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Fractal Images Compressing by Estimating the Closest Neighborhood with Using of Schema Theory

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Abstract: Problem statement: One of the methods used for compressing images and especially natural images is by benefiting from fractal features of images. Natural images have properties like Self-Similarity that can be used in image compressing. The basic approach in compressing methods is based on the fractal features and searching the best replacement block for the original image. **Approach:** In this research with this attitude that the best blocks are the neighborhood blocks, we tried to find the best neighbor blocks; this search process was improved by using genetic algorithms and Schema theory. Compressing images can be considered from three approaches, first the speed of compressing, second: quality of image after Decompressing and the third: Compressing rate. In this research in addition to reducing time for compressing, the desired quality and rate of compressing were also obtained. **Results:** Totally genetic algorithm increase the speed of convergence for reaching the best block, but using this human knowledge that neighbor blocks always have the best chance to be replaced, were included in genetic algorithms first through neighborhood and then schema theory and this significantly decrease the time for producing a compressed images. **Conclusion:** Using this algorithms show the improvement in fractal compressing images comparing to other technique in compress ratio, time complexity and quality of final image parameters.

Key words: Fractal image compression, genetic algorithm, schema theory, iterated function system

INTRODUCTION

The idea of fractal images compressing was first introduced by Barnsley (1988), so that each natural image has sub sections and the pixels of each subsection have great Self-Similarity to each other that is called Partitioned Iterated Function System or PIFS in abbreviation. Barnsley *et al*. (1993) showed that instead of using a fractal image, the conversion parameters of image can be used to be effective in compressing image; as a result the redundancy of images can be replaced and increased by some conversion. Many researchers have been done in order to speed up fractal image compression (Cangju *et al*., 2008; Huaqing *et al*., 2006; Jinshu, 2008; Prasad *et al*., 2007). Fisher (1995) suggested a method for compressing images that classified the sections of a image and then searched the smaller sections, this process increase the speed of compressing, In another work done by Jampour *et al*. (2009a; 2009b) and others in 2009, they gained favorable quality for fractal images compressing by using adjacency of image blocks and hierarchical search. Jacquin (1992) one of the Barnsley students in 1992 also offered a report that is the base of today's methods and in that report concepts like domain block and range block for more agreement were described, he divided image to small non-overlapped blocks and then tried to find the best block, his method increased the speed of the process of fractal images compressing (Jacquin, 1992; Aoued, 2004) in an article that published, presented a compatible method of image partitioning and he improved the speed of work process.

As it is mentioned we are considering fractal images compressing and one of the significant benefit of it is high rate of compressing that is usually better than Jpeg (Trieu *et al*., 2000) but the most important problem of fractal images compressing is the long time spent on searching conversion replacement and it is because of the time consumed for searching the best replacement block for the original image. Therefore by finding a solution for reducing the time spent on finding the replacement block of original image, of course it will be a proper method. because of this we use the

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combination of human knowledge and searching by genetic algorithms with Schema theory, genetic algorithm is a global search method that imitate the natural genetic process and can solve many complicated cases that have uneven search space, as most natural images have this features (large search space, unevenness), therefore using GA for this purpose can be useful.

The main motivation for using schema genetic algorithm is that according to natural properties, a chromosome with high fitness can be a good candidate for replacing, so that each block is showed by a chromosome and the best chance for finding the best replacement block is in adjacent blocks, it is covered by Crossover and mutation mechanism that is accompanying Schema theory, this result in keeping population diversity in this mechanism. In following the details of the work are presented.

MATERIALS AND METHODS

Fractal image compression: Fractal Images Compressing is based on local Self-Similarity properties and PIFS (Barnsley *et al*., 1993; Barnsley, 2006) Thus we define following words used for fractal images compressing and the general approach will be provided.

Frame: Set of adjacent pixels in an image that have the same geometric structure like square, rectangle and hexagon and so on is called frame, For example a set of 16 adjacent pixels that have the square form is called 4×4 square frame, this frame included some similar smaller sized frame (2×2), Fig. 1 shows similar frames.

