Compatible Image Compression

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Abstract: New image compression method is presented. The presented system is compatible with JPEG one. Compatibility is one of the most important factors for image compression, because JPEG system is utilized for almost every imaging devices and mobiles, etc. First the image is divided into 4 small similar images and one of the 4 images is compressed and coded by using JPEG system. At the receiver side the left 3 images are reconstructed by an interpolation technique. The employed interpolation method is cubic convolution one for image-nonedge area. A directional optimal estimator is used to reconstruct the pixel on the image edge area. Different optimal coefficients of the estimator are calculated for vertical, horizontal and diagonal image edge direction. Simulation example shows that the presented method gives us better image quality than other interpolation methods do.

1. Introduction

In those years multimedia filed is extremely advanced. A tremendous number of images are communicated not only in computer-inter-net but in mobile phone all over the world. In the image transmission compression and coding methods are always utilized for shortening the signal bits. JPEG method is the most popular one for a still image compression and codings. JPEG2000 which is a little more effective than usual JPEG is also exploited. JPEG2000, however, is not so popular because of noncompatibility with JPEG. JPEG is used for too many imaging items like a digital camera and/or mobile phones. Hence industries do not follow JPEG2000. Compatibility is so serious for every industry. In this paper a compatible method is presented.

2. Image Quadrant Division

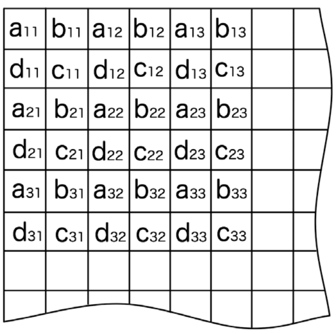

Figure 1. Original image pixel

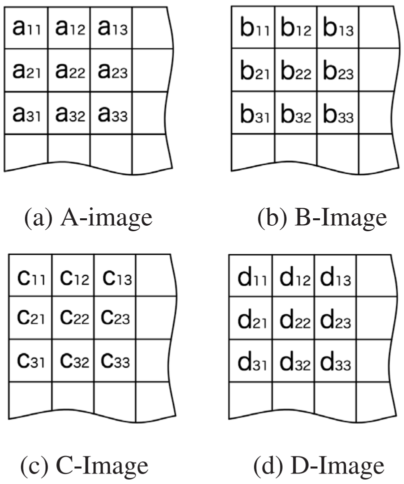

Figure 2. Divided image pixel

An original image is divided into four quadrants as follows. Assuming that Fig.1 is an original image pixel a block unit is 2x2 pixel one with elements a_{ij}, b_{ij}, c_{ij} and d_{ij}. Figure 2-a called A-image here and it is made from the elements a_{ij} (i, j=1,2$\cdots$) of the original image Fig.1. Similarly B-image, C-image and D-image are constructed from the original one Fig.1. The image size of these A$\sim$D-image is a half of that of the original one. And furthermore every images are only one pixel shifted version each other. Then these all images looks very similar. Figure 3 and Figure 4 are the examples of these images. Figure 3 is the original image with a size 512×512. Figure 4(a)$\sim$Figure 4(d) show the A-image$\sim$D-image respectively. At a glance these all images look the same. So, from the A-image we estimate other images optimally in this paper.

Figure 3. Original image

(a) A-image (b) B-Image

(c) C-Image (d) D-Image

Figure 4. Divided image

Figure 5. Image edge area

3. Optimal Estimate

In such a situation as shown in previous section these are many interpolation techniques like spline polynomial, bilinear interpolation[1], bi-cubic interpolation[2] and cubic convolution[3], etc. But here we can utilize all true values of the original image before transmitting it, then it had better to take such a technique. In this paper we design in optimal estimator for an edge pixels called edge region of the image. For the frat area that means non-edge region here we use cubic convolution interpolation technique which is the best one of all interpolation techniques except the optimal estimator proposed here.

3.1 Image edge defection

It is needed to define edge region of the image in this paper. For this purpose we use Sobel filter which is the best one here because not edge line but edge area can be detected. Sobel operator[4] is as follows:

$$f_x = \begin{pmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{pmatrix} \qquad f_y = \begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix} \tag{1}$$

$$|\nabla f(x, y)| = \sqrt{f_x^2(x, y) + f_y^2(x, y)} \tag{2}$$

$$\theta = \tan^{-1}(f_y/f_x) \tag{3}$$

f_x and f_x in Eq.(1) are Sobel operators for x direction and y direction respectively. $|\nabla f(x, y)|$ is a magnitude of the gradient. θ in Eq.(3) is the gradient direction.

Figure 5 shows several difference images. Roberts, Laplacian and Sobel filtering are utilized. From these figures it is clear that Sobel filtering result is the best one to detect the image edge area.

3.2 Optimal interpolation

In this procedure different interpolations are taken for the edge area and for the non-edge area. For the edge area optimal estimator is constructed and for the non-edge area the cubic convolution interpolation which is the best one of the all traditional interpolation techniques is utilized.

