A Fast JPEG Image Compression Algorithm Based on DCT

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Abstract*—With the advent of the information age, people rely more and more on the use of computers to obtain and process information. Computer system is faced with the transmission of multiple media file data. This paper introduces a fast JPEG image compression algorithm based on DCT. The algorithm introduces the process of image coding and decoding for JPEG. The encoding part of the image can process the BMP format image by JEPG, and compress it into a binary file for real-time storage. The image can be decompressed by the corresponding decoding program. In addition, in the process of image transmission, taking advantage of the fact that human vision is not sensitive to chroma, JPEG format can be used to encode static image, and the color RBG of JPEG image can be changed into brightness y, chroma Cr and CB, which can not only effectively reduce chroma data, but also achieve compression.

Keywords—JPEG image; run length coding; Huffman coding; lossy compression;

I. INTRODUCTION

With the rapid development of multimedia technology, still images are widely used. Its application mainly focuses on image storage and image transmission. From the specific application, we can find that still images occupy more and more resources. Under such background conditions, still image compression has become a research hotspot.

At present, JPEG (Joint Photographic Experts Group) and JPEG 2000 are the main compression algorithms for still images. JPEG is the first widely accepted compression standard for monochrome and color still images. Its name comes from "Joint Photographic Experts Group". It is a cooperative organization of ISO / CCITT. The work product of this organization is ISO international standard ISO / iec10918-1 (Digital compression and coding of continuous tone still images) Of continuous tone still images) and ITU-T Recommendation t.81. The draft JPEG standard was published in 1991 and officially approved as an international standard in 1992. After further enhancement and expansion of this working group, ISO 10918-3 and ITU-T Recommendation t.81 were formed. JPEG is a lossy compression format that uses predictive coding (DPCM), discrete cosine transform (DCT) and entropy coding to remove redundant images and color data [1]. It can compress images in a small storage space, and duplicate or unimportant data in the image will be lost, which will easily cause damage to image data. In particular, if the compression ratio is too high, the quality of the recovered image will be significantly reduced. If we pursue high-quality image, we should not use too high compression ratio. However, JPEG compression technology is very advanced. It uses lossy compression to remove redundant image data. It can obtain a very high compression rate and display a very rich and vivid image, that is to say, it can get better image quality with the least disk space. Moreover, JPEG is a very flexible format, with the function of adjusting image quality. It allows different compression ratios to compress files. It supports multiple compression levels. The compression ratio is usually between 10:1 and 40:1. The larger the compression ratio, the lower the quality; on the contrary, the smaller the compression ratio, the better the quality. For example, a 1.37mb BMP bitmap file can be compressed to 20.3kb. Of course, you can also find a balance between image quality and file size. JPEG format compression is mainly high-frequency information, color information retention is good, suitable for application in the Internet, can reduce the image transmission time, can support 24bit true color, also widely used in images that need continuous tone [2].

The core algorithm of JPEG is DCT transform coding, and its compression performance basically reflects the technical level of image compression in the late 1980s. However, since the establishment of JPEG in the past 10 years, many more effective images compression techniques have been developed, such as wavelet transform method, fractal method, region division method and so on. Among them, the wavelet transform method is the most mature and the best performance and versatility of still image compression method. Because of this, the second generation still image compression standard, namely JPEG2000, is established. Its core technology is wavelet transform coding [3-4]. Its core codec adopts wavelet transform, arithmetic coding and embedded hierarchical organization, which is more complex than the previous still image compression standards. It achieves lossless and lossy compression, progressive resolution and SNR, random access

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and other excellent characteristics in the same code stream [5-7]. As an upgraded version of JPEG, JPEG 2000 has a compression rate about 30% higher than JPEG, and supports lossy and lossless compression. One of the most important features of JPEG2000 format is that it can realize progressive transmission, that is, the outline of the image is transmitted first, and then the data is gradually transmitted, so as to continuously improve the image quality and make the image display from hazy to clear. In addition, JPEG2000 also supports the so-called "region of interest" feature, which can arbitrarily specify the compression quality of the region of interest on the image, or select the specified part to decompress first.