Fig. 1: Similar frames with different sizes in Lena picture

Domain blocks: Set of independent non-overlapped frames that make the image is named domain blocks, in compressing fractal image mechanism, the goal is finding blocks from a range that can be replaced for domain blocks, in this manner instead of using the pixels of each block, the similar block address of that range is introduced that result in compressing the image.

Range blocks: Usually for keeping sample of all pixels of original image, an image in small size is produced that have the general properties of original image, all non-overlapped and independent frames that include reduced in size image are called range blocks.

Neighborhoods: The frames of an image that are exactly adjacent to a special frame are called adjacent frame of a that certain frame and they are named first layer neighbor frame, the frames that are adjacent with distance of 1 pixel, are called second layer neighbors, third and fourth layers are defined the same way. Figure 2 show the adjacency for a frame.

Adjacency approach used for fractal images compressing: As defined previously, adjacent pixels in an image, form image frames. Adjacent pixels are mainly so much similar to each other (except in border of image); because of this a proper replacement for a frame can be chosen from adjacent neighbors of that frame. According to the tests about 60% of frames of an image are chosen from adjacent frames in layer 1 that have high quality and this show the importance of this approach.

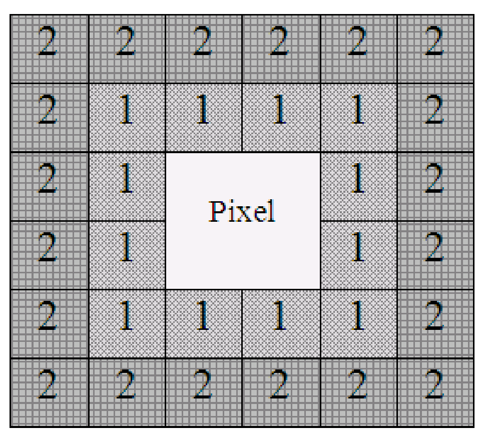

Fig. 2: Adjacency of layer 1 and 2 for pixel

Fractal image compressing mechanism: According to the mentioned definitions, general mechanism of fractal images compressing is based on producing a new smaller image based on original image (this may be done through removing column and rows of image alternately), this image is reduced in volume, then each domain Block will be replaced by one of the range blocks, the replaced block would be the most similar block in the neighborhood of certain domain block, so that mapping produced from range image can be used for decompressing domain image.

Genetic algorithms: The genetic algorithm is a biologically motivated search method mimicking the natural selection and natural genetics. Perform their work process like natural genetic, for the first time John Holland used the genetic algorithm in early 1970 as a search mechanism. One of the significant advantages of genetic algorithm is the ability to search the uneven environments that have behavioral fluctuations in response (Ming-Sheng *et al*., 2007; Mitra *et al*., 1998) so that it can easily move toward being trapped in local optimization, in fact this is the reason for using genetic algorithm in fractal images compressing, as we know each image contain many frames including adjacent pixels and with different luminous intensity so that each one can be aimed for search, the number of these frames is also a lot, therefore choosing a frame that is similar to of desired frame and it is what compatible with genetic algorithm search.

Schema theory: Undoubtedly Schema theory is one of the most important of genetic algorithm theory (Ming-Sheng *et al*., 2007), so that a predefined structure that contains human knowledge can be applied to search mechanism. Schema include a string of bits include 0, 1,'?' Character that 0 and 1 have previous meaning in genetic algorithm and '?' Means don't care state. For example in "1 0 ? ? 0 0" bits string 0, 1 can be accepted for '?' and it has 4 states including: 100000, 100100, 101000 and 101100.

Generally Schema is a descriptive frame of subsets of a chromosome that fixed sections will be alike and we should pay attention that chromosomes with the same Schema would have no improvement on each other information, but if Schema is applied on a set of chromosomes with high fitness, this fitness will be remained in future generation (Mitra *et al*., 1998). Because of this as we know that the best replacement blocks are adjacent blocks we use Schema and apply mutation and combination parameters to the search mechanism.

