coding method that has four primary advantages: (1) it supports arbitrarily shaped ROI coding without coding the shape; (2) it allows different wavelet subbands can have different ROI definitions; (3) it can control the relative importance between ROIs and BG by using appropriate scaling values; (4) the new method can efficiently code multiple ROIs with different priorities in an image at the low bit rates. We expect this idea is valuable for future research in ROI image coding and its applications.

Acknowledgment

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