

# New region of interest image coding and its applications for remote sensing image

Libao Zhang (张立保)<sup>1</sup> and Ke Wang (王珂)<sup>2</sup>

<sup>1</sup>College of Information Science and Technology, Beijing Normal University, Beijing 100875

<sup>2</sup>College of Communications Engineering, Jilin University, Changchun 130025

Received June 22, 2005

A new region of interest (ROI) coding called partial multiply bitplane alternating shift (PMBAShift) is presented in this paper. In PMBAShift, the partial most significant bitplanes of ROI are shifted up and no overlap with any bitplane of background (BG). The most significant bitplanes of BG and general significant bitplanes of ROI coefficients are shifted up by bitplane-by-bitplane alternating scaling. Finally, the least significant bitplanes of ROI and the general significant bitplanes of BG are obtained in the original position and the least significant bitplanes of BG coefficients are shifted down and no overlap with any bitplane. The new method not only retains advantages of maximum shift (Maxshift) method, but also efficiently compresses multiple ROIs according to different degrees of interest without any shape information.

OCIS codes: 100.0100, 280.0280, 100.2000, 100.7410.

Efficient image storage and transmission are in great demand for remote sensing image community. Compression techniques that achieve high quality for the regions are important to remote sensing images, and high overall compression ratio, may have the potential for widespread remote sensing acceptance. The region of interest (ROI) image coding offers an efficient implementation for coding and transmitting remote sensing images. JPEG 2000 standard in Refs. [1] and [2] defines two coding algorithms, maximum shift (Maxshift) method, and general scaling-based method. In these methods, a ROI of the image can have a better quality than the rest at any decoding bit-rate<sup>[3]</sup>. In this paper, a novel and efficient bitplanes shift coding method so-called partial multiply bitplane alternating shift (PMBAShift) method is presented, which uses four new strategies to improve ROI coding efficiency.

ROI coding is very significant for remote sensing image compression and transmission<sup>[4-6]</sup>. Maxshift method and the general scaling based method place ROI associated bits in the higher bitplanes by upshifting some bitplanes of ROI coefficients from most significant bitplane (MSB) to least significant bitplane (LSB), so that ROI coefficients can be coded firstly in the embedded bitplane coding. In Fig. 1(a), the general scaling-based method is shown and the scaling value is 4. In Fig. 1(b), the Maxshift method is shown and the scaling value is 10. As any scaling value is supported, the general scaling-based method allows fine control on the relative importance between ROI and background (BG). However, there are two major drawbacks of the general scaling-based method. First, it needs to encode and transmit the shape information of the ROIs. This rapidly increases the complexities of encoder and decoder implementations. Second, if arbitrary ROI sharps are desired, then shape coding will consume a large number of bits, which significantly decreases the overall coding efficiency. To solve above problems, a new effective solution-Maxshift method was proposed for JPEG 2000<sup>[3]</sup>. The Maxshift method is a particular case of the general scaling-based method when the scaling

value is so large that there is no overlapping between BG and ROI bitplanes, i.e., the scaling values must satisfy

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

where  $M_b$  is the nominal maximum number of magnitude bitplanes, and  $\max(M_b)$  is the largest number of magnitude bitplanes for any ROI coefficient. Figure 1(c) shows the bitplane shift in Maxshift method. All significant bits associated with the ROI after scaling will be in higher bitplanes than all the significant bits associated with the background. Therefore, ROI shape is implicit for the decoder in this method, and arbitrarily shaped ROI coding can be supported.

The Maxshift method must decode of all ROI coefficients before accessing bit-planes of the background and uses large shifting values that significantly increase the number of total bit-planes to encode. It is inflexible in interactive net browser. So it is difficult that this method handles multiple ROIs of any shapes based on different degrees of interest. A new method was presented in Ref. [7] with low scaling values to take advantages of two standard methods. It is implemented

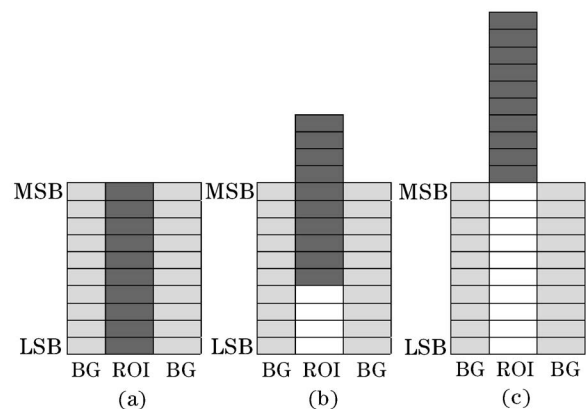


Fig. 1. Two basic scaling methods of ROI in JPEG2000. (a) No scaling; (b) the general scaling based method; (c) Maxshift method.