Genetic algorithm parameters:

Chromosome structure: For fractal compressing we matched original image with domain Block and matched smaller reduced volume image That have the exact properties of original image with range block*s*, the goal was finding the most similar block of range with domain block*s*. Suppose the input image is 256×256 and the reduced size image is 64×64, a chromosome should address all adjacent blocks from range set, as size of the chosen blocks is 2×2 the area of addressing in range blocks is from zero to eight layer, in this manner the adjacent set of a block is a 16×16 block, so that we need 4 bits for horizontal addressing and 4 bits for vertical addressing of range Block, Thus a chromosome containing the proper block address in range set has 8 bits length. Figure 3 shows the chromosome structure used in this method.

Evaluation function: As the criteria of evaluation of compressing images are included in 2 approaches of: 1-Pick Signal Noise Ratio (PSNR) and 2-Visual approach, we also use PSNR metric as evaluation function. We attend the visual difference between final image and primary image. As a result we use PSNR as evaluation function as it is showed in formula 2 below:

$$MSE = \left[\frac{1}{M \times N} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} [\hat{f}(x,y) - f(x,y)]^2 \right]^{\frac{1}{2}} \quad (1)$$

$$PSNR = 20 \times \log_{10}(\frac{255}{MSE}) \quad (2)$$

Initial population: As increase in population reduce the speed of convergence and reduction of population prevent us from reaching a proper response, we determine the population size according to experimental test done in result section, equal to 8 chromosomes.

Genetic crossover: To execute genetic crossover we used Mask method, in this method a bit series to the length of chromosome is produced that have random values and the pattern is according to the Schema theory and based on value of evaluation function with considering Pc = 0.5, then in the crossover process of 2 chromosomes, if the equal bit of Mask is zero, then each of the bits of parent chromosome are transferred to children exactly and if the equal bit from Mask is 1, then the bit of first parent chromosome is transferred to the second child and the equal bit of second parent chromosome is transferred to the first child.

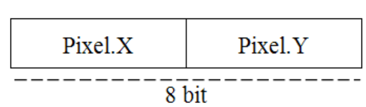

Fig. 3: Structure of used chromosome

Figure 4 shows the process of genetic crossover in the mentioned method.

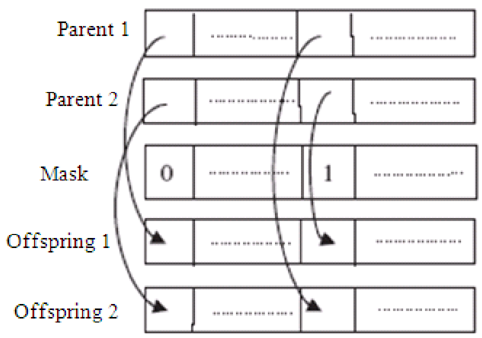

Fig. 4: Genetic crossovers by using mask (Ming-Sheng *et al*., 2007).

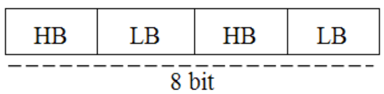

Fig. 5: High and low value sections of used chromosome

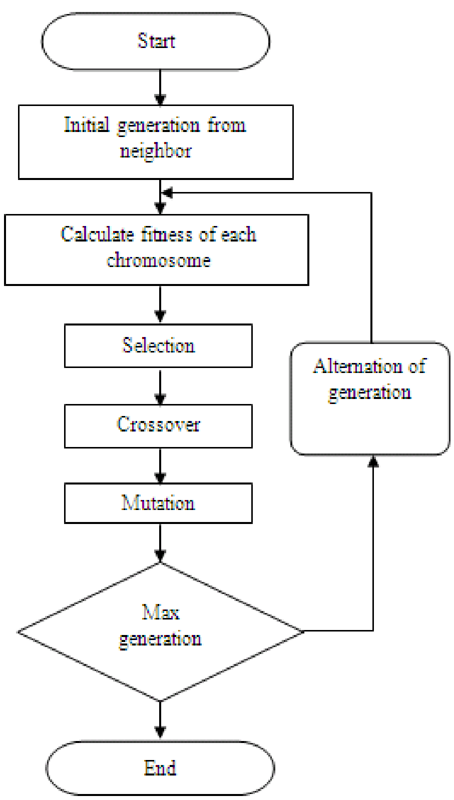

Fig. 6: Genetic algorithm flow chart

Genetic mutation: To avoid being trapped in local optimization, we used Pm = 0.01 so that mutation process is applied like natural mutation, here we apply a pattern to chromosomes according to Schema theory so that if mutation happen on a chromosome with low fitness then the bits of high value section will be changed and if mutation happen on a chromosome with high fitness hoping that there will be a proper response in neighborhood, just low value bits will change, therefore we call the 2 bits with lower level; "low value section" and the bits with higher level are called "high value section" and according to this pattern we apply the mutation to the chromosomes. Figure 5 shows high and low value section of a chromosome; also Fig. 6 shows Genetic Algorithm's mechanism.

