相関特徴に基づくカラー画像の可逆圧縮手法

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あらまし　可逆静止画像圧縮の技術は，高品質の画像記述・伝送において重要な役割を果たしている．更にリアルタイムマルチメディアシステムにおいては，圧縮比率と処理スピードの両方面から考察されるべきである．本稿には，画像の画素及び色構成の相関特徴を用いて，簡単な予測モデルを提案した．また予測値を修正するために，ニューラルネットワーク手法が利用され，予測値の収束値を最も小さくして，小さい動的な有効範囲に至ることを望む．コーディングの部分において，そのアルゴリズムが高性能及び高い圧縮比率を得ることができるため， RICE 手法 を選択した．比較実験の結果からは，我々提案した手法が伝統的なアルゴリズムより良い圧縮比率を持っていることを示した．更に，処理スピードは，JPEG-LS より速いし，圧縮効率の良い手法として考えられる．

キーワード　可逆圧縮，コーディング，予測モデル，色相関

Lossless Color Image Compressing Algorithm Using Correlation*

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Abstract: The technique of lossless image compression plays an important role in image transmission and storage for high quality. At present, both the compression ratio and processing speed should be considered in a real-time multimedia system. In this paper, a low complexity predictive model is proposed using the correlation of pixels and color components. In the meantime, neural network is used to rectify the prediction values adaptively. It makes the prediction residuals smaller and in a small dynamic scope. In the part of coding, the high efficiency RICE coding algorithm is selected so that the algorithm can get high compression ratio as well as high performance. The compared experiment results have shown that our algorithm has higher compression ratios superior or similar to traditional algorithms. Moreover, its speed is faster than JPEG-LS. In the cases that the compression efficiency is primary, our algorithm can be adopted.

Key words: lossless compression, coding, prediction model, color correlation

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1 Introduction

In some multimedia systems, such as medical image system, satellite remote sensing and geographic information systems (GIS), the images are often very large and high quality should be kept, therefore lossless image compression is important and irreplaceable. It can save storage space and transmission time greatly. Especially, when the repetitive storage is required, lossless compression technique becomes more important to keep the original images.

For the lossless compression of still images, international standard organization ITU-T and ISO/IEC established JPEG (Joint Photographic Expert Group) in 1992. In the early versions of JPEG standards for lossless compression algorithm [1], DPCM, Huffman coding, and arithmetic coding are recommended. But some fixed predictors, which with traditional DPCM or minor variations of DPCM techniques, are adopted. These simpler techniques fundamentally limit performance of algorithms because they in general can not achieve higher decorrelation of prediction data. As the result, the requirement of current applications can not be satisfied due to the low compression ratio and the long compression time [2].

Lossless image compression schemes often consist of two distinct and independent components: modeling and coding. With the progress of research in resent years, some algorithms such as CALIC [3], LOCO-I [2] and FELICS [4] have been produced. The new standards which BIG/JPEG committee have adopted from 1994 are: JBIG-2 [5] , JPEG-LS [6] and JPEG2000 [7].

JBIG-2 is the lossless compression standard, which is applied to binary image. JPEG-LS is a lossless/nearly-lossless compression algorithm which adopts LOCO-I (LOw COmplexity LOssless COmpression for Images) as its core algorithm. The algorithm uses two-dimension prediction for rectifying prediction value adaptively by context and encodes the residuals with Golomb-Rice code [8]. When predictor finds successive same pixels, it will switch to RLE. The average compression ratio of the algorithm is 2.5 for normal images, moreover its low complexity and high efficiency were widely recognized. The most different aspect between JPEG 2000 and JPEG standards is that JPEG 2000 has discarded the block coding approach based on DCT and selected multi-resolution decomposition coding approach based on wavelet transform as its core algorithm.

Usually, the compression ratio and compression time is contradictive when we design a compression scheme. The higher the complexity of prediction model is, the higher the compression ratio is when a fixed coder is selected. In many real-time applications, the compression time is more important than compression ratio [6]. Therefore the low complexity and high efficiency of the algorithm were emphasized when a compression scheme is designed, JPEG-LS is a good example.

