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High compression ratio static image coding technologies

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Abstract. In order to reduce the block effect in flat areas and retain more image edge details, an adaptive compression algorithm of image block classification based on human visual characteristics in the DCT domain is put forward, which effectively improves the quality of the compressed image. First of all, the core transformation technology of image compression encoding is analyzed, and compression comparison analysis is carried out for three typical static compression standards JPEG, JPEG2000 and JPEG-XR, to analyze the compression effects under the condition of high compression ratio. Secondly, the new idea of image block classification compression based on visual characteristics is put forward, and a new method for the DCT domain image block classification is put forward. By calculating the activity of the image block, the image block is divided into smooth area, edge area and texture area three categories. Finally, the analysis of distortion quantization is made for the unified quantization way, and the fundamental reasons of JPEG blocking effect are discussed. Then, combining with the human visual characteristics, adaptive quantization is realized for smooth area, edge area and texture area. The results showed that the image obtained by adaptive quantization compression has better visual effects and compression quality. In a word, it is concluded that adaptive quantization is beneficial for realizing high compression ratio image encoding.

Key words. Static image, compression coding, visual property, image block classification, adaptive quantization.

1. Introduction

The image is the most direct and vivid expression of the objects, and it is the most important information source for us to get the described object information. At present, the images we obtain are mainly derived from the natural scenery taken by digital cameras or other multimedia devices. The image can be divided into static image and video image according to its content [1]. Image compression has always been a hot topic in the field of image processing. With the constant updating of the

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times, compression coding technology has become an important subject of image processing, and it is gradually normalized and standardized. At present, image compression technology is very popular, and it is widely used in every field of life.

Image compression is to reduce the amount of image data, which is the typical application of data compression in images [2]. Image compression in essence is a kind of data set [3] which is relatively small in correlation, obtained by transformation and combination of image resource data with strong correlation. The general process of image compression is shown in Fig. 1.

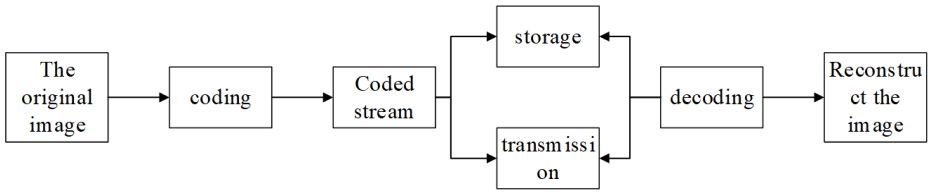

Fig. 1. Image compression process

The purpose of image compression is to minimize the redundancy of the image data. The image is, based on the form of data matrix, to make storage and transmission. As a result, a series of transformations of the data matrix can remove the redundant information, and encode the transformed data according to a certain rules, which can reduce the storage space for information. Digital images have very large amounts of data. A colorful image of 640×480 size, and a 1 G compact disk can holds only about 1000 images. Such a large amount of data undoubtedly brings great difficulties to the storage and transmission of images. There are two ways to solve this problem: to expand data transmission bandwidth; and to reduce the amount of image data. The bandwidth resource is obviously not infinitely expanded. In order to conduct more efficient data storage and transmission, to reduce the amount of image data becomes the best way to solve this problem. In consequence, the encoding algorithm with a higher compression performance becomes the object that the image processing technology pursues. By removing the intra frame and inter frame correlation of images, the image compression is achieved. While the image correlation is only considered in the static image. At the same time, the human visual system has visual characteristics, with different sensitivities to different regions. By using such characteristic of the human eye, in the process of image compression, for regions not sensitive to visual areas, in the case of without affecting the visual effect of image compression, it needs to reduce the encoding precision, so as to achieve the purpose of digital image compression. The quantization process designed in this paper is based on the order of JPEG model, introducing the adaptive quantization factors on the basis of the default quantization table given by the data unit of 8×8. The quantization factors, according to the content characteristic of image block and the sensitivity of human eye brightness, it is adjusted and modified, which improves the quantization accuracy, and improves the visual quality of image in the case of high compression ratio.

Based on the analysis of human visual characteristics, this chapter presents a new idea of compression algorithm combining image block classification, and puts

forward a method of DCT domain image classification. The traditional image features analysis is based on the spatial domain. The classification method is on the basis of DCT domain, to select the DCT AC coefficient energy as a characteristics standard to measure the image block activity, and to make the adaptive weighting about human visual system of AC coefficient energy. Thus, the image blocks are divided into three regions with different visual sensitivities, and good results are achieved.

