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고속 및 고압축을 위한 프랙탈 영상 부호화

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Fractal Coding Method for Fast Encoding and High Compression

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요 약

본논문은 고속 및 고압축을 위한 프랙탈 영상 부호화 기법에 대해서 제안한다. 먼저, 원영상의 크기를 스케일링 방식 및 비트플레인 이용하여 1/2 및 1/4로 축소한다. 이어서, 부호화 시간의 단축을 위해 제한된 영역내에서 원영상의 1/4 크기의 도메인 블록과 가장 유사한 블록을 원영상의 1/2 크기를 가지는 레인지 영역에서 찾는다. 실험 결과, 제안된 알고리즘은 재퀸의 방식에 비해 화질은 다소 저하되었으나, 부호화 시간과 압축율 은 많이 향상되었다.

Abstract

This paper proposes a novel fractal coding method for fast encoding and high compression to shorten time to take on fractal encoding by using limited search area. First, the original image is contracted respectively by half and by quarter with the scaling method and bit-plane method. And then, the corresponding domain block of the quarter-sized image which is most similar with one range block of the half-sized image is searched within the limited area in order to reduce the encoding time extremely. As the result of the evaluation, the proposed algorithm provided much shorter encoding time and better compression ratio with a little degradation of the decoded image quality than Jacquin's method.

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I. Introduction

A word fractal means that a partial shape represents the whole shape, and Mandelbrot [1] established fractal theory for the first time. In 1980's, Michael Barnsley [2] 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 [3,4] suggested a new image coding algorithm to remove the manual operation used by Barnsley's fractal image coding algorithms.

Also, Monro [5] suggests the method which performs encoding process in the unit of independent block. Although his method reduces encoding time, discontinuity on the boundary of the reconstructed image exists. The proposed method in this paper first converts a 8 bit-plane image into a 4 bit-plane image and uses the 4 bit-plane image as an original image in order to improve compression ratio. And then, the 4 bits 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 [6] of the corresponding contracted image in order to reduce encoding time considerably.

The contents of this paper are as follows. 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 and analyze the results. Finally, we finish section V with concluding remarks.

II. Theoretical Background

1. Fundamental Concept

Fractal coding adopts affine transformations with rotation, scaling, reflection and translation and can be expressed by following equation (1).

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

where W is two-dimensional affine transformation. Therefore, 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. Also, the affine transformations have to be contractive in order to ensure convergence, and the conditional equation can be expressed by following equation (2).

$$\begin{gathered} d(W(A), W(B)) \leq s \cdot d(A, B) \\ \forall \; A, B \in U, \;\; 0 \leq s \leq 1 \end{gathered} \quad (2)$$

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

2. Fractal Image Coding

Since a gray level or a color image has its pixel value, the general affine transformation can be rewritten in 3-dimensional model.

$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = w\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} a & b & 0 \\ c & d & 0 \\ 0 & 0 & P \end{bmatrix}\begin{bmatrix} x \\ y \\ z \end{bmatrix} + \begin{bmatrix} e \\ f \\ Q \end{bmatrix} \quad (3)$$

where parameters a, b, c, d, e and f are equal to those of equation (1), while parameter P is chosen a positive number with $0<P<1$. P and Q represent modified pixel value.

Ⅲ. The Proposed Fractal Algorithm

1. Construction of Bit Plane Image

Firstly, bit-plane image is constructed to enhance compression ratio. Each pixel in a gray image is 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 for 256×256 pixels like the following equation :

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots\cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots\cdots & a_{2n} \\ a_{31} & a_{32} & a_{33} & \cdots\cdots & a_{3n} \\ \vdots & \vdots & \vdots & & \vdots \\ a_{m1} & a_{m2} & a_{m3} & \cdots\cdots & a_{mn} \end{bmatrix} \quad (4)$$

where n=m=256.

Each pixel in equation (4) can be described 8 bits like the following equation :

$$[b_7\ b_6\ b_5\ b_4\ b_3\ b_2\ b_1\ b_0]\begin{bmatrix} 2^7 \\ 2^6 \\ 2^5 \\ 2^4 \\ 2^3 \\ 2^2 \\ 2^1 \\ 2^0 \end{bmatrix} \quad (5)$$

Using the equation (5), the n-bit plane image can be constructed with an bit of each pixel in the image.

Fig 1. shows a composite (b7+b6+b5+b4) bit plane image for Lenna image.