by removing all the overlapping bitplanes between ROI and BG coefficients, which relatively modified the quantization steps of coefficients. However, the method reduced the final ROI and BG qualities. A bitplane-by-bitplane shift (BbBShift) method was proposed in Ref. [8] by shifting the bitplanes on a bitplane-by-bitplane basis instead of shifting them all at once in Maxshift method. Although it supports arbitrarily shaped ROI coding without coding shapes, it is difficult for the BbBShift method to code multiple ROIs with different priority during encoding and transmission. The partial significant bitplanes shift (PSBShift) method<sup>[9]</sup> shifts part of the most significant of ROI coefficients instead of shifting the whole bitplanes as the standard methods do. But the PSBShift method needs the same scaling values for every ROI for multiple ROIs coding. Additionally, this method cannot fully decode ROIs coefficients before all BG coefficients are decoded because some residual significant bitplanes of ROIs are not shifted at the encoder. In this paper, a novel and flexible bitplanes shift coding method is proposed, which can efficiently compress multiple ROIs with different degrees of interest and ensure all ROIs to be decoded before BG is decoded.

PMBAShift method is based on the facts that at low bit rates, ROIs in an image are 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<sup>[4,5]</sup>. It divides all bitplanes of the original image coefficients into six parts: the most significant bitplanes of ROI (MSR), the most significant bitplanes of BG (MSB), the general significant bitplanes of ROI (GSR), the general significant bitplanes of BG (GSB), the least significant bitplanes of ROI (LSR) and the least significant bitplanes of BG (LSB). For different significant bitplanes in different parts, four shifting strategies are applied. First, the PMBAShift shifts up the partial most significant bitplanes in MSR, which are no overlapping with any bitplanes of BG. It can ensure that the most important bitplanes of ROI coefficients are firstly coded and transmitted. Secondly, the bitplanes in MSB and GSR are shifted up by bitplane-by-bitplane alternating scaling, which enables the flexible adjustment of compression quality in ROI and BG. Thirdly, the bitplanes in GSB and the bitplanes in LSR are obtained in the original position. Finally, the bitplanes in LSB are shifted down and no overlap with any bitplane. In Fig. 2, three improving ROI coding method, PSBShift, BbBShift, and PMBAShift, are compared.

Let the bitplane numbers in MSR, MSB, GSR, GSB, LSR, and LSB are  $s_1, s_2, s_3, s_4, s_5,$  and  $s_6$ , respectively; OLSB — original least significant bitplane be  $s_{OLSB}$ ; and OMSB — original most significant bitplane be  $s_{OMSB}$ . The scaling bitplane numbers  $s_1, s_2, s_3, s_4, s_5,$  and  $s_6$ , must satisfy

$$s_2 = s_3, \quad (2)$$

$$s_1 + s_3 + s_5 = s_{OMSB} - s_{OLSB}, \quad (3)$$

$$s_2 + s_4 + s_6 = s_{OMSB} - s_{OLSB}. \quad (4)$$

The basic steps of PBAShift method are presented as follows:

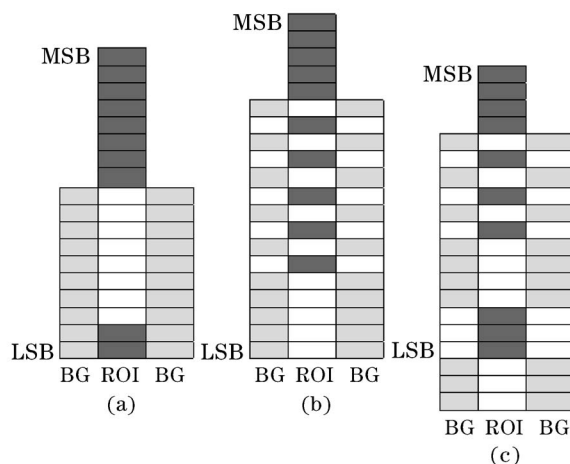


Fig. 2. Comparison of different scaling methods for single ROI. (a) PSBShift; (b) BbBShift; (c) PMBAShift.