2. State of the art

The development of image compression encoding technology is mainly divided into three stages [4]: the first generation encoding, mainly to remove data redundancy, the second generation encoding, having better compression effect and encoding rate, and the third generation encoding, combined with human visual characteristics and using multi-resolution coding.

At present, the international static image compression standard are: the JPEG standard [5], which has good compression performance and low algorithm complexity; the JPEG2000 standard [6], which supports both lossless and lossy compression two kinds of working methods, and in the lossless compression condition, it still has a higher compression ratio; JPEGXR standard [7, 8], which supports both lossy and lossless compression, which has higher compression performance than JPEG. In the same bit rate, the image compression quality is two times that of JPEG or equivalent quality only needs half of the volume.

With the development of these image encoding standards, it greatly promoted the development of image communication technology. As a result, the image information and communication technology has obtained large-scale popularization and application. The expansion of image communication technology scale has put forward higher requirements on image encoding technology, thus to further promote the development of encoding standardization work.

As the image compression and encoding technology develops rapidly, a new encoding algorithm emerges in. The encoding algorithm development experienced from simple image compression to complex image compression, and with the increasing standardization of image compression encoding, it promoted the step of the image encoding from theoretical research stage to engineering application stage, and achieved considerable achievements. As a result, the application of image compression has been throughout our life. The image types are different, and the content features are very different. The same coding algorithm is used to compress the images with different contents, and the optimal compression effect cannot always be achieved. In short, each compression algorithm has its advantages and disadvantages. In practical applications, we need to compare the performance of various compression algorithms, and select the most appropriate algorithm.

With the expansion of image application field, the image compression coding has developed rapidly, which has become an important technology in computer field, and has developed into a separate discipline system. But the traditional image compression algorithm, due to not considering human visual characteristics, the

human eye sensitive details are lost, thus affecting the quality of image compression. In consequence, the ability for using the traditional encoding method for compression of image data cannot be improved again. In order to improve the performance of image compression, researchers continue to break through innovation and find new ways and means. As a result, the second generation image encoding method that makes full use of human visual characteristics comes into being. A new encoding method not only considers the spatial frequency characteristics of the image, but also makes full use of the characteristics of human visual, so the image can obtain higher compression ratio and reconstruction quality.

3. Performance comparison of static image compression algorithms

3.1. Evaluation of image compression quality

An accurate and objective evaluation of the quality of compressed images is needed, which is a subject worthy of study in the field of image compression, and a standard to measure the compression performance of compression algorithms. The evaluation is mainly divided into subjective evaluation and objective evaluation [9]. Subjective evaluation is according to the human visual effect as a measurement standard of image compression quality. However, because the observing effect of human eye on images is easily affected by subjective effects, like image types, experimental environment and so on. Therefore, the evaluation result is uncertain, which cannot be directly used to evaluate the quality of image compression. The objective evaluation method is mainly to evaluate the quality of image compression through the calculation of formula. The main aspects are as follows:

Compression ratio, that is the ratio of the original image to the compressed image, which is usually measured by bpp. The difference of compression algorithm is the key factor that affects the compression ratio.

Encoding and decoding time is the coding efficiency.

Reconstruction of image quality. We often use peak signal to noise ratio (PSNR) and mean square error (MSE) as the evaluation criteria to evaluate the quality of image compression. MSE represents the mean square variance between the original image and the compressed image, and the calculation formula is

$$\mathrm{MSE} = \frac{1}{N_1 N_2} \sum_{n_1=0}^{N_1-1} \sum_{n_2=0}^{N2-1} \left(x[n_1, n_2] - \overline{x}[n_1, n_2]\right)^2 . \tag{1}$$

In the above formula, N represents the number of the original images, n represents the number of the compressed images.

3.2. Comparison of compression performance between three algorithms

The evaluation of image compression quality is divided into subjective evaluation and objective evaluation. Subjective evaluation refers to the visual effects of an image given to human. The objective evaluation criteria are measured by the peak signal-to-noise ratio (PSNR) of the image. This paper selected 8 bits gray image Peppers.bmp with resolution of 512×512, to make the JPEG, JPEG2000 and JPEG-XR compression. In addition, the test results are compared, and the compression performance of three kinds of compression methods in high compression ratio is analyzed.

