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The Effect of Directional Search Using Iterated Functional System for Matching Range and Domain Blocks

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Abstract**—**The effect of directional search using iterated functional system has been studied on four images taken from databases. The images are portioned successively towards smaller dimension. Presented method provides the faster rate of convergence with respect to processing time in the flat region, but the same has been found to be slower at the border of the images and edges. It has also been revealed that the PSNR is lower at the edges and border portions of the image, and it is found to be higher in the uniform gray region, under the same external illumination and external noise environment.

Keywords**—**Iterated functional system, fractal compression, structural similarity index measure, fractal block coding, affine transformations.

I. Introduction

THE concept of fractal was introduced by Mandelbrot [1] as an alternative to the traditional Euclidean geometry mainly for dealing with various objects with different shapes generated by nature. In recent years, the interest in applying this theory has been steadily growing. A recent trend in computer graphics and image processing has been to use iterated function system (IFS) to generate and describe both man-made fractals-like arbitrary structures and natural images. Barnsley et al. were the first to present the concept of fractal image compression using IFS [2]. A fully automatic image compression algorithm suitable for real life grayscale images called fractal block coding (FBC) was proposed by Jacquin [3], [4]. Due to the increased use of digital image processing, image compression has become an important technology for the transmission and storage of images.

Fractal coding has received considerable attention since it was proposed [3], [5] because of its use of the self-similarity property normally present in images. This was a new concept that was not used previously in the field of image compression. Much improvement in compression efficiency and quality in decoded image have already been reported [4], [6]-[8].

Fractal geometry has been found to be helpful to measure the geometrical size and dimension of any object of an irregular shape normally found in nature. The shape of fire flame, snowfall, glaciers, mountains, and tree leave, etc. fall in the category of an image having irregular shape and size [1]. Fractal geometry has been found to be meticulously used in image processing and pattern recognition for meaningful segmentation and compression of a digital image as well as feature selection for object recognition [8]. Almost all images possess some area which have lower frequency where the rate of change of intensity with respect to space is slower; these areas are technically called region area of the image [8]. Certain areas of any image comprise a high-frequency area where intensity suffers drastic change with respect to space, and these areas or set of pixels are called boundary or border and edges.

Predominantly three elements are pertinent for judging the quality of the compressed images as peak signal to noise ratio (PSNR), compression ratio and execution tine. In the present study, it has been observed that the uniform dark level area where the spatial rate of intensity change is moderate, the ideal opportunity for apportioned IFS towards union is less. The opposite is true where gray levels (or intensity levels) change drastically from one pixel to another. It has also been found that the PSNR value is higher in region area whereas the same is lower in edge and contour or border area. The proposed algorithm has been applied to four images viz. bird, rose, boat and peppers and the observations regarding their output parameters indicate almost identical behavior for all the four images. Although a large number of research studies are found in various journals or conference proceedings, but no report is noticed yet applying best available resources of the present authors like the present study which deals with the effect of the directional search for matching range and domain blocks for fractal-based image compression.

For fractal based compression, although searching is region based on matching between range blocks and domain blocks [6], fractal image compression based on vector quantization [9], pixels distribution and triangular segmentation [10], [11], fractal compression of wavelet sub-trees [12], adaptive threshold for quadtree partition [13], ant colony optimization algorithm for image compression based on fractal theory [14], images compression based on fast hierarchical codebook search, speed-up techniques for Fractal Image comparison and region-based fractal image compression using heuristic search local search for fractal image compression [15]-[18], distortion minimization [19], reduced domain pool based on DCT [20], image coding based on the quadtree and discrete

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cosine transform [21], [22], spatial correlation and hybrid particle swarm optimization with genetic algorithm [23], Huffman coding and entropy coder for image compression [24], [25], graph-based image segmentation [26]-[28] and isosceles triangle segmentation [29], block-coding technique for gray and color images [30], [31], hybrid compression based on fractal coding with quadtree and discrete cosine transform [32], hybrid Fractal image compression based on graph theory and equilateral triangle segmentation [33] have already been reported.

The paper is organized as follows; Section II deals with mathematical background and the basis of fractal-based image compression. Section III discusses the proposed algorithm and its flowchart, Section IV describes the results and discussion about the present study, and Section V gives the conclusion.

II. The Basics of Fractal-Based Image Compression

The IFS compression algorithm starts with some target image *T* which lies in a subset $S \subset R^2$. The target image *T* is rendered on a computer graphics monitor. In order to begin fractal image compression, an affine transformation:

$$W_1(x) = \binom{x}{y} = \begin{pmatrix} a & b \\ c & d \end{pmatrix}\binom{x}{y} + \binom{e}{f} \quad (1)$$

is introduced with coefficients that produce a new image $w_1(T)$, with dimensions smaller than that of *T*. This ensures a contraction mapping.