RESULTS

To implement the mentioned method we used MATLAB software and we analyzed the images like Lena, Elaine, Pepper and Boat in a system with 2.4 G processor, 512 MB RAM and using Windows XP as operating system. Table 1 and Fig. 7 shows the quality of Pepper, Lena image according to PSNR and based on the change in repetition of genetic algorithm, as we see: increase in generation is accompanied with increase in quality. Table 2 and Fig. 8 also show the analysis of increase in generation and length of consumed time that was tested on Lena, Pepper images.

Table 1: PSNR values for different repetition

Image	Generation	MSE	PSNR
Lena	1	6.99	31.24
	5	6.79	31.49
	50	6.11	32.41
	100	5.87	32.75
Pepper	1	6.75	31.54
	5	6.73	31.57
	50	6.04	32.51
	100	5.78	32.89

Table 2: Consuming time increase by increase in repetition of genetic algorithms

Image	Generation	Time (min)
Lena	1	1.10
	5	1.18
	50	2.34
	100	4.08
Pepper	1	1.26
	5	1.29
	50	3.34
	100	4.49

Table 3: Result of compressing rate, consuming time and image quality based on PSNR by using mentioned method

Image	Compress ratio	Time (min)	PSNR
Lena	16:1	1.10	31.24
Pepper	16:1	1.26	31.54
Elaine	16:1	0.57	31.35
Boat	16:1	1.56	30.39
Baboon	16:1	2.08	28.20

Table 4: Result of compressing rate, consuming time and image quality based on PSNR by using mentioned method comparing to JPEG standard, HCMS (Cangju *et al*., 2008) and SGA (Ming-Sheng *et al*., 2007)

Technique	Image	Elaine	Lena	Pepper	Baboon
Proposed method	Time*	57	70	86	128
	CR**	16:1	16:1	16:1	16:1
	PSNR	31.35	31.24	31.54	28.20
Jpeg standard method	Time*	1	1	1	1
	CR**	5.2:1	5.6:1	5.4:1	4.4:1
	PSNR	33.63	33.90	34.44	33.16
HCMS method (Cangju *et al*., 2008)	Time*	---	80	84	90
	CR**	---	12.4:1	10.4:1	9.6:1
	PSNR	---	29.9	28.7	28.1
SGA method (Ming-Sheng *et al*., 2007)	Time*	---	29.02	17.34	16.80
	CR**	---	32:1	32:1	32:1
	PSNR	---	27.30	29.84	19.58