The three compression algorithms are simulated by MATLAB, the PSNR values under different bit rates are calculated, and the compression effects of the three compression methods are obtained, as shown in Table 1:

Table 1. PSNR value under different bit rates for image Peppers.bmp

JPEG		JPEG2000		JPEG XR	
Actual bitrate	PSNR	Actual bitrate	PSNR	Actual bitrate	PSNR
GIVEN BITRATE bpp = 3					
2.97	42.9	3	45.7	2.98	45.01
GIVEN BITRATE bpp = 1					
1.01	37.81	1	42.4	0.98	42.1
GIVEN BITRATE bpp = 0.7					
0.7	35.87	0.7	39.9	0.69	39.89
GIVEN BITRATE bpp = 0.4					
0.41	33.18	0.4	38.3	0.401	38.01
GIVEN BITRATE bpp = 0.2					
0.2	29.78	0.2	36.45	0.2	36.11
GIVEN BITRATE bpp = 0.107					
0.1	21.26	0.1	32.6	0.107	31.9

The compression effect diagrams of three compression methods, JPEG, JPEG2000 and JPEG-XR, can be drawn from Table 1. As shown in Fig. 2, the effect can be visually compared.

3.3. Static image compression combined with human visual characteristics

According to the visual characteristics of human eyes, the human eyes are sensitive to the noise in the image smoothing area, insensitive to the noise in the texture area, and quite sensitive to the contour information of the image. Using the spatial frequency characteristics of human eyes and human visual characteristics, the image is divided into different types of regions, and adaptive quantization is achieved in different regions. This paper presents a new idea of image compression algorithm combined with image block classification. The research shows that the human visual

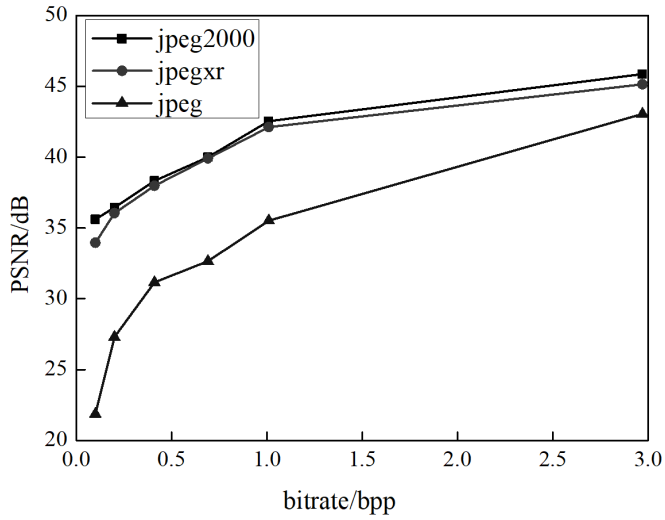

Fig. 2. PSNR value curves of three algorithms

system perceives an image through its regional features instead of pixels. Thus, an image is segmented into a series of regions with different categories, and the importance of information that each region transmits to the human eye is different. Basic idea: firstly, according to the characteristics of image blocks, the test image sub blocks are classified, and then adaptive compression is made for each kind of image blocks. Content features of image block are different, and the compression accuracy is different. In order to make the image compression maintaining high matching property with image features, and to improve the compression performance of compression algorithm, the analysis of image compression characteristics is particularly important. We often use the information entropy, mean or variance as the characteristic values of image. Taking the 8 bits gray scale image "Peppers.bmp" with resolution of 512×512 as an example, the image block activity after considering the visual weight is calculated, as shown in Fig. 3.

The weighted activity is normalized, and the range of activity and the average value are shown in Table 2.

Table 2. Activity intervals and averages

image	min	max	mean
Peppers.bmp	0	1	0.0801
Lena.bmp	0	1	0.1392
Barbara.bmp	0	1	0.2152
Baboon.bmp	0	1	0.2322

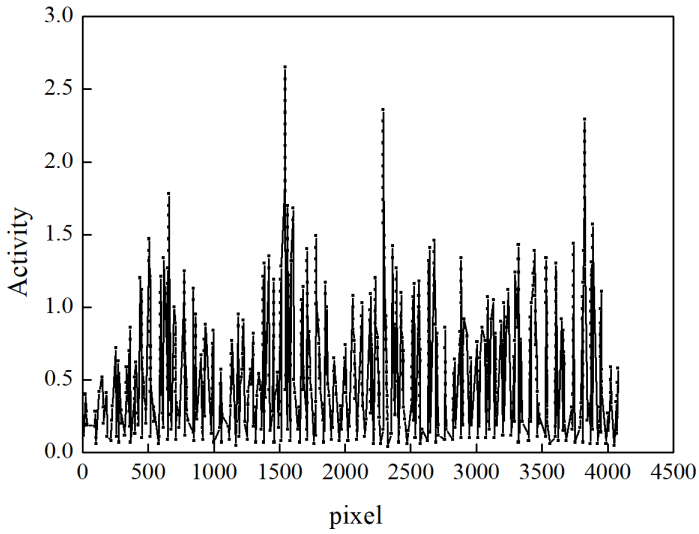

Fig. 3. Coordinate distribution of weighted activity

4. Results analysis and discussion

As can be seen from Table 1 and Fig. 2, the PSNR value of JPEG2000 is slightly higher than that of JPEGXR, and the PSNR values of JPEG2000 and JPEGXR are significantly higher than those of JPEG.