The user adjusts the coefficients a, b, c, d, e, f in order to shrink, translate, rotate, and shear the new image $w_1(T)$, on the screen so that it lies over a part of *T*. Once $w_1(T)$ is in place, it is fixed, the coefficients are recorded, and a new affine transformation $w_2(x)$, is introduced along with its sub copy of T, $w_2(T)$.

The same process is carried out with this new image as was done with $w_1(T)$. Whenever possible, overlapping between $w_1(T)$ and $w_2(T)$ should be avoided as it only complicates the situation. In this manner, a set of affine transformations w_1, w_2, w_3, …., w_n, is obtained such that:

$$\tilde{T} = \bigcup_{n-1}^{N} w_n\,(T) \quad (2)$$

where *N* is as small as possible.

The Collage Theorem assures that the attractor A of these IFS will be visually close to T. Moreover, if $\tilde{T} = T$, then $A = T$. As desired, A provides an image which is visually close to T and is resolution independent using a finite string of ones and zeros. By adjusting the parameters in the transformations, one can continuously control the attractor of the IFS. This is done in fractal image compression.

III. Proposed Algorithm and Its Flowchart

Image Compression using discrete cosine transform (DCT) and fractal based quadtree approaches are used in the proposed method. In the proposed algorithm, the matching between range and domain blocks are done direction wise. Directional searches are carried out along horizontal, vertical and angular directions (with an angle of 45˚ and 35˚ with respect to the horizontal), and these are done along both positive and negative directions. In the present study, four types of image viz. bird, rose, boat and peppers have been taken. After the fractal-based compression, the PSNR value [29] and processing lines are calculated on MATLAB 2013b platform. The PSNR is calculated using:

$$\text{PSNR}=10\,\log_{10}\frac{2552}{(\frac{1}{m*n})\sum_{c=1}^{M}\sum_{j=1}^{N}(X_{i,j}-\hat{X}_{i,j})^2} \quad (3)$$

where M×N is the size of the image, X_{ij} and $\hat{X}_{ij}$ *are the* pixel values of the original and reconstructed image at position (i, j). Normally better image quality implies a larger value of PSNR. The execution time of the program is calculated using the tic-toc code of MATLAB image processing toolbox.

The compression algorithm is as follows:

Input color image

Step 1: Partition the input image into n × n non-overlapping blocks. (An image is partitioned into a number of disjoint blocks of size B×B called range blocks and a number of blocks of size 2B×2B called domain blocks based on quadtree partitioning)

Step 2: Define a collection of local contractive affine transformation mapping of domain blocks D into the range blocks R.

Step 3: For every range block, search a corresponding domain block based on directional search (Horizontal '+' (0°), Horizontal '-' (180°), Vertical '+' (90°), Vertical '–' (270°), Angular (45°), Angular (135°), Angular (225°) and Angular (315°)) search symmetry, so that the domain block looks most of the like the past of the image in the range block. If the best match is not found, then repeat from Step 4 to Step 6, then write the compressed data in the form of a local IFS code.

Step 4: Then apply a fractal data compression technique to get the compressed IFS code.

Step 5: The resultant image is fractals encoded/compressed image.

Fig. 1 shows the flow chart of the overall compression process. The first input image is partitioned based on quadtree partitioning. Then, local contractive affine transformation mapping is applied in domain blocks D to achieve the range blocks R. For every range block; searching is made in a corresponding domain block based on directional search (Angular direction). If the best match is found, the compressed data is recorded in the form of a local IFS code. If matching is not found, again search based on directional search (Angular direction) method is repeated until the best match of domain blocks and the range blocks are found.

IV. Implementation, Results, and Discussions

The proposed method is experimented and the simulation result is observed. The simulations are carried out using core I3 processor, 512 GB RAM, and Windows XP operating system. Here four color images namely bird, rose, boat, and peppers images of size 256×256×3 are taken. Fig. 2 (a) shows

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the original image of bird, Fig. 2 (b) shows the decompressed image of bird according to proposed method, Fig. 2 (c) shows the original image of rose, Fig. 2 (d) shows the decompressed image of rose using proposed method. Fig. 2 (e) shows the original image of boat, Fig. 2 (f) shows the decompressed image of boat applying proposed method, Fig. 2 (g) shows the original image of peppers and Fig. 2 (h) shows the decompressed image of peppers obtained using the proposed method.

