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A Proposed Hybrid Color Image Compression Based on Fractal Coding with Quadtree and Discrete Cosine Transform

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***Abstract*—**Fractal based digital image compression is a specific technique in the field of color image. The method is best suited for irregular shape of image like snow bobs, clouds, flame of fire; tree leaves images, depending on the fact that parts of an image often resemble with other parts of the same image. This technique has drawn much attention in recent years because of very high compression ratio that can be achieved. Hybrid scheme incorporating fractal compression and speedup techniques have achieved high compression ratio compared to pure fractal compression. Fractal image compression is a lossy compression method in which self-similarity nature of an image is used. This technique provides high compression ratio, less encoding time and fart decoding process. In this paper, fractal compression with quad tree and DCT is proposed to compress the color image. The proposed hybrid schemes require four phases to compress the color image. First: the image is segmented and Discrete Cosine Transform is applied to each block of the segmented image. Second: the block values are scanned in a zigzag manner to prevent zero co-efficient. Third: the resulting image is partitioned as fractals by quadtree approach. Fourth: the image is compressed using Run length encoding technique.

***Keywords*—**Fractal coding, Discrete Cosine Transform, Iterated Function System (IFS), Affine Transformation, Run length encoding.

I. Introduction

RESEARCH on image processing in present day has become a challenging field; one among them is image compression. Digital image compression and decompression techniques have become an important aspect in the storing and transferring of digital image. There are mainly two categories of image compression methods-lossless and lossy methods. Lossless compression techniques allow exact reconstruction of the original, but the achievable compression ratios are only of the order approximately 2:1 [1]. The main disadvantage of lossless methods is that they cannot achieve high compression ratio. So, for image compression applications where the losses of minor graphics details are not critical, lossy methods are widely used. A widely used form of lossy image compression process is the JPEG. The extensively used JPEG process based on Discrete Cosine Transform (DCT) is a form of lossy image Compression [2], operates by splitting images into differ new frequency parts. The most important lossy image compression techniques used either orthogonal transforms (e.g. wavelet, DCT, JPEG) or codebook based techniques (e.g. vector quantization, fractal compression) [1]-[4].

Fractal is based on the concept of fractional geometry which is used to describe irregular and fragmented objects or patterns. There are various objects like cloud, fire flame, snow fall, mountain, waves, and trees etc. which are difficult to describe or deal with the help of other geometry. Fractal compression [3] was used to encode the images which have self similarity [4]. A lot of work has been carried out by various scientists to compress either gray scale [5], [6] or color images. An increasing number of products [7] like cellular phones, laptop computers, and cameras used in surveillance [8] transmit and receive videos and images by means of portable wireless devices. The demand for efficient techniques which can store and transmit visual information has been increased with the increasing use of color images in the continuous growth of multimedia application [9]. Due to this demand, image compression has become a crucial factor and the requirement for efficient algorithms that can yield large compression ratio with low loss has increased [10].

In fractal image compression, compressed images are represented by contractive transforms. These transforms are consists of group of a number of affine mappings on the whole image, known as Iterated Function System (IFS).Contractive transformation is applied to the IFS called Collage theorem. This theorem is the core of the fractal coding [11]. Fractal image compression is a modern image compression technique based on self similarity. In this compression, the image is decomposed twice, into overlapping domain blocks to make a domain pool. Then the image is decomposed again into non-overlapping range blocks. After decomposition, for each range block best matched domain block in the domain pool with a contractive affine transformation is searched. Finally the best matched domain block can be found for each range block in the original image [12]. To improve the coding efficiency of fractal image compression, quad tree technique can be used. To reduce encoding time, proposed a hybrid scheme based on DCT and fractal with quadtree technique and run length encoding.

The rest of the paper is organized as follows: Section II describes some of the recent related works, Section III describes the Mathematical background, and the proposed methodology is described in Section IV. Experimental results of the proposed methodology are explained and discussed in Section V. Finally, conclusion is provided in Section VI.

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II. Related Works

Many researchers have proposed for the color image compression process. In this section, a brief review of some important works from the existing literature is presented.

Sofia Douda et al. [13] proposed a new method based on the DCT coefficients. In this method, the domain blocks with a low activity are discarded from the domain pool. The activity of blocks is based on the lowest horizontal and vertical DCT coefficients.

Ruhiat Sultana et al. [14] proposed an advanced fractal image compression algorithm based on quadtree that construct search attractor directly from the big domain block. And if domain block cannot search the similar range block, the most similar range block is searched and calculates the correctional value to construct the fictitious range block.