II. RESEARCH STATUS OF IMAGE COMPRESSION

A. JPEG compression

1) JPEG compression principle

In JPEG algorithm, the image is firstly divided into blocks, which are not overlapped, and then each block is processed by two-dimensional discrete cosine transform (DCT). The transformed coefficients are basically uncorrelated, and the energy of the coefficient matrix is concentrated in the low-frequency region. The quantization results retain the coefficients of the low-frequency part and remove the coefficients of the high-frequency part. The quantized coefficients were reorganized by zigzag scanning, and then encoded by Huffman.

2) Research status and Prospect of JPEG compression

In view of the block effect and poor decompression of JPEG in high compression ratio, many improved methods have been proposed in recent years. The most effective method is DCT zero tree coding: DCT zero tree coding makes the coefficients in DCT blocks into log2n sub-bands, and then encodes them with zero tree coding scheme. At the same compression ratio, the PSNR is higher than EZW. However, in the case of high compression ratio, block effect is still the fatal weakness of DCT zero-tree coding. Hierarchical DCT zero-tree coding: this algorithm makes DCT transformation to the image, and concentrates the low-frequency blocks to do the reverse DCT transformation; it does the same transformation for the new image, so on, until it meets the requirements. Then, the hierarchical DCT transform and zero-tree permutation coefficients are encoded by zero-tree. One of the biggest problems of JPEG compression is the serious block effect when the compression ratio is high. Therefore, in the future research, the block effect produced by DCT transform should be combined with human visual characteristics [8-10].

B. Jepg2000 compression

1) Compression principle and characteristics of JPEG2000

The coding process is mainly divided into the following processes: preprocessing, core processing and bit stream organization. The preprocessing part includes image segmentation, DC level displacement and component transformation. The core processing part consists of discrete wavelet transform, quantization and entropy coding. The image compression ratio of JPEG 2000 format can be increased by 10% ~ 30% based on the current JPEG, and the compressed image appears more delicate and smoother. For the current JPEG standard, lossless and lossless compression cannot be provided in the same compressed stream. In JPEG 2000 system, lossy and lossless compression can be performed by selecting parameters. At present, JPEG images on the network are transmitted by "block" mode, while JPEG 2000 format images support progressive transmission, which makes users do not have to receive the compressed code stream of the whole image. [11-13] Because JPEG2000 adopts wavelet technology, it can obtain the compressed bit stream of some ROI randomly, and transmit and filter the compressed image data.

2) Prospect of PEG2000 compression

JPEG2000 standard is suitable for all kinds of image compression coding. Its application fields include Internet, remote sensing, mobile communication, medical treatment, digital library and e-commerce. JPEG2000 image compression standard will become the mainstream static image compression standard in the 21st century [14-15].

III. JPEG IMAGE COMPRESSION ALGORITHM BASED ON DCT

A. Overview of algorithms

In the coding process, the input image is first decomposed into 8 × 8 data blocks, and then each block is transformed into 64 DCT coefficient values by using forward two-dimensional DCT. Among them, one value is the DC coefficient, that is, the average value of 8 × 8 spatial image sub blocks, and the remaining 63 are AC coefficients. Next, the DCT coefficients are quantized, and finally the quantized DCT coefficients obtained by transformation are processed Encoding and transmission, forming a compressed image format. In the process of decoding, the encoded quantized DCT coefficients are decoded first, then the inverse quantization is performed, and then the DCT coefficients are converted into 8 × 8 sample image blocks (using two-dimensional DCT inverse transform), and finally the blocks after operation are combined into a single image. This completes the image compression and decompression process.

2) DCT coefficient quantization

Coefficient quantization is a very important process, which is the source of information loss (or distortion) in DCT coding and decoding. Uniform quantizer is used in JPEG compression algorithm. The definition of quantization can be expressed as follows: divide 64 DCT coefficients by their corresponding quantization steps, and round them up

$$Q\left(u,v\right)=IntegerRound\left(F\left(u,v\right)/S\left(u,v\right)\right)$$

The quantization coefficient is obtained. Where Q (U, V) is the quantization coefficient amplitude and S (U, V) is the quantization step size. It is an element of the quantization table. It usually takes different values according to the position of DCT coefficients and color components. The size of the quantization table is 8 × 8, which corresponds to 64 DCT coefficients (generally, the image is decomposed into 8 × 8 image blocks for processing). The effect of quantization is to get a higher compression ratio by discarding the information which has little influence on vision under the premise of certain subjective fidelity image quality. Because DCT coefficients contain spatial frequency information, the size of elements in the quantization table can be selected by making full use of the characteristic that human eyes are sensitive to different frequencies. Fine quantization (quantization step size is small) is used for important coefficients of vision. For example, low frequency coefficients are fine quantized, and high frequency coefficients are coarse quantized (with large quantization step).