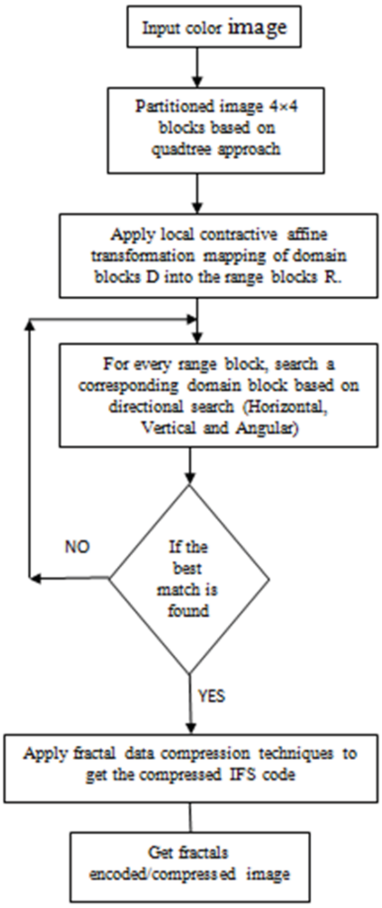
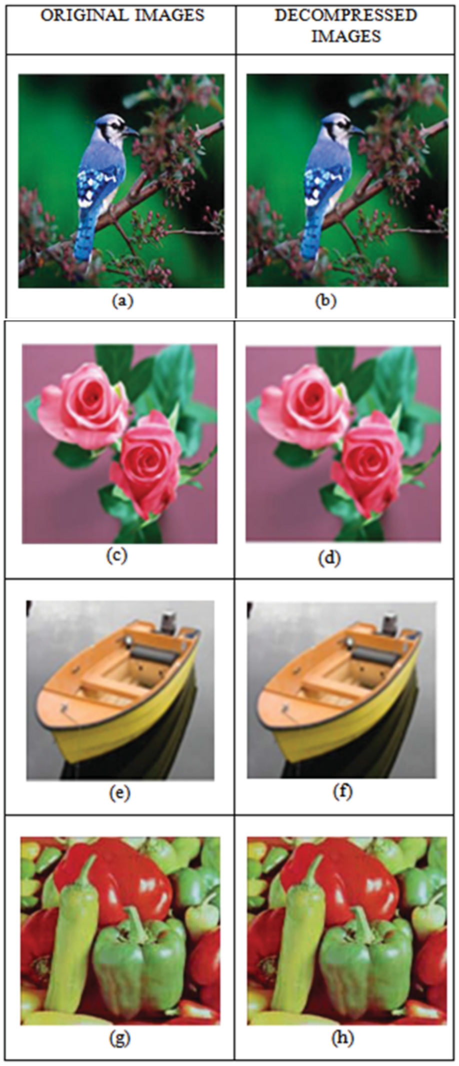


Fig. 1 The overall fractal encoding process

Tables I A and B represent the values of PSNR (dB), execution time (sec) and compression ratio for various color images viz. bird, rose, boat and peppers with respect to the various directional search (angular search). From Tables I A and B it has been noted that in different angular directions, the values of PSNR (dB), execution time (sec) and compression ratio vary.

Figs. 3-5 show the comparison values of PSNR (dB), execution time (sec) and compression ratio for searching at different angular directions of 0°, 45°, 135°, 90°, -180°, 225°, -270° and 315° for bird, rose, peppers and boat.



Figs. 2 (a), (c), (e), and (g) the original images of bird, rose, boat and peppers and (b), (d), (f), and (h) the decompressed images of bird, rose, boat and peppers, respectively

V. Conclusions

This paper briefly presents the basic theory of fractal image compression. In this study, mainly three factors are relevant for having compressed image viz. PSNR or SSIM, processing time and compression ratio. It has been found that the uniform gray level region where spatial rate of intensity change is slow, the time taken to achieve partitioned iterated functions towards convergence is less. But the execution time becomes higher, where gray levels (or intensity levels) change drastically from one pixel to another. It has also been found that the PSNR value is higher in region area whereas the same is lower in edge and contour and border area present in a digital image. Proposed fractal-based image compression, although searching has been done along angular directions for matching between range blocks and domain blocks, still it has been observed that proposed methods provide high compression ratio, PSNR (dB) and reduced execution time. The presented approach is found to be able to improve the quality of the recovered image and compression ratio significantly.