Gohar Vahdati et al. [15] proposed a fractal image compression method based on spatial correlation and hybrid particle swarm optimization with genetic algorithm. There are two stages to the algorithm. The first stage exploits local optima used the spatial correlation between neighboring blocks. If the local optima are not satisfied, the second stage of the algorithm is done to explore further similarities from the whole image.

Kharate and Patil [16] proposed that the compression ratio done and the quality had been considerably improved by appropriate selection of the mother based on the nature of images. The technique they have proposed had been based on Threshold Entropy with enhanced run-length encoding based wavelet packet best tree. As complete tree had not been decomposed, their method had minimized the time complexity of wavelet packets decomposition. Sub bands that include significant information based on threshold entropy had been chosen by their algorithm.

D. Venkatasekhar and P. Aruna [17] proposed that Genetic algorithm which was used to find the best block of replacement, so fractal image is done easily. Here Genetic algorithm with Huffman coding was used for fractal image compression.

Khalil [18] implemented a Run Length coder that had been made simple and more effective. Their proposed algorithm had worked on quantized coefficients of the DCT where several concurrent tokens existed.

Vijaya-Prakash and Gurumurthy [19] proposed a technique to enhance the data compression technique. In their work, a new DCT and Quantization architecture had been designed for performing image compression. Compression of image data could be achieved by employing the DCT. Later, compression has been achieved by performing quantization of the DCT data coefficients.

Yih-Lon Lin and Wen-Lin Chen [20] proposed the method in which particle swarm optimization method is adopted with classification and Dihedral transformation to speed up the fractal image encoder. The PSO algorithm was used to search the best match solution in the search space. In the search mechanism, similarity measures were performed only when both the domain and range blocks are of the same type.

To reduce encoding time, proposed a hybrid scheme based on DCT and fractal with quadtree technique and run length encoding.

III. Mathematical Background

A. Self-Affine and Self-Similar Transformation

Fractal image compression algorithm is based on the fractal theory of self-similarity and self-affine transformations [21].

Definition 1. A self-affine transformation $w: R^n \to R^n$ is a transformation of the form $w(x) = T(x) + b$, where T is a linear transformation on R^n and $b \epsilon R^n$ is a vector.

Definition 2. A mapping $w: D \to D$; $D \subseteq R^{n\ n}$ is called a contraction on D if there is a real number *c ϵ (0, 1),* such that $d\big(w\,(x), w(y)\big) \leq cd(x,y)$ for $x, y \epsilon D$ and for a metric d on R^n real number c is called the contractility of w.

Definition 3. If $d\big(w\,(x), w(y)\big) \leq cd(x,y)$, then w is called a similarity. A family $\{w_1 \ldots\ldots\ldots. w_m\}$ of contractions is known as a local iterated function system (LIFS). If there is a

Subset $F \subseteq D$ such that for a LIFS $\{w_1 \ldots\ldots\ldots. w_m\}$,

$$F = \cup_{i=1}^{m} w_1\,(F) \tag{1}$$

then F is said to be invariant for that LIFS. If F is invariant under a collection of similarities, F is known as a self-similar set.

Let S denote the class of all non-empty compact subsets of D. The δ-parallel body of $A \in S$ is the set of points within distance δ of A, i.e.

$$A_\delta = \left\{x \,\epsilon\, D\text{: there exists } \alpha \,\epsilon\, A \text{ such that } |x - a| \leq \delta \right\} \tag{2}$$

Let us define the distance $d(A, B)$ between two sets A, B to be

$$d(A,B) = inf\{\delta: A \subset B_\delta \ and \ B \subset A_\delta\} \tag{3}$$

The distance function is known as the Hausdorff metric on S (other distance functions can also be used).