3) Coding DCT quantization coefficients

The quantified coefficients need to be rearranged in order to increase the number of consecutive "0" coefficients, that is, the run length of "0". The method is to arrange them according to the zigzag pattern, as shown in the figure below. In this way, an 8 × 8 matrix is transformed into a 1 × 64 Vector, and the low-frequency component appears first and the high-frequency component appears later. The upper left corner elements of the matrix are DC components, and the other 63 coefficients are AC components. The frequency increases gradually from top left to bottom right.

B. Color conversion and sampling method

1) Color conversion

The color data in BMP image is converted from RGB-YCbCr, y is brightness, CB Cr is blue and red respectively. Conversion formula

$$Y=0.2990R+0.5870G+0.1140B$$

$$Cb=-0.1687R-0.3313G+0.5000B$$

$$Cr=0.5000R-0.4187G-0.0813B$$

In this way, three new primary color values can be obtained after the conversion, which can be used as an independent image plane for compression coding.

2) Sampling analysis

After the color conversion, the brightness value y of each point is retained, while the chroma value CB Cr is a point every two points. Color sampling can be performed in the row and column directions of the image. If the sampling ratio is 1:1:1, no sampling is needed. If the sampling ratio is 2:1:1 in the row direction, a point is reserved at every two points in the row direction, and a point is reserved in the column direction. In this way, if the original CBCR matrix size is m * s, then after 2:1:1 sampling, M / 2 * s / 2 = 1 / 4m * s is formed, only 1 / 4 of the original image is reduced. If you want to reduce the image distortion, the feasible direction is not sampling or column direction No sampling.

C. Run length coding and zigzag scanning method

In the quantized DCT coefficient matrix, most of the AC coefficients are floating-point numbers near the zero point, except that the DC value is not zero. After rounding, there are a large number of AC coefficient values of 0 in each 8 * 8 block. In order to string as many AC coefficients as possible with the value of 0 to facilitate AC coding and improve the compression ratio, the 64 elements in each 8 * 8 block of YCbCr matrix must be arranged in zigzag (in this way, as many as possible 0 can be concatenated together). The process diagram is as follows.

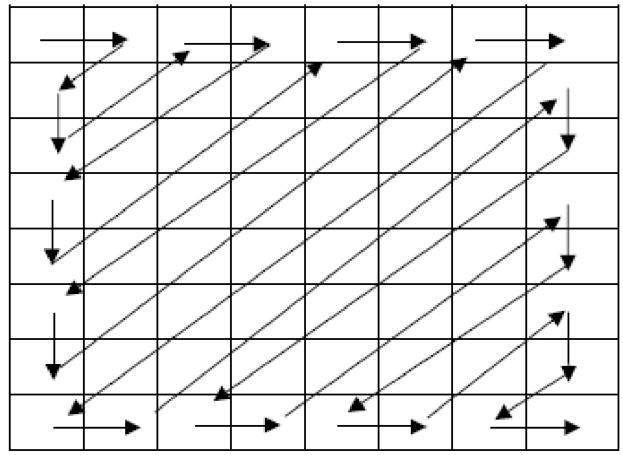

Fig.3. The quantized coefficients are scanned in Z-shape

The arrow direction indicates the new position order of elements in the original 8 * 8 after zigzag sorting.

