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Research on Image Fractal Compression Coding Algorithm Based on Gene Expression Programming

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***Abstract*—A kind of image fractal compression coding algorithm based on Gene expression programming is put forward to deal with such problems as low image compression rate and slow image fractal compression coding speed. Firstly, the sub-block division is conducted on the original image and its relative gradient image with Image Adaptive Quadtree Segmentation methods according to the characteristics of self-similarity of original image and its relative gradient image; Secondly, the solution process of relative gradient image fractal compression coding and the action mechanism of Gene expression programming in compression encoding is analyzed theoretically. The expression methods of gene and chromosome of image fractal compression coding.Experimental results show that if the relative gradient and gene expression programming are applied in image fractal compression coding in a combined way, the global optimization ability will be stronger, the speed of searching optimal solution will be about 2 times faster than the genetic algorithm and the image compression rate will be higher.**

Keywords- Adaptive segmentation; Gene expression programming; Image compression; Fractal encoding;Intelligent Algorithm

I. INTRODUCTION

Image compression technology has important applications in information storage, network transmission, radio and television, military, national defense, satellite navigation, meteorology, education, medical treatment and other industries. However, the compression ratio of the image compression algorithms used at present is very low and difficult to meet the actual needs. Fractal image compression is a completely different coding method from traditional compression technology. M.F. Barnsley [1] has conducted fractal compression coding on several specific images and obtained 10000:1 high compression ratio. Although the coding process requires manual participation, it also shows the great potential of fractal technology in image compression coding [2-6]. For this purpose, considering Gene expression programming (GEP) may overcome the problems of low survival rate of individuals (chromosome) and slow convergence rate in genetic algorithm, and the search speed is 2-4 magnitudes faster than genetic algorithm [7-10], the Gene expression programming has been applied in fractal image compression coding to improve the encoding speed and decoding quality of Image fractal compression.

II. IMAGE FRACTAL COMPRESSION AND GENE EXPRESSION PROGRAMMING

A. Fundamentals of Fractal Compression

Mandelbrot has revealed the essential characteristics of fractal and determined the theoretical framework of fractal geometry [2]. Barnslcy and Sloan (USA) have found the general process of simplifying the graph into a series of affine transformations and defined Iterated function system. This technique lays a foundation for fractal image compression [1].

B. Similarity of Image and Its Relative Gradient Image

Theorem shows that if the gradient difference of two images ($f(x,y)$ and $g(x,y)$) is small, when the gradient image of both sub-images is similar, they themselves are similar.

Definition 1.1 The relative gradient of image $f(x,y)$ is defined as:

$$\hat{g}(x,y)=\frac{g(x,y)}{f(x,y)-\bar{g}(x,y)} \tag{1}$$

Where, $\bar{g}(x,y)$ is the grayscale average of 4 pixel points. When the denominator is 0, make it equal to 1, namely

$$\bar{g}(x,y)=\frac{1}{4}\{f(x,y)+f(x+1,y)+ f(x,y+1)+f(x+1,y+1)\} \tag{2}$$

From the above formulas (1) and (2), the following can be derived: If two images are similar, the gradient images will be similar and the relative gradient images will also be similar. Therefore, the self-similarity of original image and relative gradient image can be obtained. During the matching search, the grayscale compression factor s and grayscale migration factor o may not be considered. Only those blocks that are close to the mean value and mean

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square deviation in the relative gradient image to be matched, thus greatly reducing the overhead of time.

C. Basic Theory of Gene Expression Programming

Similar to genetic programming, the gene expression programming is developed on the basis of genetic algorithm. However, it adopts a new method of individual description, which is different from genetic algorithm. Its formal description requires two types of symbol, namely terminator and function [7-8]. GEP is defined as follows in a formalized way:

Definition 1.2 The Gene expression programming environment is a two-tuples and recorded as:

GEP=<F, T>

Where, F indicates the function set; T indicates the set of terminators. e.g.: F= {+,-,*, /} , T= {a,b,c,d}.

Chromosomes of gene expression programming are made up of K- expressions [8]. Definition of k-expression, gene head, tail, and basic GEP algorithm refer to literature [8].

III. SELF ADAPTIVE IMAGE SEGMENTATION METHOD BASED ON RELATIVE GRADIENT

The segmentation steps of relative gradient image are shown as follows:

(1) Divide the image B into four non-overlapping sub-blocks $R_1 \sim R_4$ as the initial division. A sub-block R_i is called a range block. Image B is the parent block of sub-blocks R_i (i = 1～ 4). Parent block B is called domain block; the size of parent block is 4 times of sub-block.