Given a LIFS $\{w_1 \ldots\ldots\ldots. w_m\}$, there exists an unique compact invariant set F, such that

$$F = \cup_{i=1}^{m} w_1\,(F) \tag{4}$$

F is known as the attractor of the system. If E is a compact non-empty subset such that $w_i(E)$ and $w_i(E) \subset$ E and

$$W\,(E) = \cup_{i=1}^{m} w_1\,(F) \tag{5}$$

define the k-th iteration of $w, w^k(E)$, to be

$$w^0(E) = E, w^k(E) = w\left(w^{k-1}(E)\right) \tag{6}$$

For $K \geq 1$, then got

$$F = \cup_{i=1}^{\infty} w^k\,(E) \tag{7}$$

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The sequence of iteration wk (E) converges to the attractor of the system for any set E. This means that it may carry out a family of contractions that approximate complex images and, using the family of contractions, the images can be stored and transmitted in a very efficient way. Another present method is a LIFS; it is straightforward to obtain the encoded image. If anyone wants to encode an arbitrary image in this way, they will have to find a family of contractions so that its attractor is an approximation to the given image. Barnsley's [3] Collage Theorem states how well the attractor of a LIFS can approximate of any given images.

B. Collage Theorem

Let $\{w_1 \ldots\ldots\ldots. w_m\}$, be contractions on R^n so that for any $x, y \in R^n$ and any *i*,

$$|w_i(x) - w_i(y)| \leq \text{c} \tag{8}$$

where $c \in (0,1)$ is a constant. Let $E \subset R^n$ be any non-empty compact set. Then

$$\text{d}\,(E, F) \leq 1/(1-\text{c})\, d\ (E = \cup_{i=1}^{\infty} w_i(E)) \tag{9}$$

where F is the invariant set for the w_i, and d is the Hausdorff metric [22].

As a consequence of this theorem, any subset of R^n can be approximated within an arbitrarily tolerance by a self-similar set, i.e., given $\delta > 0$, there exist contracting similarities $\{w_1 \ldots\ldots\ldots. w_m\}$ with invariant set F satisfying $d(E, F) < \delta$. Therefore, the problem of finding a LIFS $\{w_1 \ldots\ldots\ldots. w_m\}$ whose attractor F is arbitrary close to a given image I is equivalent to minimize the distance

$$d(I = \cup_{i=1}^{m} w_i\,(I)) \tag{10}$$

C. Affine Transformation

An affine transformation maps a plane to itself. The general form of an Affine Transformation is

$$\text{W}\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} e \\ f \end{bmatrix} \tag{11}$$

Affine transformations can skew, stretch, rotate, scale and translate an input image.

D. Contractive Transformations

A transformation *w* is said to be contractive if for any two points P_1, P_2, and the distance

$$d\big(w\,(P_1), w(P_2)\big) < sd\,(P_1, P_2) \tag{12}$$

for some s < 1, where d = distance. This formula says the application of a contractive map always brings points closer together (by some factor less than 1).

E. Fractal Image Coding

A fractal is a geometric form which has self-similar irregular details. The idea of fractal image coding is based on the assumption that a large amount of self-similarity is present in the image at the microscopic or block-image level. Thus, the image redundancies can be exploited by means of block-based self-affine transformations [23], [4]. This is different from common transform coding approaches where a single invertible transform maps the image to a set of uncorrelated coefficients among which only the dominant ones are retained and further processed for storage and transmission. In the encoding phase, 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. For each range block, the best matching domain block is searched in the domain pool (a collection of domain blocks) by performing a set of transformations on the blocks so that a given metric (e.g. root mean square) is minimized. Data compression is achieved by storing only the set of transformations, i.e. the fractal code, which contains the complete information required to reconstruct the image. The reconstruction (or approximation) of the original image is obtained by iterating the set of transformations on an arbitrary initial image.

F. Quad Tree Partitioning

The first practical block-based fractal coding scheme was developed by [4]. The weakness of this approach is that some regions of the image may not be covered well due to the use of range blocks of fixed size. A quad tree-based fractal encoding scheme [24] is an extension of the Jacquin's method and was used in this study. A quad tree partition is a representation of an image as a tree in which each node corresponds to a square of the image. Each node contains four sub nodes, corresponding to the four identical size quadrants of the square. The root of the tree is the original image. After some initial number of partitions is performed, the squares at the nodes (i.e. range blocks) are compared with domain blocks (which are twice the range size) in the domain pool. The size of the domain block is shrunk by pixel averaging to match the range size, and the affine transformation (offset and scaling) of the pixel values is found by minimizing the root mean squares (RMS) difference between the range pixel values and the transformed domain pixel values. Apart from offset and scaling, a domain block has eight possible isometric orientations (4 rotations and reflection with 4 rotations) to match a given range block. Thus, the domain pool can be thought of as being enlarged by including all rotations and reflections of each domain block. All the possible domain blocks are explored and compared with a range. If the depth of the quad tree is less than an assumed maximum depth and if the optimal RMS difference is larger than a threshold, the range block is further subdivided into four quadrants and the process is then repeated until the optimal RMS is less than the threshold. The set of transformations and domains are stored and the encoding process is completed.