D. DCT transformation method

To compress data in JPEG, we need to do a DCT transform first. The principle of DCT involves mathematical knowledge. Here we don't need to go into it. Anyway, it's almost the same as Fourier transform. After this transformation, the rules between the points in the picture are presented, which is more convenient for compression. In JPEG, every 8 x 8 points are processed as a unit. Therefore, if the length and width of the original image are not multiples of 8, they need to be filled into multiples of 8 first, so as to deal with the block by block. In addition, since Cr and CB are recorded once by 2x2, in most cases, it is necessary to supplement the integer block of 16x16. They are arranged from left to right and from top to bottom. In JPEG, DCT is applied to y, Cr and CB respectively. The range of Y, Cr and CB values for DCT transformation is - 128 ~ 127 (y is subtracted by 128).

Forward DCT (FDCT) is used in JPEG encoding and inverse DCT (IDCT) is used in decoding. The two-dimensional formula is given below:

2D-FDCT:

$$F(u,v)=\frac{1}{4}C(u)C(v)\left[\sum_{i=0}^{7}\sum_{j=0}^{7}f(i,j)\cos\frac{(2i+1)u\pi}{16}\cos\frac{(2j+1)v\pi}{16}\right]$$

$$C(u),C(v)=1/\sqrt{2},\ \text{when}\,u,v=0$$
$$C(u),C(v)=1,\text{others}$$

$$f(i,j)=\frac{1}{4}\left[\sum_{u=0}^{7}\sum_{v=0}^{7}C(u)C(v)F(u,v)\cos\frac{(2i+1)u\pi}{16}\cos\frac{(2j+1)v\pi}{16}\right]$$

D-IDCT:

2Arrange DCT results

DCT transforms one 8x8 array into another. However, all the data in the memory is linear. If we store these 64 numbers in a row, there is no correlation between the point at the end of each line and the point at the beginning of the downward line. Therefore, it is generally stipulated in JPEG to sort out 64 numbers in the following order.

$$C(u), C(v) = 1/\sqrt{2}, \text{when} u, v = 0$$
$$C(u), C(v) = 1, \text{others}$$

0， 1， 5， 6， 14， 15， 27， 28，

2， 4， 7， 13， 16， 26， 29， 42，

3， 8， 12， 17， 25， 30， 41， 43，

9， 11， 18， 24， 31， 40， 44， 53，

10， 19， 23， 32， 39， 45， 52， 54，

20， 22， 33， 38， 46， 51， 55， 60，

21， 34， 37， 47， 50， 56， 59， 61，

35， 36， 48， 49， 57， 58， 62， 63

In this way, the adjacent points in the sequence are also adjacent in the picture.

a) quantification

For the 64 spatial frequency amplitude values obtained previously, we will quantize them by their amplitudes. The operation method is to divide the corresponding values in the quantization table and round them.

```
for i=1:64
    dc(i)=round(B(i)/q(i));
end
```

Where B (I) is the coefficient after cosine transformation, q (I) is the quantization table data; round () is the mathematical function for rounding. The following two JPEG standard quantization tables. (in the same order as above)

TABLE 1. LUMINANCE QUANTIZATION TABLE

16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

TABLE 2. COLORIMETER

17	18	24	46	99	99	99	99
18	21	26	66	99	99	99	99
24	26	56	99	99	99	99	99
47	66	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99

These two tables are made according to the psychological visual valve, and the processing effect of 8 bit brightness and chroma images is good. Of course, we can use any quantization table. The quantization table is defined after the dQT marker of JPEG. Generally, define one for y value and one for C value. Quantization table is the key to control JPEG compression ratio. This step removes some of the high frequencies and loses a lot of detail. But in fact, the human eye is far less sensitive to high spatial frequencies than to low frequencies. So the visual loss after processing is very small. Another important reason is that there will be a color transition between the dots of all pictures. A large amount of image information is contained in low spatial frequency. After quantization, a large number of continuous zeros will appear in the high spatial frequency band. The quantized data may exceed the processing range of 2-byte signed integers.

IV. CONCLUSION AND PROSPECT

This paper presents a fast JPEG image compression algorithm based on DCT. This paper introduces that JPEG adopts a variety of coding methods, including run length coding and Huffman coding, which have high compression ratio. Before coding, the data is divided into blocks, discrete cosine transform (DCT) and quantization, and the high-frequency signal is discarded to achieve compression. In decoding, entropy decoding, inverse quantization and inverse discrete cosine transform (IDCT) are performed.

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