AN IMPROVED SHAPE-BASED ARBITRARY SHAPE ROI CODING METHOD WITH SA-DWT IN JPEG2000

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ABSTRACT

JPEG2000 image coding standard supports two region-of-interest (ROI) coding methods: the maximum shift (Maxshift) method and the general scaling based method. This paper extends the general scaling based method of JPEG2000, and presents an effective ROI coding method based on shape coding with Shape-Adaptive Discrete Wavelet Transforms (SA-DWT) applied to the arbitrary shape ROI and background respectively. The proposed method not only allows the coding of multiple arbitrary shape ROI, but also the image quality of ROI boundary will not decrease for the wavelet coefficients shifting of background. Coding results illustrate the performance of the proposed coding method.

1. INTRODUCTION

Region-of-interest (ROI) image coding [1] is one of new features included in the JPEG2000 standard [2]. This feature allows for encoding the ROI in an image with better quality than the background (BG). Two kinds of ROI coding methods are defined in JPEG2000 standard: the maximum shift (Maxshift) method and the general scaling based method [1]. The former is given in part-I of JPEG2000 standard [3], and the latter is supported by part-II of the JPEG2000 standard [4].

The general scaling based method can determine the relative importance of the ROI and the BG by the scaling value s. But the general scaling based method must code the shape information of ROI, and the shape coding will consume a large number of bits. So the current JPEG2000 standard attempts to avoid this problem and only defines rectangle and ellipse shaped ROI. The Maxshift method supports the arbitrary shape ROI coding. Unlike the general scaling based method, the Maxshift method cannot control the relative importance between ROI and BG. Another limitation of the Maxshift method is that does not support multiple ROIs coding, where multiple ROIs with different priorities may be involved. Considering the limitations of the two standard methods defined in JPEG2000, some authors presented improved methods for ROI image coding. A bitplane-by-bitplane shift (BbBShift) method was proposed in [5]. The BbBShift method supports arbitrary shaped ROI coding, and it can finer control the ROI and BG quality than the Maxshift method. Unfortunately, the BbBShift method does not support multiple ROI coding. In [6], L. LiJie *et al.* proposed a method called Most Significant Bitplane Shift (MSBShift). The method differs from the method of the BbBShift in the way the ROI and BG bitplanes are arranged. In [7], a new approach removes all the overlapping bitplanes between ROI and BG coefficients, which results in the loss of a significant amount of ROI information for smaller shift values. The above methods all avoid the shape coding of arbitrary shape ROI. Mahesh M. Subedar *et al.* proposed a new arbitrary shape ROI coding method based on shape coding in [8]. This method adopts the simple Differential Chain Coding (DCC) to code the shape information of arbitrary shape ROI. Performance results illustrate that the method is effective. This paper improves the method proposed by Mahesh M. Subedar *et al.* and presents a more simple and effective shape-coding method of arbitrary shape ROI —Vertical Edge Differential Chain Coding (VEDCC). The proposed algorithm supports multiple arbitrary shape ROIs coding, and has the flexibility to control the relative importance between ROIs and BG. The VEDCC is an effective and less complex shape coding method, which consuming only a very small fraction of the overall bit budget. After studying these methods, we find a common disadvantage of these ROI coding methods: The pixel values of ROI boundary of decoding image distort very large because of the shifting of background wavelet coefficients. For this problem, this paper takes the place of JPEG2000 wavelet transforms with Shape-Adaptive Discrete Wavelet Transforms (SA-DWT)[9]. The method largely improves the image quality of ROI boundary.

This paper is organized as follows. Section 2 introduces the proposed arbitrary shape ROI coding method for JPEG2000 using SA-DWT in detail. Experimental results are presented in Section 3, and a conclusion is given in Section 4.

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2. ARBITRARY SHAPE ROI CODING METHOD FOR JPEG2000 USING SA-DWT

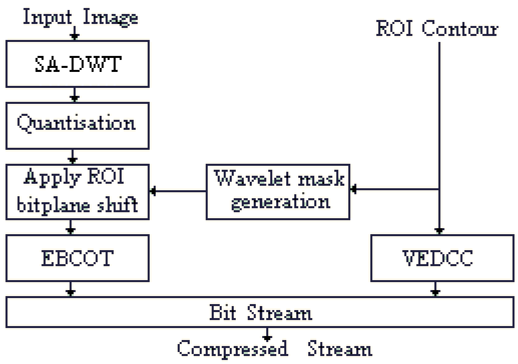

Fig.1. Proposed ROI coding method block diagram

The block diagram of the proposed method is shown in Fig. 1. Firstly, the shape information of arbitrary shape ROI is coded with the VEDCC algorithm and the code stream is embedded in the file head of JPEG2000. Secondly, SA-DWT is applied to the arbitrary shape ROI and BG respectively. And the generated wavelet coefficients are quantized. Thirdly, a proper scaling factor s is selected for shifting the quantized wavelet coefficients according to the wavelet mask of arbitrary shape ROI. Lastly, the bitplanes are coded with EBCOT algorithm [10]. The decoding is inverse process of coding.