*: Time is based on second; **: CR = Compression Rate

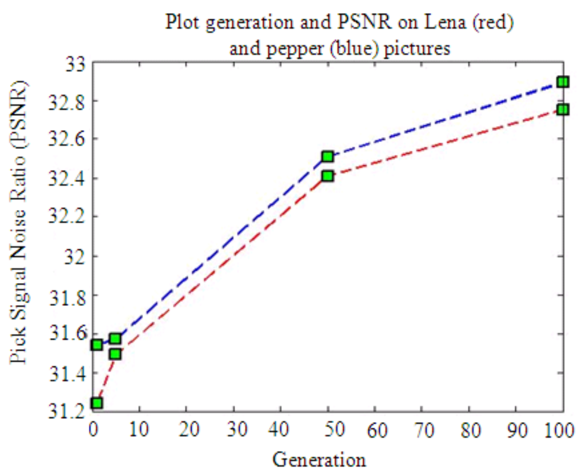

Fig. 7: Quality improvement based on PSNR by increase in repetition

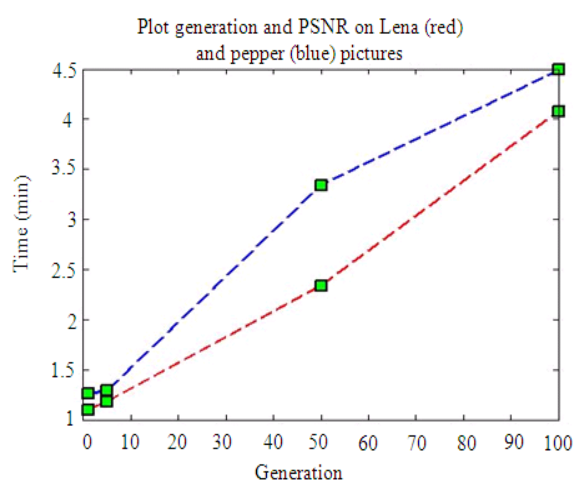

Fig. 8: Search time increase with increase in repetition in genetic algorithm

Fig. 9: Right picture is the original picture of Lena and the left is after applying the method

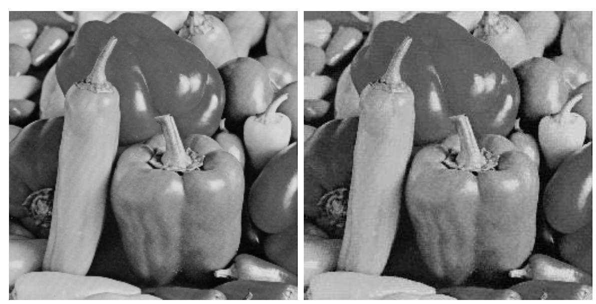

Fig. 10: Right picture is the original picture of Pepper and the left is after applying the method

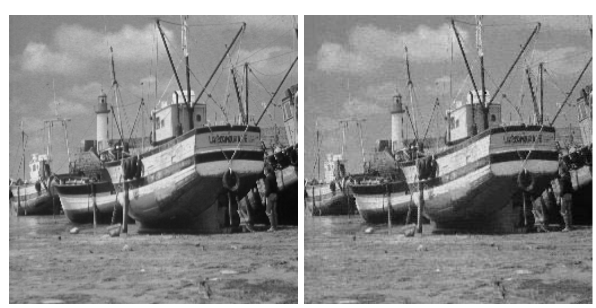

Fig. 11: Right picture is the original picture of Boat and the left is after applying the method

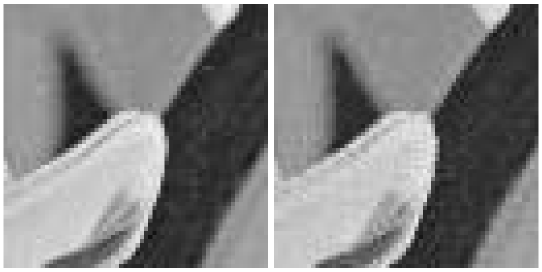

Fig. 12: Right picture is part of the original picture of Lena and the left is the result of applied method with 210% zoom

As we see in Fig. 9-12 and Table 3, the rate of compressing in each image, the time consumed and quality show the total promotion by using PSNR, however in Table 4 compressing rate, consuming time and quality of final image (by using PSNR) in this method are compared to the standard JPEG, HCMS method (Cangju *et al*., 2008) and SGA method (Ming-Sheng *et al*., 2007) and that show higher quality comparing to Jpeg standard and HCMS.

DISCUSSION

The developed Fractal Images Compression with schema theory has been evaluated by our team in Kerman institute of higher education research center; the result shows this technique capable compressing images in suitable time with very good quality, therefore it is depend on images and all details that they are in an image. In addition Fractal Image Compression with Schema Theory capable compress images with high compress ratio in a suitable time.

Schema Theory can be transfer human knowledge and it is good idea because we know the best candidate blocks are nearest blocks.

CONCLUSION

Using schema theory with Genetic Algorithm show the improvement in fractal compressing images such as decrease the time for producing a compressed images and also increase the quality of decompress picture and increase the PSNR metric because neighbor blocks often has the best similarity that can be transfer this human knowledge to our algorithm by schema theory.

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