(2) According to formula (1), get the relative gradient image of the original image B . According to the segmentation scheme in (1), divide the relative gradient image and get four range sub-blocks $R_{g1} \sim R_{g4}$ and domain blocks B_g in relative gradient image. Each sub-block R_i of the original image has a corresponding block in B_g by the calculation of the relative gradient. The domain block B and B_g has this correspondence as well.

(3) Calculate mean value $\bar{R}_{gi}(i=1,2,3,4)$ and mean square error σ of sub-block in $R_{gi}(i=1,2,3,4)$ and B_g . If the mean value of sub-block $R_{gi}(i=1,2,3,4)$ and parent block is the same and the difference of mean square error is smaller than the given error threshold ε , the sub-block R_{gi} is self-similar to parent block B_g and the sub-block R_i of corresponding original images is self-similar to parent block B . The coordinates in the top left corner of sub-block R_i and parent block B are recorded. The fractal code of the sub-block R_i is recorded and saved in the document. And then turn the step to (5).

(4) If the matching of R_{gi} fails in step (3), it is not self-similar to the parent block. The sub-blocks in the corresponding original image R_i are divided into four sub-blocks $R_{i1}, R_{i2}, R_{i3}, R_{i4}$ and the parent block B_i is divided into four sub-blocks $B_{ij}(j=1,2,3,4)$; R_{gi} is subdivided into four sub-blocks $R_{gi1}, R_{gi2}, R_{gi3}, R_{gi4}$ in the relative gradient image. Parent block B_{gi} is divided into four sub-blocks $B_{gij}(j=1,2,3,4)$;

(5) Repeat the operation of each sub-block R_{gij} in step (3) - (4) until all sub-blocks have been coded successfully. If the matched parent block cannot be found when the size of sub-block reaches the specified minimum sub-block size, the parent block with the minimum error will be regarded as the matched block.

(6) The codes of all sub-blocks make up the fractal compression coding of image B and are stored in a document.

IV. ACTION MECHANISM OF GEP IN FRACTAL IMAGE COMPRESSION

A. Solution to Fractal Image Compression Coding

Suppose the given target image B is a grayscale image. As shown in formula (1), x, y are the coordinates of each pixel in the image; a, b, c, d, e, f, s, o are transformation parameters and real numbers. We can use these eight transformation constants to represent the coding of compressed affine transformation. If IFS of one image is composed by n compressed affine transformations, IFS coding of the image may be simplified to the coding of 8×n transformation parameters and transformation number (n) of IFS. Image compression coding process is changed to the process of solving 8×n transformation parameters of limited compression transformation of IFS. From the above formulas (1) and (2), the following can be derived: If two images are similar, the gradient images will be similar and the relative gradient images will also be similar. Therefore, the self-similarity of original image and relative gradient image can be obtained. The grayscale compression factor s and the grayscale migration factor o cannot be considered in the matching search. Therefore, the fractal image compression coding should be only carried in 2D space $I^2 = [0,1]^2$. The compression coding process includes: Solve iterated function system IFS composed by n compressed affine transformations of image on 2D space $I^2 = [0,1]^2$; Every compression transformation consists of six parameters (a,b,c,d,e,f). The coding of fractal image is the coding of 6n parameters and n transformations actually. In $I^2 = [0,1]^2$ space, the full search for optimal Fractal Image coding is NP problem [2].

B. Approximation Solution Mechanism of GEP

The mechanism of approximation to the optimal solution of GEP is: Suppose B is a binary image. According to self-similarity of fractal image, collage theorem and strong evolutionary search ability of GEP algorithm, it should fast approximate to the true value solution of original binary image in I^2 space. However, in the process of approximation, the following three problems should be solved:

Firstly, the coding representation of GEP gene and chromosome; Secondly, design fitness function to select good individuals, accelerate the evolution of the system and solve the problem; Thirdly, randomly generate a finite number of individuals (chromosome) and fast approximate to the true value solution of original binary image through 9 genetic and evolutionary operations (Individual selection, variation, inversion, insertion, root insertion, gene transformation, single point recombination, two point recombination and gene recombination).

V. IMAGE FRACTAL COMPRESSION ALGORITHM BASED ON GENE EXPRESSION PROGRAMMING

According to the analysis and discussion in section 2 and section 3, the Image fractal compression algorithm based on Gene expression programming was proposed. The algorithm is described as follows:

Input: Original image, population size, gene head and tail length, number of genes, maximum iteration number, fitness value of termination iteration, variation rate, insertion rate, recombination rate and other initial parameters;

Output: Optimal fractal iterated function system (IFS)

Step1: Read in the data of original image;

Step2: According to formula (1) and (2), calculate and save relative gradient images;

Step3: Implement self-adaptive quadtree segmentation steps (1) - (6) in section 2;

Step4: Gene expression coding is used to describe the gene and chromosome in domain codebook pool and range pool sub-block library;

Step5: Population initialization;

Step6 Calculation of fitness value; Step7: While (fitness<=Maxf or gen<Maxg) {Step8: Selection operation; Step9: Variation operation;

Step10: Inversion string operation; Step11: Insertion string operation;

Step12: Root insertion string operation; Step13: Gene transformation;

Step14: Single-point recombination; Step15: Two-point recombination;

Step16: Gene recombination; Step17: Calculation of fitness value of individual, mean value and mean square error of sub-blocks ;}

Step18: Output optimal coding IFS.