2.1. Vertical Edge Differential Chain Coding

In the general scaling based method of ROI coding for JPEG2000, the vertical edge differential chain coding (VEDCC) is adopted to code the ROI contour information. Before describing the steps of the proposed contour-coding algorithm, we define the following:

Nc : Number of contours in the multicontour image.

$N(j),\quad j=1,2,\cdots,Nc$: Number of horizontal position in the jth contour.

$P(j),\quad j=1,2,\cdots,Nc$: The most left and right edge location of the starting row of the jth contour.

$Q(j,m),\quad j=1,2,\cdots,Nc,\quad m=1,2,\cdots,N(j)$: The most left and right edge location column number of the mth horizontal position in the jth contour.

$R(j,m),\quad j=1,2,\cdots,Nc,\quad m=1,2,\cdots,N(j)-1$: The differential value of the most left and right edge location column number of the mth horizontal position in the jth contour.

The algorithm steps of VEDCC are as follows:

1) Initialize the variable:

$$\begin{cases} Nc=0, j=0, N(j)=0, m=0, \\ P(j)=(0,0,imagewidth), \\ Q(j,m)=(0,0), R(j,m)=(0,0) \end{cases} \tag{1}$$

2) Scan the given ROI contour image row-wise from left to right and from top to bottom. If a nonzero pixel is captured in x row and *left_y* column, continue to scan and if a zero pixel is captured in *right_y* column again, the operation is as formula (2). Otherwise, stop;

$$\begin{cases} Nc=Nc+1, j=j+1, N(j)=1, m=1, \\ P(j)=(row, left\_col, right\_col), \\ Q(j,m)=(left\_col, right\_col) \end{cases} \tag{2}$$

3) Continue to scan the same row, and if a nonzero pixel is captured again, think it as a new ROI. After the scanning pixels change from nonzero to zero again, perform the formula (2);

4) Scan the next row. If capturing the left edge column number *left_y* and right edge column number *right_y* of nonzero pixels, we compared the column number range of scanning row with that of the previous row ROI. If there is the overlapping region between the column number range of the scanning row and only that of the ith $(i=1,2,\cdots,j)$ ROI, the column number range belongs to ith ROI. Perform the formula (3).

$$\begin{cases} m=m+1, N(i)=N(i)+1, \\ Q(i,m)=(left\_col, right\_col) \\ R(i,m-1)=Q(i,m-1)-Q(i,m) \end{cases} \tag{3}$$

If there is the overlapping region between the column number range of the scanning row and that of multiple ROIs, the operation is as formula (4).

$$\begin{aligned} &\min[abs((left\_col - Q(i,m).left\_col) \\ &+ (right\_col - Q(i,m).right\_col))] \end{aligned} \tag{4}$$

where the min[●] is the operation that calculate the minimum value, and i is the ROI number that has overlapping region with the column number range of the scanning row. If getting the minimum value from the formula (4) in i=k (k<=j), we think the column number range belongs to the kth ROI. Perform the formula (3). If there isn't overlapping region between the column number range of the scanning row and that of any ROIs, think the column number range belongs to a new ROI and perform formula (2);

5) After the whole image has been scanned, perform the arithmetic coding for the formula (5). And the coded bitstream is stored in JPEG2000 file header.

$$\begin{cases} Nc, N(j),\quad P(j),\quad R(j,m), \\ j=1,2,\cdots,Nc,\quad m=1,2,\cdots,N(j)-1 \end{cases} \tag{5}$$

The VEDCC algorithm scans the image only once and is very simple, so it affects the complexity and running time of JPEG2000 encoder/decoder very small. Moreover, the arithmetic coding is adopted to code these differential data. Therefore, the shape information bitstream of the arbitrary shape ROI consumes only a very small fraction of the overall bit budget of JPEG2000.