Fig 1. Bit-plane(a7+a6+a5+a4) images for Lenna image

2. Limitation of Search Area

First, the original image is contracted respectively by half and by quarter with the scaling method. And then, the corresponding domain block of the quarter-sized image which is most similar with one range block of the half-sized image is searched within the limited area in order to reduce the encoding time extremely. The idea is illustrated in Fig. 2. Fig. 2 shows classificaiton of search area in the domain pool. The limitation of search area is as follows :

Case 1 : Area a, c, g and i

Search range of these areas is 8 pixels in the arrow direction in Fig.2

Case 2 : Area b, d, f and h

Search range of these areas is 4 or 8 pixels in the arrow direction in Fig.2

Case 3 : Area e

Search range of these areas is 4 pixels in the arrow direction in Fig. 2

If the selected block is an edge block, the block is divided into 2 by 2 size blocks, and the limited search area is the same as before.

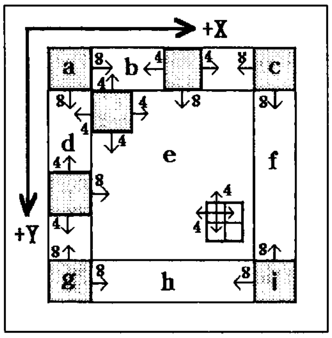

Fig 2. Classification of search area

3. Block Classifier

In this paper, we use a block classifier to satisfy the following relationships in order to classify the block type (shade or edge).

$$\text{Edge block if } \sum_{i=1}^{B^2} (Pi - Pavg) >= Th \quad (6)$$

$$\text{Shade block if } \sum_{i=1}^{B^2} (Pi - Pavg) < Th \quad (7)$$

where one block size is B x B (B=4 for parent block and B=2 for child block), Pi is value of each pixel in the block, and Pavg is the average pixel value of the block. Threshold value, Th, has been determined by considering compression ratio and image quality through experiments with more than 20 image samples. We have assigned 10 as the threshold value for both parent block and child block.

4. Bit Allocation

For improvement of compression ratio and reduction of search time, each block in an image is classified into two types : shade type and edge type. Bit allocation for the proposed fractal algorithm is as follows : 6 bits for shade blocks and 15 bits for edge blocks. The details are shown in Table 1.

Table 1. Bit allocation

Block type	Parameters	Information in bits	
		Details	Total
Shade	block type	2	6
	mean pixel value	4	
Edge	block type	2	15
	mean pixel value	4	
	coordinates	6	
	isometry	3	

The computation of bit rates is as follows. Let Is and Ie denote the total bits required for expressing the shade block and the edge block respectively. Let Ns and Ne denote the total number of the shade block and edge block respectively. If the parent block has size of B ×B and the child block has size of B/2×B/2, the bit rate is given by:

$$\frac{N_pI_C + N_sI_s + N_eI_e}{N_pB^2} \text{ bits/pixel} \quad (8)$$

where Ic is the bits for twelve possible coding configuration of a parent block. The configurations can thus be encoded with Ic=4 bits. Np is the total number of parent blocks in the image.

5. Decoding

Decoding is carried out using transmitted fractal parameter values. Shade type blocks are decoded with B size while edge type blocks are decoded with B/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 reconstructed image.

6. Estimation of the Reconstructed Image

The estimation of the reconstucted image uses the root mean square error (RMSE) and peak signal-to-noise ratio (PSNR).

Ⅳ. Simulation Results

We simulated Miss America, Girl, Cronk, Lenna and Peppers images with 256 gray level and 256 by 256 size.

Figures 3, 4, 5, 6 and 7 show original images and decoded images. Although Jacquin's algorithm decreases encoding time by using block classification, it takes a few hours. However, as shown in Table 2, 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 5.28dB to minimum 2.58dB, there is a little degradation of image quality. But in the light of subjective vision, there is almost no difference.

(a) Original image

(b) Classified shade block

(c) Decoded image

Fig 3. Miss America image

(a) Original image

(b) Classified shade block

(c) Decoded image

Fig 4. Girl image

(a) Original image

(b) Classified shade block

(c) Decoded image

Fig 5. Cronk image

(a) Original image

(b) Classified shade block

(c) Decoded image
Fig 6. Peppers image

(a) Original image

(b) Classified shade block

(c) Decoded image
Fig 7. Lenna image

Table 2. Performance comparison between proposed method and Jacquin's method

Methods / Images	Proposed method			Jacquin method		
	Encoding time(sec)	bpp	PSNR (dB)	Encoding time(sec)	bpp	PSNR (dB)
Miss America	34	0.35	34.30	9180	0.71	37.04
Girl	57	0.57	29.81	14040	0.82	32.87
Cronk	45	0.48	31.13	7020	0.54	34.76
Peppers	61	0.67	28.29	11279	0.85	32.57
Lenna	79	0.57	25.66	20640	0.89	27.24

V. Conclusions

The proposed fractal algorithm has reduced encoding time and increased compression ratio. We not only considerably reduce encoding time by using limited search area method but also improve compression ratio by using bit-plane. 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 20561 seconds to minimum 6975 seconds for five different images.

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