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A Fast Algorithm for Fractal Image Coding

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Abstract

In this paper, we propose a fast algorithm for fractal image coding to shorten long time to take on fractal image encoding For its performance evaluation, the algorithm compares with other traditional fractal coding methods. In the traditional fractal image coding methods, an original image is contracted by a factor in order to make an image to be matched. Then, the whole area of the contracted image is searched in order to find contractive transformation point of the original image corresponding to the contracted image. It needs a lot of searching time on encoding and remains limitation in the improvement of compression ratio. However, the proposed algorithm not only considerably reduces encoding time by using scaling method and limited search area method but also improves compression ratio by using bit-plane. When comparing the proposed algorithm with Jacquin's method, the proposed algorithm provides much shorter encoding time and better compression ratio with a little degradation of the decoded image quality than Jacquin's method.

I. Introduction

As most of information in daily life is obtained by eyesight, research of visual communication which can exchange visual information has been performed for a long time. For video phone, in the case that image pictures of 256 by 256 size with 256 gray levels are transmitted by 30 frames per second, high comression ratio of 1570 is required because data of about 15.7Mbps is transmitted and channel width of PSTN(Public Switched Tele- phone Network) is about 10Kbps. Even when 1 image frame is transmitted within 1 second, compression ratio of 52 is required. Therefore, the developement of image compression techniques to transmit and store such tremendous information has been required, and performed actively. Today, image compression techniques such as predictive coding, transform coding, block truncation coding, vector quantization coding, subband coding, hierarchical coding, wavelet coding and fractal coding have been developed and used in several application areas.

A word "fractal" means that a partial shape represents the whole shape, and Mandelbrot[1],[2] established fractal theory for the first time. In 1980's, Michael Barnsley[3]-[5] applied the fractal theory to practical image codings. Although his coding method provided very high compression, it required a lot of time on encoding because manual operation was required. Jacquin[6]-[9] suggested a new image coding algorithm to remove the manual operation used by Barnsley's fractal image coding algorithms. Jacquin's method divides an original image and the corresponding contracted image into range blocks and domain blocks, and then the corresponding domain block which is most similar to the range block of the original image is searched in the contracted image. Jacquin's method increases the amount of compu- tation because of searching the whole area of the contracted image to find the similar domain block, thus taking a lot of time in encoding process. Also, Monro[10],[11] suggested the method which performed encoding process in the unit of indepen- dent block. Although his method reduced encoding time, discontinuity on the boundary of the recon- structed image existed due to fixed block unit. The proposed method in this paper first converts a 8 bits-plane image into a 4 bits-plane image[12],[13] and uses the 4 bits-plane image as an original image in order to improve compression ratio and encoding time. And then, the reconstructed original image is reduced by half with scaling method. Finally, the corresponding domain block which is most similar to the range block of the reduced original image is searched in the limited area of the corresponding contracted image in order to increase encoding time considerably.

The contents of this paper are as follow. In section Ⅱ, we describe theoretical background of fractal coding. In section Ⅲ, we explain the proposed algorithm of the fractal image coding. In section Ⅳ, we compare the proposed method with the traditional Jacquin's method through the simulation and analyze the results. Finally, we finish section Ⅴ with concluding remarks.

Ⅱ. Theoretical Background

A. IFS Concept

IFS(Iterative Function System) consists of affine transformations with rotation, scaling, reflection and translation and can be expressed by following equation(1).

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = W\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} e \\ f \end{bmatrix} \quad (1)$$

Equation (1) implies that coordinate (x, y) on plane is replaced with new coordinate (x', y') by parameters a, b, c, d, e and f. The parameters a, b, c and d indicate rotation, scaling and reflection, while the parameters e and f indicate translation. Also, the affine transformations which construct IFS have to be contractive in order to ensure convergence, and the conditional equation can be expressed by following equation (2):

$$d(W(A), W(B)) \leq s \cdot d(A, B) \\ \forall \quad A, B \in U, \quad 0 \leq s \leq 1 \quad (2)$$

where U is metric space, d is a metric in metric space. And s is contraction ratio for transformation w.

B. Fractal Image Coding

Since a gray level or a color image does not have 2 dimensional property but 3 dimensional property because of pixel value, general affine transformation can be written in 3 dimensional model.

$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = w_i \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} a_i & b_i & 0 \\ c_i & d_i & 0 \\ 0 & 0 & P \end{bmatrix}\begin{bmatrix} x \\ y \\ z \end{bmatrix} + \begin{bmatrix} R_x \\ R_y \\ Q_i \end{bmatrix} \quad (3)$$

where parameter a_i, b_i, c_i, d_i, R_x and R_y are equal to those of equation (1), while parameter P is chosen a positive number with $0<P<1$. P and Q_i represent modified pixel value. The association of the corresponding domain blocks of the contracted image with some range blocks of an original image in a fractal coding.

