Color Image Compression Algorithm based on Wavelet Transform And LZW

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Abstract

The image must be compressed to reduce the pressure of large amounts of image data and information brings to the memory storage capacity, communication channel bandwidth and computer processing speed. The paper presents a color image compression algorithm combining wavelet transform with LZW. In the method, we firstly extract the Y, Cb and Cr components of the color image and each component is retained by a different scale factor. Then we convert the three-dimensional quantized components into a one-dimensional vector, and the difference obtained after the third difference processing is compressed by LZW algorithm. Finally, we get the compressed code. The experimental results show that the compression algorithm can effectively compress the color image and facilitate the storage and transmission of color image data.

Keywords

Color image compression; Wavelet transform; LZW algorithm.

1. Introduction

With the rapid development of computer technology, electronic information technology and communication technology, people can use image information everywhere. However, the large amount of information contained in the image information brings great difficulties to storage, processing and transmission. Therefore, image compression is very important and necessary [1]. It is of great significance for image data storage and transmission to explore more efficient and better compression performance. For the compression of grayscale images, some new methods have been put forward, but the research on color image compression method is rare. Color image has its own inherent characteristics: three primary colors—red, green and blue (RGB) in image has a certain relevance and similarity. So how to use this correlation to improve the compression ratio further is the focus of color image compression research [2] . Only to fully consider the redundancy information in color space of color image and the color visual characteristics of human's eye,we can more effectively dig out the compression potential of color image based on the traditional method[3].

Discrete wavelet transform is widely used in the field of image processing. The image signal after wavelet transform is decomposed into low frequency component and high frequency component. The low frequency component shows the approximate value of pixel value, and the other three detail sub-signals show vertical, horizontal and diagonal detail of the image[4]. LZW is a dictionary-based compression algorithm that does not require statistical statistics on the source, and can be adapted to generate coding dictionaries and decoding dictionaries, so it is particularly suitable for encoding repetitive characters or strings [5].

In view of the characteristics of color images, the literature [6] also converts the image into YCbCr color space for processing. However, sub-sampling of the two chrominance components will undoubtedly lose the larger coefficients in the chrominance component, resulting in signal to noise ratio of the reconstructed image is low. In [7], the RGB component isomorphic coding algorithm is used, but the algorithm is complex and the visual characteristics of the human's eye is not token into account, so it is difficult to improve the signal-to-noise ratio at a certain compression ratio. In this paper, decomposed coefficients of the image are converted to YCbCr space to be preserved in different proportions.Then the processed coefficients coefficients are compressed by LZW algorithm to be compressed coefficients sequence. The experiments show that the algorithm can greatly improve the image compression ratio while maintaining high signal to noise ratio of reconstructed image, which helps to store and transmit the image.

2. Principle of the algorithm

2.1 Wavelet transform theory of image

If $f(t) \in L^2(R)$, then the expression of the discrete wavelet is:

$$WT_f(a,b) = \int_{-\infty}^{+\infty} f(t)\psi^*_{j,k}(t)dt = \langle f(t), \psi_{j,k}(t) \rangle \tag{1}$$

The function $f(t)$ is the inner product expression of the discrete wavelet transform [8], where $\psi_{j,k}(t)$ is the discrete wavelet function, $a_0 > 0$ is a constant and the symbol $<,>$ represents the inner product.

In the practical application, according to the different requirements, we need multilayer image decomposition, that is, the image data is decomposed with wavelet transform, then the continuous decomposition of the lowest frequency sub band LL can meet the requirements of multi-level decomposition. Fig.1 is the sketch map of the two level decomposition of image with wavelet transform.