3.2.1 Cubic convolution interpolation

Cubic convolution interpolation is employed only for non-edge area in the image. The general expression of cubic convolution method is shown as:

$$P = [f(l{-}1){-}v) \;\; f(l{-}v) \;\; f(l{+}1){-}v) \;\; f(l{+}2){-}v)] \cdot \\ = \begin{bmatrix} P_{k-1,l-1} & P_{k,l-1} & P_{k+1,l-1} & P_{k+2,l-1} \\ P_{k-1,l} & P_{k,l} & P_{k+1,l} & P_{k+2,l} \\ P_{k-1,l+1} & P_{k,l+1} & P_{k+1,l+1} & P_{k+2,l+1} \\ P_{k-1,l+2} & P_{k,l+2} & P_{k+1,l+2} & P_{k+2,l+2} \end{bmatrix} \cdot \begin{bmatrix} f((k{-}1){-}u) \\ f(k{-}u) \\ f((k{+}1){-}u) \\ f((k{+}2){-}u) \end{bmatrix} \tag{4}$$

where P is an interpolation point value and $P_{k,l}$ is an image pixel value.The pixel position is shown in Figure 6.

$$f(t) = \begin{cases} 1 - 2|t|^2 + |t|^3 & 0 \le |t| \le 1 \\ 4 - 8|t| + 5|t|^2 - |t|^3 & 1 \le |t| \le 2 \\ 0 & 2 \le |t| \end{cases} \tag{5}$$

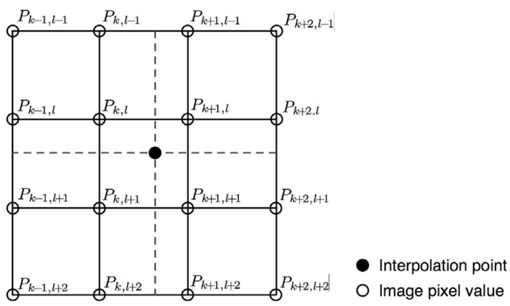

Figure 6. Lattice data of the image for interpolation

$$\begin{aligned} k &= [u] \\ l &= [v] \end{aligned} \tag{6}$$

where[ ] is called Gaussian Sign. Consequently when B-image in Figure 2(b) is from A-image in Figure 2(a), u=1/2, v=0, similarly for c-image in Figure 2(c) u=v=1/2 and for D-image in Figure 2(d) u=0, v=1/2.

3.2.2 Optimal interpolation

In such case as interpolation construction of the image we can utilize a true value of the image before transmitting it because we get whole image pixel values at transmitting side. Then we are able to design an optimal estimator for the interpolation problem. Here we employ such scheme only for edge area because blurring at image edge area makes the reconstructed image spoiled strongly for our human eye. Assuming A-image in Figure 2(a) gotten at the receiving side we design an optimal estimator to make B, C, D-images from the A-image:

(a) B-image estimator

From Figure 1 since B-image pixel is adjacent to A-image pixel the estimator for B-image pixel b_{ij} is formed as

$$\hat{b}_{i,j} = k_1^b a_{i,j} + k_2^b a_{i,j+1} \tag{7}$$

where $\hat{b}_{i,j}$ is the estimate of $b_{i,j}$ and k_1^b and k_2^b are real coefficients to be estimated optimally:

$$\phi(k_1, k_2) = \sum_{i,j \in Re} (b_{i,j} - (k_1^b a_{i,j} + k_2^b a_{i,j+1}))^2 \tag{8}$$

$$(Re\ :\ \text{edge area})$$

From

$$\frac{\partial \phi(k_1^b, k_2^b)}{\partial k_1^b} = 0 \quad \text{and} \quad \frac{\partial \phi(k_1^b, k_2^b)}{\partial k_2^b} = 0 \tag{9}$$

we obtain

$$k_1^b = \frac{\sum_{i,j\in Re} a_{i,j} \cdot a_{i,j+1} \cdot \sum_{i,j\in Re} b_{i,j} \cdot a_{i,j+1}}{\sum_{i,j\in Re} a_{i,j}^2 \cdot \sum_{i,j\in Re} a_{i,j+1}^2 - \left(\sum_{i,j\in Re} a_{i,j} \cdot a_{i,j+1}\right)^2} - \frac{\sum_{i,j\in Re} a_{i,j+1}^2 \cdot \sum_{i,j\in Re} b_{i,j} \cdot a_{i,j}}{\sum_{i,j\in Re} a_{i,j}^2 \cdot \sum_{i,j\in Re} a_{i,j+1}^2 - \left(\sum_{i,j\in Re} a_{i,j} \cdot a_{i,j+1}\right)^2} \tag{10}$$

$$k_2^b = \frac{-\sum_{i,j\in Re} a_{i,j+1} \cdot a_{i,j} \cdot \sum_{i,j\in Re} b_{i,j} \cdot a_{i,j}}{\sum_{i,j\in Re} a_{i,j}^2 \cdot \sum_{i,j\in Re} a_{i,j+1}^2 - \left(\sum_{i,j\in Re} a_{i,j} \cdot a_{i,j+1}\right)^2} + \frac{\sum_{i,j\in Re} a_{i,j}^2 \cdot \sum_{i,j\in Re} b_{i,j} \cdot a_{i,j+1}}{\sum_{i,j\in Re} a_{i,j}^2 \cdot \sum_{i,j\in Re} a_{i,j+1}^2 - \left(\sum_{i,j\in Re} a_{i,j} \cdot a_{i,j+1}\right)^2} \tag{11}$$