Ⅲ. The Proposed Algorithms

A. Construction of Bit Plane Image

Each pixel in a gray image in represented by 8 bits. The image is composed of eight 1-bit planes, ranging from plane 0 for the least significant bit to plane 7 for the most significant bit. The level of a gray image can be described like the following equation(4).

$$a_7\,2^7 + a_6\,2^6 + \cdot \cdot \cdot + a_0\,2^0 \qquad (4)$$

Using the equation (4), the n-bit plane image can be constructed with a_n bit of each pixel in the image. This paper uses a image with 256 gray levels for the proposed fractal coding.
Fig. 1 shows several bit plane images and a composite bit plane image for Lenna image.

B. Limitation of Search Area

The proposed algorithm uses Fig. 1(e) as an *reconstructed original image*. First, the original image is contracted by half and quarter with scaling method. And then, the corresponding domain block of the quarter-sited image which is most similar with one range block of the half-sized image is searched within the limited area in order to reduce encoding time extremely. The idea in illustrated in Fig. 2. The limited search area is divided into i parts, and search range of each part is 4 or 8 pixels. If the selected block is edge block, the edge block is divided into 2 by 2 size blocks, and the limited search area is the same as before.

(a) a_7 bit-plane image (b) a_6 bit-plane image

(c) a_5 bit-plane image (d) a_4 bit-plane image

(e) a_7+a_6+a_5+a_4 bit-plane image

Fig. 1. Bit-plane images for Lenna.

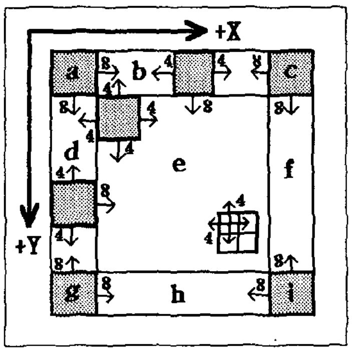

Fig. 2. Classification of search area.

C. Bit Allocation

For improvement of compression ratio and reduction of search time, each block in images is classified into two types : shade type and edge type. Bit allocation for the proposed fractal algorithm is as follows : 5 bits for shade blocks and

17 bits for edge blocks.

D. Decoding

Decoding is carried out using transmitted fractal parameter values. Shade type blocks are decoded by 4 by 4 size while edge type blocks are decoded by 2 by 2 size. Of course, the decoding process should be recursively iterated to get a reconstructed image. In most cases, 8 iterations for decoding are enough for tolerable recon- structed image.

IV. Simulation Results

We simulated Miss, Girl, Cronk, and Lenna images with 256 gray level and 256 by 256 size. Figures 3, 4, 5 and 6 show original images and decoded images for 4 images. Although Jacquin's algorithm decreases encoding time by using block classification, it takes a few hours. However, as shown in Table 1, the proposed algorithm not only reduces encoding time extremely but also improves compression ratio with a little degradation of the decoded image. When PSNR falls in range from maximum 6.61dB to minimum 3.58dB, there is a little degradation of image quality. But in the light of subjective vision, there is almost no difference. According to simulation results, it is interesting that 4 bits plane image is better than 3 bits plane image in terms of compression ratio and encoding time.

(a) Original image (b) Decoded image
Fig. 3. Miss America image.

(a) Original image (b) Decoded image
Fig. 4. Girl image.

(a) Original image (b) Decoded image
Fig. 5. Cronk image.

(a) Original image (b) Decoded image
Fig. 6. Lenna image.

As shown in Table 1, the proposed algorithm not only reduces encoding time extremely but also improves compression ratio with a little degrada- tion of the decoded image. When PSNR falls in range from maximum 6.61dB to minimum 3.58dB, there is a little degradation of image

quality. But
in the light of subjective vision, there is almost no difference. According to simulation results, although not stated in the table, it is interesting that 4 bits plane image is better than 3 bits plane image in terms of compression ratio and encoding time.

Table 1. Performance comparison between proposed method and Jacquin's method

Images	Proposed method			Jacquin method		
	Encoding time(sec)	bpp	PSNR [dB]	Encoding time(sec)	bpp	PSNR [dB]
Miss America	35	0.35	33.30	9180	0.71	37.04
Girl	58	0.57	28.81	14040	0.82	32.87
Cronk	46	0.48	30.13	7020	0.54	34.76
Lenna	80	0.71	23.66	20640	0.89	27.24

V. Conclusions

Proposed fractal algorithm have reduced encoding time and have increased compression ratio. We not only scaled down the original image which was composed of 4 bit-plane into 1/2 and 1/4 but also limited search range to sharply drop encoding time and improve compression ratio. Compared with Jacquin's algorithm, the proposed algorithm increases compression ratio in range from 0.36 bpp to 0.06 bpp and reduces remarkably encoding time in range from maximum 20560 seconds to minimum 6974 seconds for four different images.

In future, we will concentrate on developing new algorithms to increase PSNR with little loss of encoding time and compression ratio.

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