Decoding process is done by iterating the set of transformations on an arbitrary initial image and the quadtree partition is used to determine the ranges in the image. For each range block, the size of the domain block that maps to it is shrunk by two via 2 × 2 pixel averaging. The pixel values of the shrunken domain block are then placed in the location in

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the range determined by the orientation information after scaling and offsetting. Computing all the range blocks constitute one iteration. After several iterations, the reconstructed image will be very close to the original image.

IV. Proposed Method

Image Compression using DCT and fractal based quad tree approaches are the proposed methods. The proposed methods are separate as first; the input image is partitioned into a number of disjoint non-overlapping blocks of size B×B called range blocks and a number of blocks of size 2B×2B called domain blocks. Second; then apply DCT to every blocks of the partitioned image. Third; then the DCT coefficients of each block are quantized. Fourth; the zero coefficients are prevented by scanning the block values in a zig-zag manner; zig-zag scanning improves the compression efficiency and extracting the nonzero coefficients. Fifth; the resulting image is partitioned using fractal based quad tree approaches. Lastly; the image encoded using Run length encoding technique. The entire procedures as

Image is partitioned into a number of disjoint non-overlapping blocks of size 4×4 called range blocks and a number of blocks of size 8×8 called domain blocks. The DCT apply to every blocks of the partitioned image (range blocks and domain blocks) for quantized the DCT coefficients. The entire DCT quantized coefficients are rearranging in a zigzag manner to prevent zero coefficients and improves the compression efficiency. A list of non-zero tokens for each bock proceeded by their count will be obtained [24]. Fig. 1 shows the zigzag scanning.

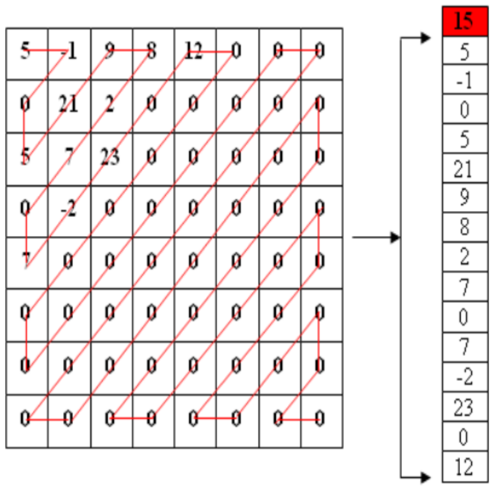

Fig.1 Zigzag scanning

Image compression based on fractal used the property of self-similarity of fractal objects. Some of the blocks obtained by dividing the color image into several 8×8 blocks are similar. The concept of fractal image compression is used to prevent performing repetitive compression on the similar block. Fractal image compression used before encoding the quantized image blocks. Similar blocks in a given input image are identified using fractal image compression i.e., the matched domain blocks for each range block in an image. This process is repeated until best matches are not found.

The quantized values are further compressed by Run length encoding technique to give a better overall compression. It is very simple compression technique and achieves best results with images containing large area of color and especially monochrome images. In this process represents a string by replacing each sequences of consecutive identical characters with (char; length). This method works us when the characters repeat often [24], [25].

The decompression process is easy. The compressed image is decompressed by reversing the entire procedures. Figs. 2 and 3 show the entire compression and decompression processes respectively.

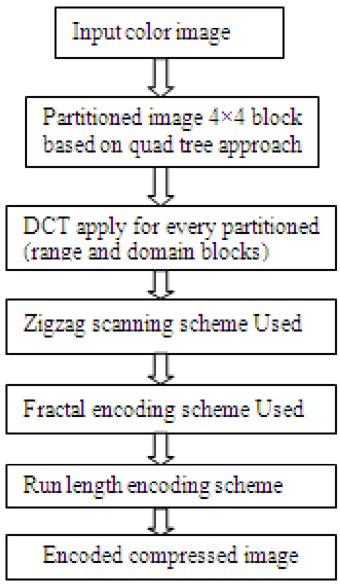

Fig. 2 Proposed compression method

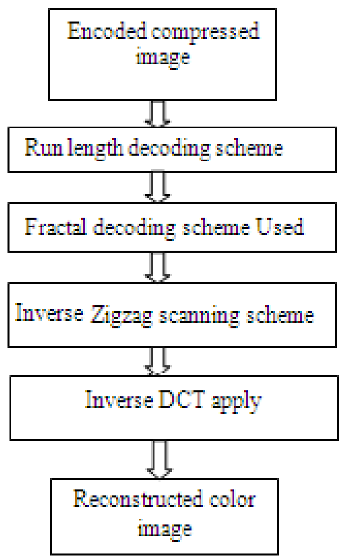

Fig. 3 Proposed decompression method

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The proposed compression and decompression algorithms are as follows