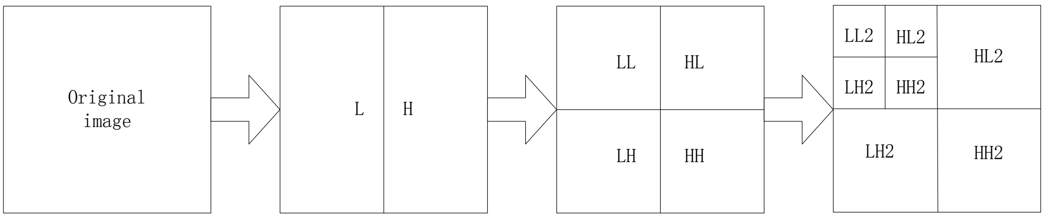

Fig.1 The process of two level image decomposition

2.2 Color space conversion

The color space is a three-dimensional space formed by the colored stimulus values in the color system. At present, three-color stimulus value always used in the digital color system is RGB, and color images are usually composed of RGB components. However, there is a great correlation between the RGB components of the color image, and the redundant information between the components is large. Compressing the image directly in the RGB color space, the effect is not very satisfactory. The ideal color space should satisfy that the energy of the image is as much as possible on a component, and the correlation between the components is as small as possible so that the image can be effectively compressed. We choose YCbCr space to process the image in the paper. Where Y is the luminance component, Cb is the blue chrominance component and Cr is the red chrominance component of the image. And the energy of the color image is concentrated on the luminance component. The eyes of mankind is more sensitive to the Y component of the video, therefore, after subtracting the chrominance component by sub-sampling the chrominance component, the naked eye will notice the change in image quality.

Formula that RGB space of color image convert to YCbCr space is as follows[9]:

$$\begin{bmatrix} Y \\ C_b \\ C_r \end{bmatrix} = \begin{bmatrix} 0.2990 & 0.5870 & 0.1140 \\ -0.1687 & -0.3313 & 0.5000 \\ 0.5000 & -0.4187 & -0.0813 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{2}$$

It is very easily to get the inverse transformation formula from the formula(2).

2.3 LZW compression and decompression algorithm

LZW (Lempel Ziv Welch) is the earliest widely used general data compression method on computers [10]. LZW is a dictionary encoding, is to use the repeatability in the date to achieve compression. The specific implementation steps of LZW coding algorithm are as follows [11]:

(1) Initializing the dictionary, clearing the prefix P;

(2)Reading the next character as the current character C, and then format entry <P, C>;

(3) To determine whether the entry <P, C> is in the dictionary;

① If the entry is in, then we assign the number of the entry <P, C> to P;

② If entry is not in, we need add the entry <P, C> into the dictionary, and let P = C, then output P;

(4)To determine whether the string table is full or has been completed coding;

① If the code is full or complete, we clear the dictionary, loop steps (1) to (4).

② Otherwise, we set the end code.

(2) if not, we output the encoded data stream Related to P.

End of encoding.

LZW decoding is the inverse of LZW coding. When we execute the LZW decoding, we need loop read the code, and output the string corresponding to the code in the string table, and add a new item to the table.

3. Algorithm Flow in the paper

The flow chart of the proposed color image compression algorithm in the paper is shown in Fig. 2

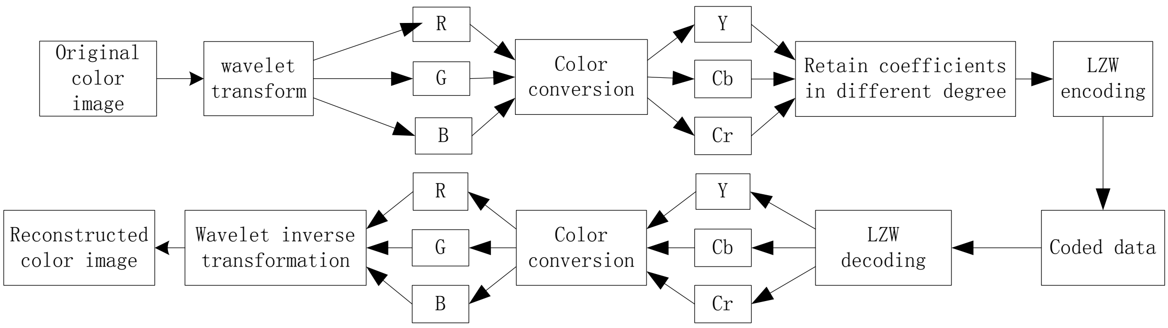

Fig.2: Algorithm Flowchart

Specific steps are as follows:

(1)A color image with a size of m * n * 3 is decomposed by wavelet;

(2) The decomposed coefficients are converted from RGB space to YCbCr space, and 100*K1*K2 percent of maximum number is reserved in each color channel, but other coefficients will be set to 0. The K1 value of Y is greater than the K1 value of Cb and Cr basing on the visual characteristics of human eyes.

(3) The processed coefficient matrix is transformed into a one-dimensional coefficient sequence with size of 3 * m * n, and the difference between any adjacent coefficients of the sequence will constitute a new one-dimensional sequence. The step is repeated three times and the final one-dimensional sequence is obtained. The sequence contains a large number of 0 will be compressed by LZW to obtain the compressed stream. The first number of each new sequence is retained during the process to be used in subsequent inverse operations.