If we deal with the color image as three non-related gray-scale images, the approaches above can be applied to lossless color image compression directly. Most of the leading image compression techniques, such as CALIC, FELICS, LOCO-I, and so on, have done as this [9]. Having some differences from these methods, in this paper, a lossless color image compression algorithm with low complexity and high efficient is designed. Firstly, the color components are transformed into three independent components. Then a two-dimension prediction model with weighted coefficients is designed. At the same time, the template of neural network is introduced to rectify the predictive values adaptively so that the algorithm can have smaller residuals and more concentrated distribution. In the part of coding, the RICE coding algorithm which has high efficiency is selected. All these ensure the algorithm can get high compression ratio as well as high performance. The comparative experiments have shown the results expected. The paper is organized as follows: Section 2 describes the proposed algorithms for lossless color image compression in detail. Section 3 gives experimental results of the new approach compared with other methods. Conclusions are offered in Section5.

2 Algorithm Description

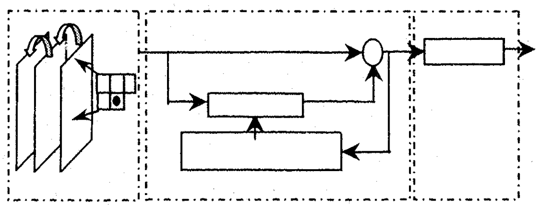

Fig.1 Lossless color image compression scheme

In most color images, both adjacent pixels and pixels in the corresponding positions of each color plane are highly correlated and contain redundant information. If the redundant information is removed as much as possible, the goal of image compression will be achieved. By designing certain kind of transforming model, the original data is mapped into a different type of representation for next coding process. And if we can assign short codes to these transformed data in the coding process, it means the mount of data after coding decrease greatly [10]. The scheme of lossless color image compression is shown in Fig.1. It consists of three parts: preprocessing, prediction modeling, and encoding.

2.1 Preprocessing for Color Planes

Color image can be regarded as of multiple gray-scale images, where the pixels of different color components are arranged in succession or interlaced. Although multiple gray-scales may have different distributions in different color spaces, the color image can be consider as combination of variant color components. For example, the usual RGB space can be thought as R, G, B three planes which are arranged continuously. For most color image, not only adjacent pixels, but the pixels in the correspond positions of each color components are highly correlated.

In preprocessing part, the correlations between color planes have been considered. By using the lossless color space transform as in literature [6], it can decorrelate the color planes and improve compression ratio. The color space transform can be finished by Eq.1, where **A1**, **A2**, **A3** represent the original three color vectors respective and **A1'**, **A2'**, **A3'** represent the three resulting color vectors. From Eq.1, it can be seen that the transform is loseless and reversible, at the same time, the **A2** is kept unchanged. By the color transform, the range of color vector is lessened.

$$\begin{pmatrix} A1' \\ A2' \\ A3' \end{pmatrix} = \begin{pmatrix} 1 & -1 & 0 \\ 0 & 1 & 0 \\ 0 & -1 & 1 \end{pmatrix} \begin{pmatrix} A1 \\ A2 \\ A3 \end{pmatrix} \qquad (1)$$

2.2 Prediction Model and Adaptive Adjustment Algorithm

Because there is high correlation between adjacent pixels and it is assumed the image pixels are arranged in top-down, left-right format with serial input of three RGB planes, the predictive value of current pixel can be got. The pixel in the image is represented by $X_k(i, j)$. Here, i = 0,1,2,..., W-1; j = 0, 1,2,..., H-1. W represents image width; H represents image height; k = R, G, B represent three color planes. The value of current pixel is predicted by weighted values of four pixels in the up-left direction. If the predicted pixels are in first column, last column, or first row of red plane, special process will be applied that the pixels do not exist are replaced by neighboring pixels or default values. The predicted value of pixel $X_k(i,j)$ is given by Eq.2.

$$\overline{X_k(i,j)}=W_1X_k(i,j-1)+W_2X_k(i-1,j-1)+W_3X_k(i-1,j)+W_4X_k(i-1,j+1) \qquad (2)$$

where Wl(l=1,2,3,4) is the weighted coefficients, and initial value is Wl=0.25. The predictive residual can be gotten via Eq. 3.

$$\Delta = X_k(i,j) - \overline{X_k(i,j)} \qquad (3)$$

If only fixed prediction model is used, it is possible that there is predictive value shift, or the residual value shift in whole coding process. In our algorithm, a neural network template based on perceptron is used to rectify adaptively the coefficients of the predictive model. The algorithm inspects the residuals in real time, and if value is beyond a threshold, a feedback will be sent to the perceptron so that it could generate a new group of weighted coefficients by rectifying W_l with Delta learning method [12] (See Eq.4).

$$\Delta W_l = \sum_{k=1}^{4} \alpha * x_k / 128 * \Delta \qquad (l = 1,2,3,4) \qquad (4)$$

In the formula, α =0.001 is gotten by experience, X_k is the Kth prediction pixel, Δ is the residual of previous pixel.