The compression algorithm:

Step 1: Input color image

Step 2: Partitioned the input image into n*n non-overlapping blocks based on quadtree approach. (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)

Step 3: Apply DCT to every partitioned of the image.

Step 4: Quantize the DCT coefficient of each block.

Step 5: Scan the block values in zigzag manner to exploit zero coefficients.

Step 6: The resultant image is partitioned as fractals using quadtree decomposition.

Step 7: Encode the image using Run Length Encoding to compress the image.

The decompression algorithm:

Step 1: Input compressed image,

Step 2: Apply Run Length decoding technique

Step 3: Apply fractal decoding technique.

Step 4: Apply inverse zigzag to the image

Step 5: Then apply inverse DCT to the resultant image

Step 6: Get decompress the image

V. Implementation, Results and Discussions

In this section the method is implemented and tested and the simulation results are advanced for three approaches, first method is standard fractal coding. In this scheme, first input image is partitioned into non-overlapping blocks. After the partitioned apply fractal coding scheme for getting the fractal encoded compressed image. Fig. 4 shows the flow diagram for standard fractal encoding scheme.

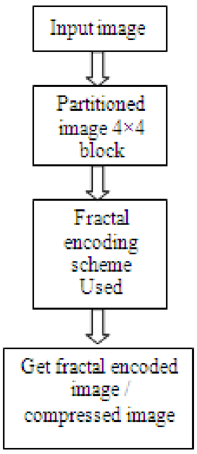

Fig. 4 The standard fractal encoding scheme

Second, the proposed method –I, first DCT is applied on the entire image and then partitioned it into range bocks. After partitioned apply fractal encoding scheme. Fig. 5 shows the flow diagram for proposed method-I fractal encoding scheme. It is a very easy method but this scheme has two main disadvantages. First, transforming the entire image is a very time consuming process and second, the quantization error on each coefficient is difficult to relate to the distortion actually perceived by the eye. To overcome these problems, we proposed method-II, first partition the entire image into n*n non-overlapping blocks based on quadtree approach (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). After partitioned apply DCT to every partitioned of the image. Then quantize the DCT coefficient of each block and scan the block values in zigzag manner to exploit zero coefficients, lastly resultant image is partitioned as fractals using quadtree decomposition and encode the image using Run Length Encoding to compress the image. In proposed method-II has many advantages compared to other mentioned methods are, first, it takes less time to transform a large number of small bocks then to transform a large bock having an equivalent number of pixels. Second, partitioning an image into bocks also helps in contorting distortion, increase the PSNR, and compression efficiency compared to others methods.

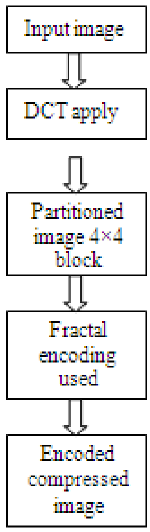

Fig. 5 The flow diagram for proposed method-I

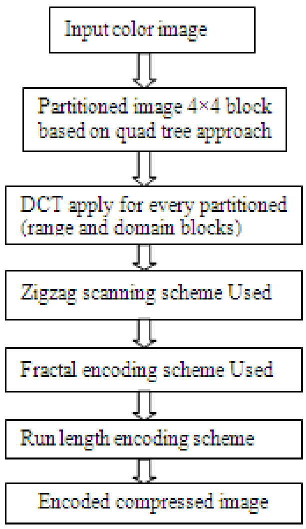

Fig. 6 The flow diagram for proposed method-II

TABLE I
COMPARISON BETWEEN STANDARD FRACTAL CODING, PROPOSED METHOD-I AND PROPOSED METHOD-II WITH RESPECT TO PSNR, ENCODING TIME AND COMPRESSION RATIO