VI. EXPERIMENT RESULTS AND ANALYSIS

The programming is achieved in PC that CPU is P4, 2.8GHz with 512MB internal memory, and the software operating environment is Windows XP SP3 and Microsoft Visual C++ 2005. The original binary image used in the experiment is a 128×128 C curve, as shown in Figure 3 (a). The image size is 11.6KB.

The setting of main parameters obtained from fractal image compression algorithm based on genetic algorithm (GA) is shown in Table 1:

Table 1. Setting of Experience Value of Main Parameters of GA Algorithm

Parameter Description	value
Pop_size Initial population	50
Gap Next-generation individuals	5
p_c IFS Hybrid probability	0.5
p_m IFS Variation probability	0.9
ξ Number of compression affine transformations	4
λ Contraction factor	0.5
Generations Maximum algebra	10^5

The setting of main parameters based on gene expression programming (GEP) algorithm experiment is shown in Table 2:

Table 2. Setting of Basic Parameters of GEP

Parameter Description	value
Pop_size The initial size of the population	50
Gap Next-generation individuals	5
Mutation rate	0.044
Reverse string, insert string, root string, transform	0.1
Single point reorganization	0.4
Two point reorganization	0.2
Gene recombination	0.1

Optimal IFS solutions (ω_1 and ω_2) obtained from fractal image compression algorithm based on genetic algorithm (GA) are shown in Table 3:

Table 3. Optimal IFS Solution of GA Algorithm in C Curve ω_1 and ω_2

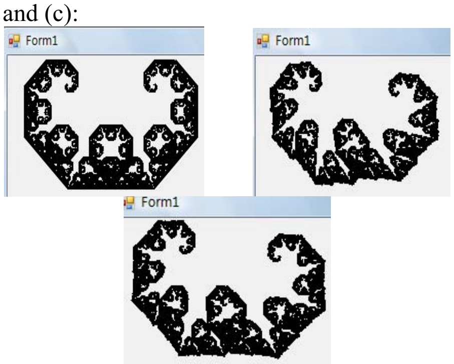
a	b	c	d	e	f
0.500124	-0.484755	0.500014	0.499214	0.0001547	-0.000253
0.474554	0.511477	-0.425844	0.536544	0.4478541	0.4147888

Optimal IFS solutions (ω_1 and ω_2) of C curve obtained from GEP algorithm are shown in Table 4:

Table 4. Optimal IFS Solution of GEP Algorithm in C Curve ω1 and ω2

a	b	c	d	e	f
0.491241	-0.490174	0.500626	0.510234	0.0001102	-0.000021
0.464512	0.500477	-0.465269	0.526545	0.457154	0.4747183

Original image and decoded reconstructed image of fractal image compression based on genetic algorithm (GA) and the algorithm in this paper are shown in Figure 1(a) and (b), (a) and (c):



(a) Original image (b) GA Decoded reconstructed image (c) GEP decoded reconstructed image

Figure 1. Comparison of C Curve Original Image, GA Decoded Reconstructed Image and GEP Decoded Reconstructed Image

Experimental results show that a fractal compression Iterated function system (IFS) for solving C curve of binary image is presented. After 680 generations of genetic evolution, the best genetic solution is obtained by GA-based algorithm. After 350 generations of evolution, the algorithm obtained the best genetic solution. Therefore, the search speed and evolutionary convergence speed of GEP are about 2 times faster than GA algorithm in the process of solving the Iterated function system IFS based on fractal image compression algorithm of GEP. This algorithm has some advantages. As shown in Table 3 and 4, IFS system consists of two compressed affine transformations ω_1 and ω_2. The size of original image is 11.6KB. IFS of the original image is solved with GEP fractal image compression algorithm. Therefore, the original images only requires the storage space with $2 \times 6 = 12$ real numbers and 48 bytes. The compression rate is about 4‰.

VII. CONCLUSIONS

Considering the fast approximation and fast search ability of relative gradient self-similarity and Gene expression programming, the image fractal compression coding algorithm based on Gene expression programming was constructed. Fractal coding of images is solved through GEP fast search and evolutionary convergence ability. The evolutionary convergence and search speed is faster than GA algorithm. The intelligent segmentation based on image and the fractal image compression coding algorithm based on depth learning will be researched in the next step.

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