- (1) For any bitplane  $l$  of a ROI coefficient:
  - If  $0 \leq l \leq s_5$ , no shift  $l$  and encoding directly;
  - If  $s_5 < l \leq s_3 + s_5$ , shift  $l$  up to bitplane  $s_6 + s_4 + 2(l - s_5) - 1$ ;
  - If  $s_3 + s_5 < l \leq s_1 + s_3 + s_5$ , shift  $l$  up to bitplane  $l - s_5 + s_6 + s_4 + s_2$ .
- (2) For any bitplane  $l$  of an BG coefficient:
  - If  $0 \leq l \leq s_6$ , shift  $l$  down to bitplane  $-(l + 1)$ ;
  - If  $s_6 < l \leq s_4 + s_6$ , no shift  $l$  and encoding directly;
  - If  $s_4 + s_6 < l \leq s_2 + s_4 + s_6$ , shift  $l$  up to bitplane  $s_4 + s_6 + 2(l - s_4 - s_6)$ .

At the decoder, for any given non-zero wavelet coefficient, the first step is to identify whether it is a bitplane of ROI coefficient or BG coefficient. ROI decoding algorithm is presented as follows:

- (1) If  $l > s_6 + s_4 + s_3 + s_2$ , then  $l \in \text{ROI}$ , shift  $l$  down and the scaling value is  $s_2 + s_4 + s_6 - s_5$ ;
- (2) If  $l = s_6 + s_4 + 2i - 1, i = 1, 2, 3, \dots, s_2$ , then  $l \in \text{ROI}$ , shift  $l$  down and the scaling value is  $(l + s_4 + s_6 - 1)/2 - s_5$ ;
- (3) If  $l = s_6 + s_4 + 2i, i = 1, 2, 3, \dots, s_3$ , then  $l \in \text{BG}$ , shift  $l$  down and the scaling value is  $(l - s_4 - s_6)/2$ .
- (4) If  $0 \leq l < s_6 + s_4$ , then  $l \in \text{BG}$  or  $l \in \text{ROI}$ , no shift  $l$  and decoding directly;
- (5) If  $l < 0$ , then  $l \in \text{BG}$  and shift  $l$  up and the scaling value is  $-l$ .

Maxshift method can support the multiple ROI coding. However, the drawback of Maxshift is that the coefficient bitplanes of all ROIs must be scaled with the same values, which does not have the flexibility to allow for an arbitrary scaling value to define the relative importance of ROIs and BG wavelet coefficients, and cannot code ROIs according to different degrees of interest. Additionally, all bitplanes of the BG coefficients cannot be decoded until the all bitplanes of all ROIs are decoded.

The proposed PMBAShift method not only can support arbitrary ROIs shape without shape coding, but also allows arbitrary scaling value between the multiple ROIs and BG, which enables the flexible adjustment of compression quality in ROIs and BG according to different degrees of interest. The basic scheme of PMBAShift method for multiple ROIs is introduced in Fig. 3. As illustrated in Fig. 3, at the low bit rates, different bitplanes are decoded with different degrees of interest. At the mediate bit rates, the most significant bitplanes

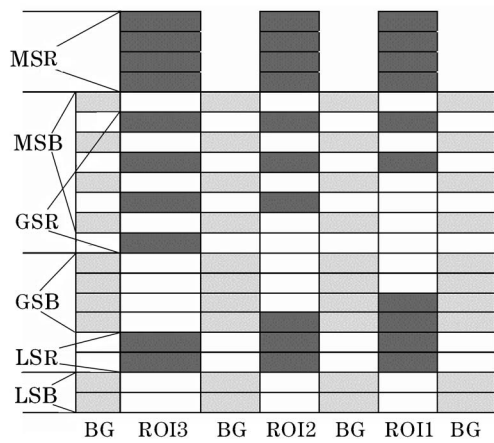


Fig. 3. PMBAsHift method for multiple ROIs.

of BG and general significant bitplanes of ROIs can be decoded. At the high bit rates, both ROIs and BG can be coded with high quality and difference between them is not very noticeable. Additionally, PMBAsHift can also support some BG bitplanes which are prior to encode if the ROI detail is imperceptible random noise or not important.