Based on the simulation, calculation and analysis of three kinds of compression algorithms, it can be known that, under the condition of low compression ratio, the compression effects of three kinds of encoding algorithm are very good, almost no distortion. In moderate compression ratio, the compression effect is better, and JPEG exhibited slight blocking effect. When continuing to increase the compression ratio, the block effect is obvious. Under the condition of high compression ratio, JPEG exhibits serious block effect, while JPEG2000 and JPEGXR compression effect can still satisfy the visual requirement. At the same time, it can be seen that, under the condition of the same compression ratio, for JPEG2000 and JPEGXR, there was no significant difference in visual effects. As this algorithm is studied aiming at serious block effect produced under high compression ratio, the images with visual effect under the conditions of high compression ratio are compared. And it can clearly be seen that, the image block effect in edge region and flat region significantly reduced, while the visual effect is improved obviously.

In Fig. 3, the maximum activity value is 2.69, the minimum is 0.016, and the average value is 0.23. It can be seen that image classification results are different under different thresholds, and the threshold range of better visual effect is [2Tv, 4Tv] (Tv represents the average activity). Simulation experiments are made on many images, all satisfying this property.

After normalizing the weighted activity, the range of normalization is [0,1], the corresponding maximum value is 1, the minimum value is 0, and the average value

is 0.08. It can be seen from table 2 that, the content characteristics are different for different images, so the best threshold of activity classification is different. Therefore, the individual image block activity is very large, so in determining the threshold value, it is not feasible to determine the threshold with the maximum for reference, but to take the average value as the reference standard.

5. Conclusion

In the existing image encoding system based on block, in the case of high compression ratio, it has block effect. For the image encoding based on block, the transform and quantization is an independent process. For each block, filters with different parameters were used for filtering. The quantization error generated by block filtering results in that adjacent block boundaries are not continuous, and such discontinuous will have a blocking effect. In the practical application of image coding, the block effect seriously affects the visual quality of images. In order to improve the quality of image reconstruction, new coding algorithms emerge in endlessly, but good compression algorithms often increase the cost of algorithm complexity. The increase of algorithm complexity not only increases the coding time and reduces coding efficiency, but also increases the memory consumption. In the static image compression, bit rate control is very important. Without accurate rate control, it cannot meet the requirement of accurate compression, and it undoubtedly brings great drawbacks to the application of the algorithm. For JPEG standards, the standard only provides a unified quantization table, but cannot set compression ratio. JPEGXR, as a completely new static image compression standard, has the same problem.

Based on the above problems, we, based on the JPEG standard algorithm, design the non uniform quantizer based on content characteristics classification. In that the image in different regions have different sensitivities, the final quantization is adjusted, which significantly improves the image quality at a given bit rate.

It can be seen that the adaptive quantization compression ratio compression standard JPEG has higher PSNR. For different images, the improvement degrees are not the same. The images with high complexity have rich details, so the improvement degree of PSNR value is higher. For the images with rich texture, the improvement degree of PSNR value is smaller. And for the same image, with the increase of compression ratio, the improvement degree gradually declined.

According to the new adaptive quantization method of the human visual characteristics, adaptive quantization is achieved for the smooth area, edge area and texture region. Fist of all, in the selection of a fixed threshold, the image blocks are classified. And then according to the sensitivity characteristics of human eyes to different regions, different correction coefficients are determined, and the final quantization table is determined. Finally, simulation results are made, and the results show that the algorithm has good compression effect.

The main work and innovations of this paper are summarized as follows: The effects of the sensitivity characteristics of human visual on the compression effect are studied. A compression algorithm new idea combining image block classification is proposed. DCT blocks of image are divided into three regions with different

visual sensitivities, the simulation experiments of the algorithm are made, and the compression effect of this algorithm is compared with that of the JPEG algorithm.

The relationship between the local image features and image block classification is discussed. The traditional variance, information entropy and so on image features are abandoned. The sum of total energy of DCT transform AC coefficient matrix is taken as the activity of image sub block, to make classification of image blocks, and to realize adaptive quantization of image blocks after classification according to the eye visual characteristics.

Through a large number of simulation experiments, the adaptive compression method is proved to be effective in improving the quality of image compression from two aspects of subjective evaluation and objective evaluation. It can be used to compress the whole images, and can also be used to compress each sub image after one image is layered (partitioned).

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