Test images	Fractal coding technique			Proposed method-I			Proposed method-II		
	PSNR (dB)	Time (sec)	Compression ratio	PSNR (dB)	Time (sec)	Compression ratio	PSNR (dB)	Time (sec)	Compression ratio
Peppers	31.48	58.07	38.07	37.49	51.02	42.57	37.49	45.05	42.59
Baboon	32.43	59.01	37.57	37.48	52.45	41.49	37.49	46.01	42.48
Lena	31.39	58.02	38.73	37.49	51.02	42.57	37.53	45.01	42.63
Rose	33.39	57.54	39.07	38.48	50.57	42.83	38.48	44.52	43.07

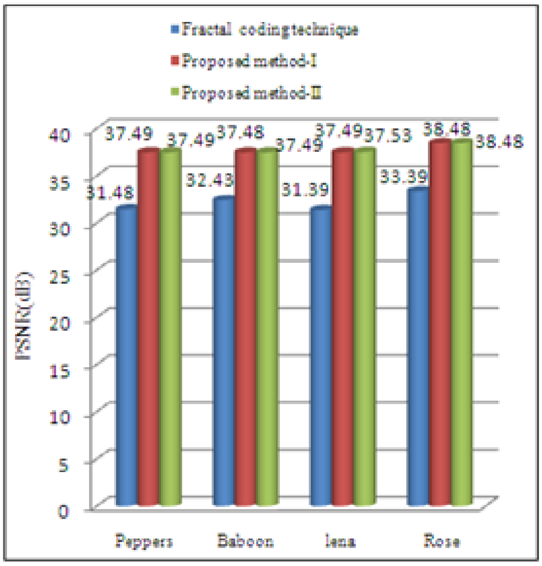

Fig. 7 The comparison value of PSNR for Peppers, Baboon, Lena and Rose between standard fractal coding method, proposed method-I and proposed method-II

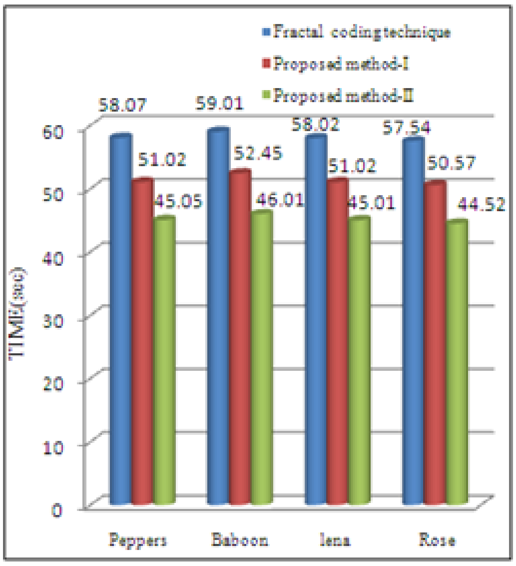

Fig. 8 Comparison of encoding time for Peppers, Baboon, Lena and Rose between standard fractal coding method, proposed method-I and proposed method-II

The proposed method has been implemented using Matlab12 and this methods has been evaluated using four color images namely as Peppers, Baboon, Lena and Rose. Table I shows the comparison between standard fractal coding, proposed method-I and proposed method-II.

From the comparison table, it is very clear that our proposed method-II is best compared to standard fractal coding method and proposed method-I with respect to PSNR, encoding time and compression ratio. Fig. 7 shows the comparison value of PSNR for Peppers, Baboon, Lena and Rose between standard fractal coding method, proposed method-I and proposed method-II. From the comparative graph of PSNR, it has been noted that in our proposed method-I the value of PSNR is highly increased compare to standard fractal coding method and in our proposed method-II the value of PSNR is slightly increased compare to proposed method-I.

Fig. 8 shows the comparison of encoding time for Peppers, Baboon, Lena and Rose between standard fractal coding method, proposed method-I and proposed method-II. From the comparative graph of encoding time, it has been noted that proposed method-II required less encoding time compared to other mentioned methods.