The multiple ROIs coding scheme of PMBAsHift has three important differences with the single ROI coding scheme. First, the scaling bitplane numbers in MSB for every ROI are the same. In other words,  $s_1$  for all ROIs is a constant. This can ensure that all ROIs in an image sustain higher quality than BG at low bit rates. So the scaling values in MSR for every ROI  $s_1$  must satisfy

$$s_{1-ROIk} = c \quad (k = 1, 2, 3, \dots). \quad (5)$$

In Eq. (5),  $c$  is constant. Second, the scaling bitplane number in GSR for all ROIs is the maximum scaling value in GSR. So  $s_3$  must satisfy

$$s_3 = \max(s_{3-ROIk}) \quad (k = 1, 2, 3, \dots). \quad (6)$$

Third, the whole scaling values for every ROI are the constant

$$s_{1-ROIk} + s_{2-ROIk} + s_{5-ROIk} = c \quad (k = 1, 2, 3, \dots). \quad (7)$$

Figure 4 shows the comparison of compression results for  $512 \times 512$  Woodlandhills image among Maxshift, BbBSHift, PSBSHift, and PMBAsHift at 1.0 bpp. ROI is the downtown and the area is about 9.41% of the whole image. The compression performance of PMBAsHift is better for the whole image than other method at low bit rates. Figure 5 is the Multiple ROI coding results for  $512 \times 512$  San Diego Shelter Island image. Two ROIs are chosen in the image. ROI-1 is the island and ROI-2 is the downtown. The priority order of these ROIs is ROI-1 > ROI-2. We hope that the ROI-1 has the best quality at low bit rates. From Fig. 5, it can be found that at low bit rates (e.g.,  $\text{bpp} < 1.0$ ), all ROIs have the higher quality than BG and ROI-1 has the highest quality between ROIs. When the bit rates increase, because the most significant bitplanes of BG coefficients are

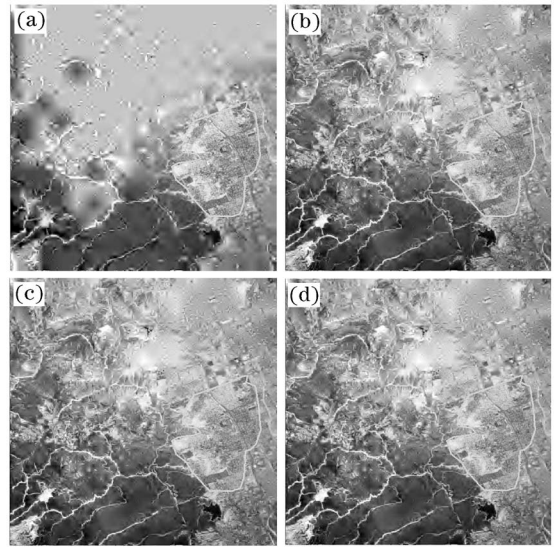


Fig. 4. Comparison of compression results among different ROI coding methods for single ROI at 1.0 bpp. (a) Maxshift method; (b) BbBSHift method; (c) PSBSHift method; (d) PMBAsHift method.

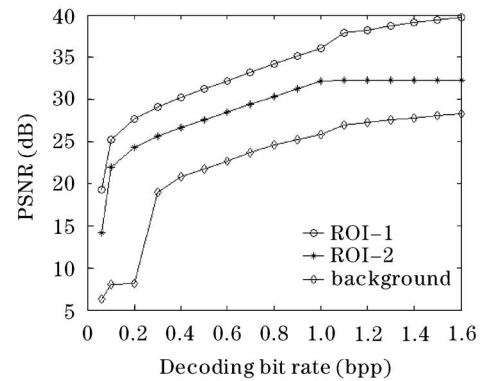


Fig. 5. PMBAsHift method for multiple ROIs at low bit rates.