(4) The decompression process is the inverse of the process (3),and the decompressed coefficient will uee to reconstruct the image with inverse wavelet transform.

4. Experimental results and analysis

In this paper, the objective evaluation index compression ratio (Cr), peak signal to noise ratio (PSNR) is defined as follows:

$$Cr=\frac{L_1}{L_2} \tag{3}$$

$$PSNR = 10\lg 10 \frac{255^2}{(MSE(R) + MSE(G) + MSE(B))/3} \tag{4}$$

Respectively, L_1 represent the length of the coefficient before encoding and L_2 represent the length of the coefficients after encoding, and $MSE(R)$, $MSE(G)$, $MSE(B)$ is the mean square differences of the R, G, and B color components.

The experiment is achieved in the CPU2.20GHz PC with the mat lab simulation. All experimental images (Lena, Tiffany, Baboon, Peppers) are commonly used 512 * 512 size color images in domestic and foreign academic journals. We use CDF9 / 7 wavelet to achieve 5 level image decomposition as same as literature [6] [7] in the paper.

As shown in Fig.3 is the original image of Peppers. Fig.4-Fig.6 is the reconstructed image of Peppers with compression ratio and signal to noise ratio in different K1, K2 values (K1 is expressed as a proportion of the Y, Cb, Cr component, and the K1 value of the Y component is 0.92) .It can be seen that the smaller the K1 or K2, the larger the compression ratio and the lower the signal-to-noise ratio, the greater the image distortion. We can also know that the effect of K2 is greater than K1 on the quality of the reconstructed image.

Fig. 3 Original image of Peppers

Fig.4 K2=1/100（2:1:1）

Cr=106.1 PSNR=35.68

Fig.5 K2=1/200（2:1:1）

Cr=154.2 PSNR=33.12

Fig.6 K2=1/100（4:1:1）

Cr=124.4 PSNR=34.55

For the Tiffany color image, when we take K1=0.92 for Y component, K1=0.04 for the Cb, Cr component and the K2 values are 1/10, 1/20, 1/40, 1/80 respectively, the bit rate and signal to noise ratio are shown in Table 1. The original image bit rate is 3 * 8b / p.

Table 1. Compression comparison of Tiffany image in different methods

Algorithm in the paper		Algorithm in Literature [6]		SPIHT	
Bit rate	PSNR	Bit rate	PSNR	Bit rate	PSNR
0.60	40.45	2.0	36.45	2.0	36.95
0.38	38.50	1.0	34.27	1.0	34.32
0.25	36.43	0.5	31.98	0.5	31.93
0.16	34.45	0.2	31.24	0.2	29.25

It can be seen from the data in Table 1 that compared with the literature [6] and SPIHT, the algorithm in the paper can obtain higher signal-to-noise ratio at lower bit rate, which shows the superiority of the algorithm.

In experiment of Lena, Baboon, Peppers color image, we take K1=0.92 for Y component, and take K1=0.23 for Cb, Cr component (4: 1: 1). Then we select a reasonable K2 value, data in Table 2 can be obtained.

Table 2. Comparison of compression effect

Image	Algorithm in the paper		Algorithm in Literature [7]		JPEG2000	
	Cr	PSNR	Cr	PSNR	Cr	PSNR
Lena	301.4	31.38	277.7	25.95	277.7	25.76
	185.8	35.55	181.0	27.47	181.0	27.44
Baboon	305.2	25.41	289.2	19.37	289.2	19.02
	125.8	27.87	95.3	20.57	95.3	20.85
Peppers	222.2	29.57	192.4	25.52	192.4	24.95
	110.2	35.31	94.9	28.14	94.9	27.24

It can be seen from the data in Table 2 that when the compression ratio is higher, the signal-to-noise ratio is higher than that of the literature [7] and the JPEG2000, that is, the less the distortion, which indicating that the algorithm is a relatively better algorithm.

5. Conclusion

In this paper, PSNR can be higher than the traditional algorithm under the lower bit rate or higher compression ratio when we use the color image compression algorithm combining wavelet transform with the LZW proposed in the paper to compress color image.So it can maintain the signal distortion of image as little as possible in the effective compression. The structure of the algorithm is simple so that it is easy to achieve.The algorithm is heleful to improving the color image compression and efficiency of transmission.

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