TABLE I A
HORIZONTAL (+ AND -) AND VERTICAL (+ AND -) COMPARISON WITH RESPECT TO PSNR (DB), EXECUTION TIME (SEC) AND COMPRESSION RATIO FOR FOUR TEST IMAGES

Test images	Horizontal '+' (0°)			Horizontal '-' (180°)			Vertical '+' (90°)			Vertical '–' (270°)		
	PSNR (dB)	Time (sec)	Compression ratio	PSNR (dB)	Time (sec)	Compression ratio	PSNR (dB)	Time (sec)	Compression ratio	PSNR (dB)	Time (sec)	Compression ratio
Bird	31.30	42	39.17	32.13	43	39.33	33.11	42	39.21	34.14	41	40.02
Roses	34.69	42	39.44	35.63	42	39.93	34.77	41	40.06	33.03	43	39.53
Peppers	33.52	42	39.87	33.97	44	39.47	34.01	43	39.89	32.30	42	39.69
Boat	35.67	42	39.93	35.71	43	40.03	34.93	42	39.79	34.01	44	39.56

TABLE I B
ANGULAR (45°, 135°, 225°, 315°) COMPARISON WITH RESPECT TO PSNR (DB), EXECUTION TIME (SEC) AND COMPRESSION RATIO FOR FOUR TEST IMAGES

Test images	Angular (45°)			Angular (135°)			Angular (225°)			Angular (315°)		
	PSNR (dB)	Time (sec)	Compression ratio	PSNR (dB)	Time (sec)	Compression ratio	PSNR (dB)	Time (sec)	Compression ratio	PSNR (dB)	Time (sec)	Compression ratio
Bird	33.65	44	39.07	34.91	45	39.33	34.90	46	39.01	34.33	46	38.02
Roses	33.10	45	38.98	34.01	46	39.97	35.10	46	38.66	34.41	45	39.13
Peppers	34.01	46	39.23	33.90	45	39.47	33.95	45	38.57	33.90	46	38.50
Boat	33.97	45	38.95	33.76	45	39.03	33.67	46	39.61	334.96	46	38.59

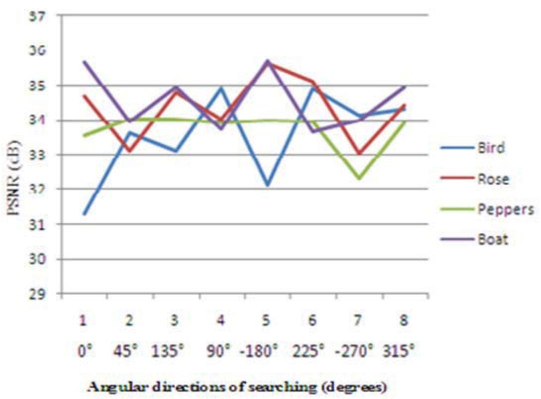


Fig. 3 Comparison of the PSNR (dB) value at angular 0°, 45°, 135°, 90°, -180°, 225°, -270° and 315° directions for Bird, Rose, Peppers and Boat

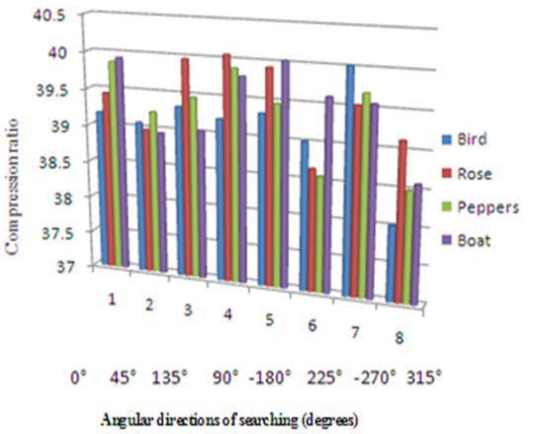


Fig. 4 Comparison of the compression ratio at angular 0°, 45°, 135°, 90°, -180°, 225°, -270° and 315° directions for Bird, Rose, Peppers and Boat

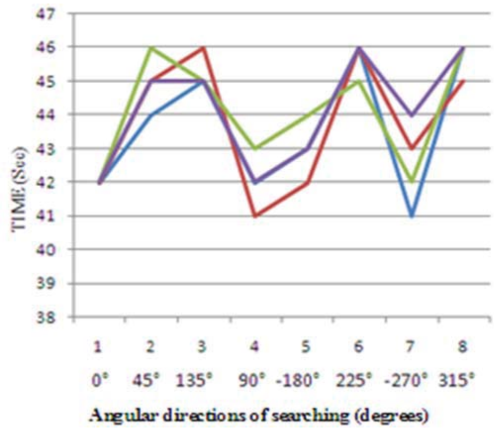


Fig. 5 Comparison of the execution time (sec) at angular 0°, 45°, 135°, 90°, -180°, 225°, -270° and 315° directions for Bird, Rose, Peppers and Boat

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