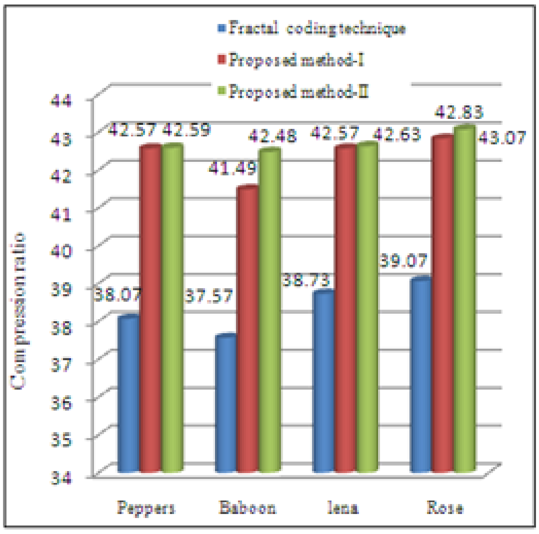

Fig. 9 Comparison of compression ratio for Peppers, Baboon, Lena and Rose between standard fractal coding method, proposed method-I and proposed method-II

Fig. 9 shows the comparison of compression ratio for Peppers, Baboon, Lena and Rose between standard fractal coding method, proposed method-I and proposed method-II. From the comparative graph of encoding time, it has been

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noted that proposed method-II required less encoding time compared to other mentioned methods.

From the comparison of PSNR, Time and Compression ratio for Peppers, Baboon, Lena and Rose, proposed method-I am better but proposed method-II is best.

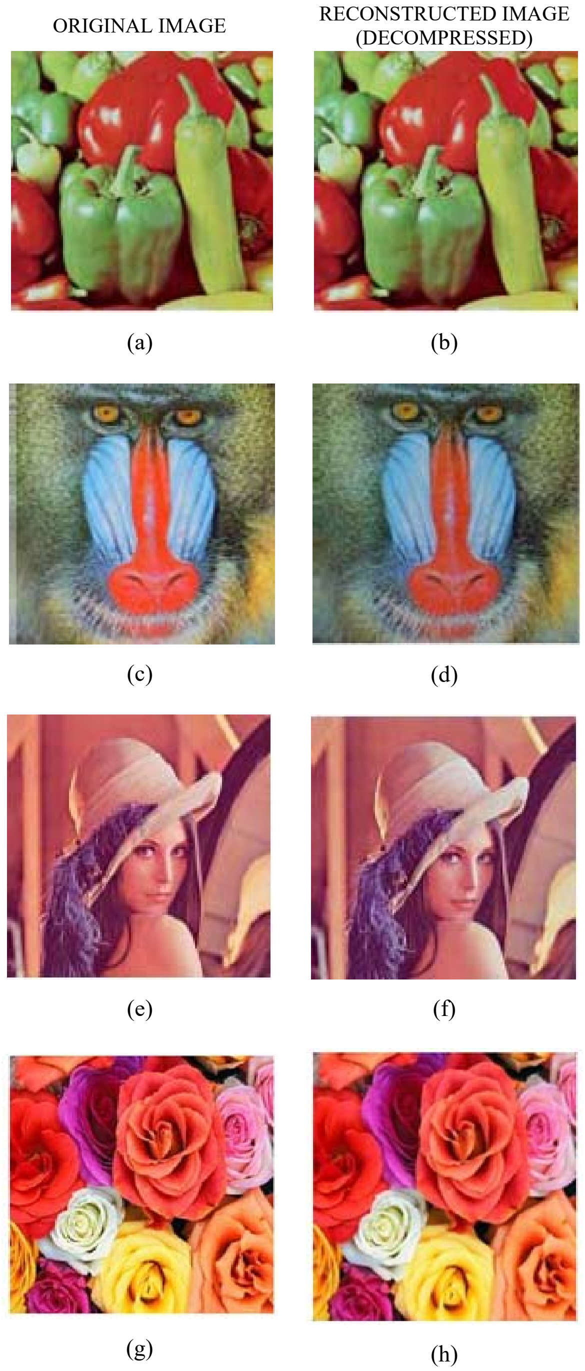

Fig. 10 (a), (c), (e) and (g) the original images of Peppers, Baboon, Lena and Rose and (b), (d), (f) and (h) the reconstructed (decompressed) images of Peppers, Baboon, Lena and Rose

Figs. 10 (a), (c), (e) and (h) show the original images of Peppers, Baboon, Lena and Rose and (b), (d), (f) and (g) show the reconstructed (decompressed) images of Peppers, Baboon, Lena and Rose.

VI. Conclusions

The main goal of this paper is to propose a new hybrid fractal coding scheme and it shows some merits of the proposed methods. It has been observed that fractal coding alone does not provide best results compared to method-I and method-II. Hybrid coding scheme provide the best result compared to others existing scheme and also provide high processing speed and high quality image with high compression ratio.

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