2.2. Shape-Adaptive Discrete Wavelet Transforms

The conventional wavelet transform is only performed in rectangular image region and cannot be done in arbitrary shape region. Li *et al.* presented a shape-adaptive discrete wavelet transforms (SA-DWT)[9] technique for coding arbitrary shape still texture. One of the features of the SA-DWT is that the number of coefficients after SA-DWT is identical to the number of pixels in the original image. Another feature is that the spatial correlation, locality properties of wavelet transforms, and self-similarity across subbands are well preserved in SA-DWT.

There are two components in the SA-DWT. One is a way to handle wavelet transforms for arbitrary length image segments. The other is a subsampling method for arbitrary length image segments at arbitrary locations. A proper subsampling method is important for the SA-DWT.

3. EXPERIMENTAL RESULTS

The paper embeds the VEDCC and SA-DWT algorithm into JPEG2000 according to the presented method structure. Table. 1 shows the PSNR comparison results of three images between the reconstructed image of JPEG2000 general scaling based method and the proposed method, with the character face being the ROI, at different bit rates and a ROI scale factor s=4 (The presented PSNR results are compared over the observed ROIs). Coding results are illustrated with two examples the "Barbara" image (512 x 512) and "Lena" image (512 x 512). Fig. 2 shows the reconstructed "Barbara" image that are coded by the general scaling based method of JPEG2000 and the proposed algorithm, with the woman's face being the ROI, at a bit rate of 0.08bits/pixel (bpp), and a ROI scale factor s=4. The results of experiment show the ROI PSNR of the presented method is higher 0.88dB than that of the general scaling based method of JPEG2000. From the images, it can be seen that the proposed method results in better ROI image quality and in clearer ROI boundary as compared with the JPEG2000 general scaling based method at the same bit rate. Fig. 3 illustrates the image quality of the "Lena" image that is coded by the proposed method, with the 'Lena' being the ROI, at different bit rates and ROI scale factors. Fig. 3 (a) shows the reconstructed image at a bit rate of 0.4bpp and a ROI scale factor s=4. Fig. 3 (b) shows the reconstructed image at a bit rate of 0.04bpp and a ROI scale factor s=8. The results illustrate the performance of proposed method is very good at extremely low bit rates.

In order to evaluate the coding efficiency of the proposed VEDCC algorithm, we compare the bit numbers of the shape information coding generated by the VEDCC algorithm with that generated by the DCC [8] algorithm for the ROI contours of Fig.2 and Fig.3. The results are shown in the Table. 2. From the table, it can be seen the coding efficiency of the proposed VEDCC algorithm is better than the DCC algorithm, and the shape information bitstream consumes only a very small fraction of the overall bit budget of JPEG2000.

Table. 2: The evaluation of shape information coding efficiency for "Barbara" image and "Lena" image

	ROI contour coding of "Barbara"	ROI contour coding of "Lena"
DCC	88 Bytes	318 Bytes
VEDCC	17 Bytes	250 Bytes

4. CONCLUSION

This paper effectively extends the general scaling based method of JPEG2000, and presents an ROI coding method based on shape coding with Shape-Adaptive Discrete Wavelet Transforms (SA-DWT) applied to the arbitrary shape ROI and background respectively. The presented method not only supports the coding of multiple arbitrary shape ROIs, and has the flexibility to control the relative importance of the ROI and BG region image quality by the scaling factor, but also the image quality of ROI boundary will not decrease for the wavelet coefficient shifting of background. Coding results illustrate that the performance of the proposed coding method is very effective.

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(a) General scaling based method of JPEG2000 PSNR=29.07dB (b) The proposed algorithm PSNR=29.95dB

Fig. 2: Comparison of "Barbara" reconstructed image, at a bit rate of 0.08bpp, and a ROI scale factor *s*=4.

(a) A bit rate of 0.4bpp, and s=4 (b) A bit rate of 0.04bpp, and s=8

Fig. 3: Comparison of "Lena " reconstructed image coded by the proposed algorithm at different bit rates and ROI scale factors

Table.1: PSNR comparison of the reconstructed image of JPEG2000 general scaling based method and the proposed method

Image	General scaling based method		The proposed method	
	Bpp	PSNR(dB)	Bpp	PSNR(dB)
Zelda (256x256)	0.3146	36.4802	0.3128	37.9025
	0.0784	24.5897	0.0736	26.5654
	0.0390	19.4880	0.0367	21.5681
Lena (512x512)	0.3178	40.4831	0.3180	41.2546
	0.0796	32.4107	0.0789	33.3002
	0.0398	28.5460	0.0397	29.2112
Man (1024x1024)	0.0799	35.8886	0.0798	36.5097
	0.0395	33.4263	0.0398	33.8287
	0.0077	27.7791	0.0074	28.0326