(b) C-image estimator

Similarly to B-image estimator (a) the estimate $\hat{c}_{i,j}$ of $c_{i,j}$ is formed as

$$\hat{c}_{i,j} = k_1^c a_{i,j} + k_2^c a_{i,j+1} + k_3^c a_{i+1,j+1} + k_4^c a_{i+1,j} \tag{12}$$

Consequently four coefficients are those in this case because c_{ij} is 2-dimensional control point of a_{ij} pixels. The procedure for determining these coefficients $k_1 \sim k_4$ is just the same as Eqs(9)∼(11).

(c) D-image estimator The procedure is almost completely the same as produce of B-image estimator (a).

$$\hat{d}_{i,j} = k_1^d a_{i,j} + k_2^d a_{i+1,j} \tag{13}$$

All these coefficients should be transmitted with A-image data by traditional method likes JPEG. But additional required bits are only few for these coefficient.

3.3 Procedure

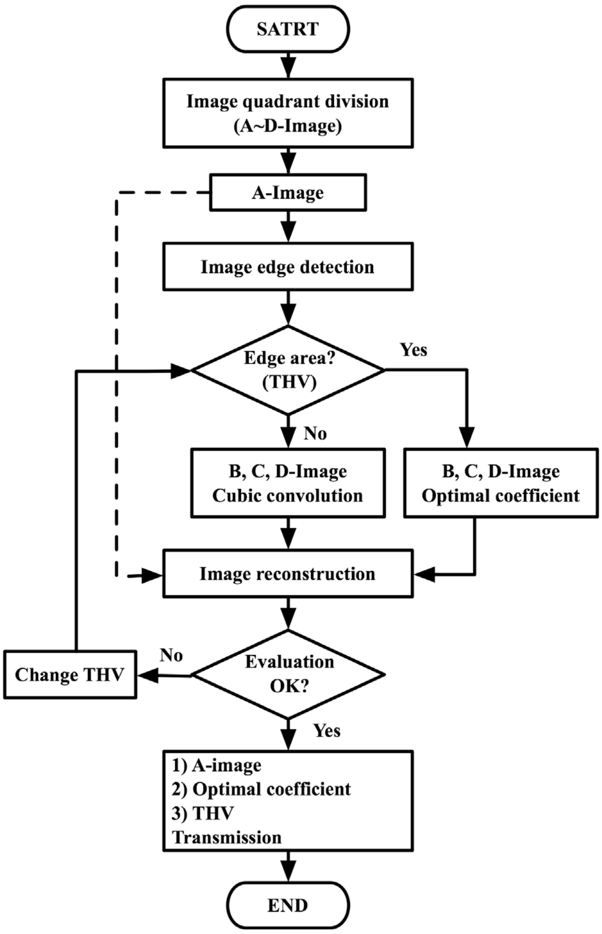

Figure 7. Flow chart

Figure 7 shows a flow chart of the proposed procedure. First the original image is divided into four sub-images called A-image, B-image, C-image, and D-image. Next step is to detect an image edge area from A-image through Sobel filter and threshold processing. Threshold value (THV) determined experimentally first, but if the final reconstructed image is unsatisfactory the THV is changed step by step. B, C, and D-images are interpolated optimally for image edge area and for non edge area these are interpolated by cubic convolution. Then total image reconstruction is accomplished at the transmitting side already. This is for the certification at the receiving side. Evaluation is made by using SNR.

When the reconstructed image is satisfied, A-image is transmitted with optimal coefficients and THV value. At the receiving side image should be reconstructed in the same manner in Figure 7.

4. Simulation

Figure 8(a), 8(b), and 8(c) are an original image and the reconstructed images processed by proposed interpolation and by the cubic convolution interpolation only respectively. The SNR of Figure 8(b) is 33.02dB and that of cubic interpolation image Figure 8(c) is 32.07dB. The SNR looks about the same

(a) Original image

(b) Proposed interpolation (SNR = 33.02dB)

(b) Cubic interpolation (SNR = 32.07dB)

Figure 8. Simualtion result

but the image edge line is more beautiful in Figure 8(b) than in Figure 8(c). This is the effect of optimal interpolation. The bit rate is 0.25bit/pixel for both images. The required bits are only less than 100 bits for optimal coefficients.

5. Conclusions

Convenient compatible image compression method has bean presented. Almost all traditional compression and coding methods are able to use here. In the simulation example JPEG method is utilized. Generally in the image transmission problem image quality and quick transmission time are the most important. Another important fact is compatibility. All such problems are cleared for the proposed method. Image quality of our reconstructed image is one of the best qualities of all reconstructed images. Especially image edges are clear and fine. For a quick transmission time if the required bit is small and then the computer load is very light. The feature of our method is that we can certify the reconstructed image at the transmission side. The proposed method is suitable for mobile image transmission because of its simple and convenient form.

References

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