2.3 Coding Algorithm

RICE coding algorithm [11] encodes the each pixel into unary and binary parts. First, it should select coding coefficient k. Unary part is consist of 1, and the number of 1 is determined by quotient gotten from residual divide by 2k. Binary part is the binary representation of the remainder. And the length of bits is determined by k. We can see from above analysis, the code length of RICE is determined by k. The larger the k is, the longer the binary code length is, and the shorter the unary code length is. An adaptive strategy is designed to predict k according to the correlation between pixels, and the result is that the performance of compression has been improved.

3 Experimental Results

To verify the results of our compression algorithm described above, our results are compared with that of Huffman algorithm, LZW, FELICS, and especially JPEG-LS[6] lossless compression algorithm. The test images are all color images and are in RGB color space, where every color-pixel is represented by 24 bits (8 bits per pixel). These images include two scenery images, one aerial photograph and one computer generated image, also the standard color images peppers and lena are selected so that results are more convincible. The experiment is finished on a PC (Pentium II 300M, RAM 64M). All of our algorithms are developed in C.

Compression results are represent in bits per pixel (= 8/compression-ratio) as shown in Tab.1. The results of our algorithm outperform those of LZW and near to those of traditional Huffman algorithm. And our results are fairly equal to those of FELICS. But our results are 15% shorter than those of JPEG-LS. The compression time at the Tab. 2 shows our algorithms are remarkably faster than Huffman and LZW. Moreover, for the low complexity and high efficiency JPEG-LS, our algorithms can also save 8-17% compression time. Structure of our algorithm are similar to that of JPEG-LS in prediction and coding, but the running speed of JPEG-LS is affected due to the introduction of context modeling which is used to increase the compression ratio. Besides, we also apply our algorithm on the original image without preprocessed. Compared results show that the compression ratio is improved by 20-25% with preprocessing because the correlation between color components is greatly reduced through preprocessing.

Table 1: Comparison of compression results

image	***height *width***	***compressing results***				
		Huffman	LZW	FELICS	JPEG-LS	ours
scenery1	2048*1536	2.92	5.01	*	2.13	2.87
scenery2	2056*2400	2.27	4.20	*	1.83	2.31
aerial	2200*1196	2.65	3.92	*	1.90	2.42
computer's	1636*1070	2.47	3.08	*	2.21	2.55
peppers	512*512	4.67	5.84	5.14	3.88	4.34
lena	512*512	5.12	6.78	4.84	4.52	4.81

Table 2: Comparison of compressing time

image	***height* width***	***compressing time(s)***			
		Huffman	LZW	JPEG-LS	ours
scenery 1	2048*1536	6.88	9.87	6.21	5.10
scenery 2	2056*2400	9.35	13.32	8.68	7.27
aerial	2200*1196	6.83	7.90	6.62	5.55
computer's	1636*1070	5.24	8.68	4.46	3.89
peppers	512*512	2.18	3.12	0.60	0.51
lena	512*512	2.87	3.89	1.05	0.90

4 Conclusion and Future Work

In this paper, a prediction model based on correlation in different color components and different pixels is proposed. This model adopts a template of neural network to adjust adaptively and map the predictive values, and it causes the high concentration of residual distribution and a small range of values. As the result, entropy is decreased dramatically and better compression result can be gotten. In our scheme, the low complexity is specially emphasized in every part of algorithm. Furthermore, the highly efficient RICE coding algorithm is selected in the encoding part. All of these efforts make our approach fast and efficient.

The experiment results clearly show that our algorithms have better compression result which is super or equal to traditional algorithms. And our result is fairly equal to those of FELICS. Although JPEG-LS has a higher compression ratio, it is slower in compression time than our algorithm. The compression time reflects the efficiency of the algorithm. Our approach is quite suitable for the applications in which time is primary, such as huge amounts of image archiving system, digital art image indexing system and so on.

As the future work, we want to modify the prediction model so that it is suitable for color components lossless transform and better compression results can be obtained.

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