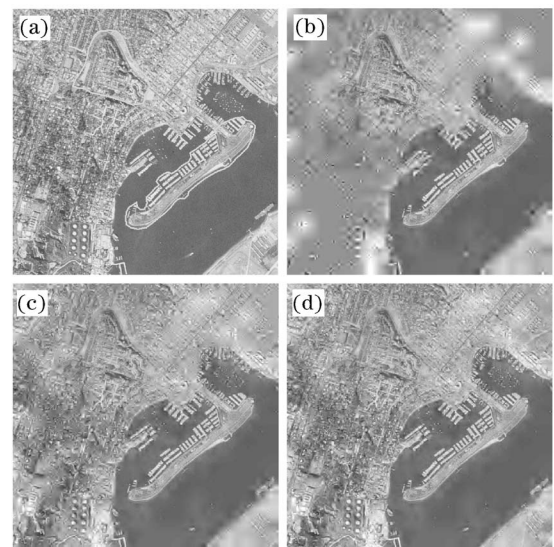


Fig. 6. Comparison of compression results for San Diego Shelter Island among different multiple ROI coding methods at 1.0 bpp. (a) Original image; (b) Maxshift method; (c) PSBSHift method; (d) PMBAsHift method.

**Table 1. Comparison of PSNR Values for San Diego Shelter Island among Different Multiple ROI Coding Methods for ROIs (0.8 bpp)**

Region	PSNR (dB)			
	Maxshift	BbBShift	PSBShift	PMBAShift
ROI-1	41.91	33.65	35.96	34.22
ROI-2	38.33	30.21	32.47	30.64
BG	15.67	23.83	20.25	24.68

up-shifted bitplanes, the BG quality increases to some degree quickly. Hence, the PMBAShift method can support multiple ROI coding based on different degrees of interest. In Fig. 6, the comparison of compression results for four reconstructed San Diego Shelter Island images with two ROIs among Maxshift, BbBShift, PSBShift, and PMBAShift is shown at 1.0 bpp. Table 1 shows the comparison of PSNR values for San Diego Shelter Island among different multiple ROI coding methods for ROIs at 0.8 bpp. For PMBAShift, the PSNR value of BG is the highest and the PSNR values of ROIs are better than BbBShift.

In this paper, an efficient and fast ROI coding method called PMBAShift is presented. The complexity of PMBAShift is less and the coding efficiency is higher than that of the general scaling-based method. Compared with the Maxshift method, a more complicated procedure needs to be included in the PMBAShift method so that the shift bitplanes and compensation bitplanes shift back and reconstruct the original bitplanes in decoder. The codestream generated by the PMBAShift method is compliant with the JPEG2000 format. In addition, for multiple ROI coding, this proposed method not only can support different degrees of interest at different decoding rates, but also does not limit the ROIs shapes. Compared the PSBShift with BbBShift method, BbBShift is the most complex method and PSBShift is the simplest method. However, the presented method has the flexible scaling value for all ROI coefficients, which can help to

reduce the memory demands and control the quality between ROIs and BG efficiently.

The new method has four primary advantages. Firstly, it can support multiple ROI coding with different degrees of interest in an image by bitplane-by-bitplane alternating shift. Second, it supports arbitrary shapes ROI encoding without coding any shape information, which ensures the low complexity for coding ROIs in real-world applications. Third, the new method can ensure all ROIs to be decoded before BG is decoded. Finally, PMBAShift can control efficiently the quality between ROIs and BG by adjusting scaling values. We expect this idea is valuable for future research in ROI image coding and its applications.

This work was supported by the National Natural Science Foundation of China (No. 40372129 and 59638220), and the Youth Teacher Foundation of Beijing Normal University. L. Zhang's e-mail address is libaozhang@163.com.

## References

1. "JPEG 2000 core coding system" <http://www.jpeg.com/jpeg2000/j2kpart1.html>.
2. A. Skodras, C. Christopoulos, and T. Ebrahimi, *IEEE Signal Processing Magazine* **12**, 36 (2001).
3. C. Christopoulos, J. Askelöf, and M. Larsson, *IEEE Signal Processing Lett.* **7**, 247 (2000).
4. J. Xiao, Y. Zhou, C. Wu, J. Yang, and L. Xiang, *Acta Opt. Sin.* (in Chinese) **24**, 1494 (2004).
5. J. Deng, C. Wu, and J. Chen, *Acta Opt. Sin.* (in Chinese) **24**, 299 (2004).
6. L. Zhang and K. Wang, *Proc. SPIE* **5286**, 931 (2003).
7. R. Grosbois, D. Santa-Cruz, and T. Ebrahimi, *Proc. SPIE* **4472**, 267 (2001).
8. Z. Wang and A. C. Bovik, *IEEE Signal Processing Lett.* **9**, 160 (2002).
9. L. Liu and G. Fan, *IEEE Signal Processing Lett.* **10**, 35 (2003).