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A Proposed Hybrid Fractal Image Compression Based on Graph Theory and Isosceles Triangle Segmentation

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Abstract : Fractal coding is a very specific technique in the field of color image compression. However, it has not been widely used because of its long encoding time and high computational complexity Fractal image compression has received much attention from the research community because of some desirable properties like resolution independence, fast decoding, and very competitive rate-distortion curves. Despite the advances made, the long computing times in the encoding phase still remain the main disadvantages of this technique. However, many solutions have been proposed for this problem, but there is not yet a standard for fractal coding. In this paper we proposed fractal coding based on isosceles triangle segmentation and apply graph-based image segmentation to fractal image compression, separating the initial image into many logic areas, and then encoding each area with fractal image compression method. Experiments show that, compared with the typical approaches, proposed approach can accelerate the fractal coding speed on the premise of guaranteeing the decoded images quality.

Keywords: *Fractal compression, Iterated Function System (IFS), Affine Transformation, Isosceles Triangle Segmentation, Graph based image segmentation, Local Iterated Function System (LIFS), Partitioned Iterated Function System (PIFS).*

1. INTRODUCTION

Image compression has remained an important research area for many years due to the increasing demand on data transfer and storage. The basic objective of image compression is to reduce the bit rate for image compression or storage requirement while maintaining an acceptable image quality. Image compression, in general, is classified as lossless compression scheme and lossy compression scheme. Lossless compression scheme is an error free compression technique where the original data can be recovered after decompression. Although, lossless compression scheme provides low compression ratio but it has several applications for example the compression of medical images, where the loss of information are not acceptable whereas in lossy compression scheme, some extent of original data is lost so that after decompression process an approximation of the original data is obtained. In lossy compression scheme, the high compression ratio is achieved than lossless compression scheme. In fact, lossy compression scheme is used for compression natural images where perfect reconstruction is not essential and we can afford the partial loss in the image data as long as it is within tolerance. During designing of lossy compression scheme, two important issues are considered i.e the compression ratio and the tolerance in the visual quality degradation. There is a tradeoff between compression ratio and the tolerance in the visual quality degradation. If we go for higher compression ratio, then the visual quality of the decompressed image will be degraded.

In the field of image compression, several efficient lossy image compression schemes are used namely JPEG. The extensively used JPEG process based on Discrete Cosine Transform (DCT) is a form of lossy image Compression[1], 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) [2 - 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 based image compression method is originated from Barnsley's research for IFS system[3, 5] and the image fractal block coding proposed by Jacquin[4]. In 1988, in 1988, Barnsley applied fractal image compression based on IFS system to computer graphics, and compressed the aerial image, which made him get a compressed ratio 1000:1, but the approach requires manual intervention. Subsequently, Jacquin proposed a new fractal image compression method based on image block, and the method can conduct automatically without manual intervention. Therefore, Jacquin's method has become a typical representation for this research direction; fractal image compression has become practical since then. Currently, fractal image compression has got extensive attention by the research community because of its novel ideas, high compression ratio and resolution independent characteristics[6], and it is recognized as one of the most three promising next generation image compression technology[7], besides, fractal compression can also be applied to audio and video compression[8 - 10].

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[11-12] or color images. Although fractal based image compression has many advantages, but in the process of fractal encoding, it needs a lot of computing, and this results in a long encoding time. Currently, fractal compression's research focuses on how to shorten the encoding time[13-20]. Compared with traditional image segmentation algorithm, we proposed a new hybrid fractal image compression based on graph theory and isosceles triangle segmentation. And experimental results show that, compared with traditional approaches, our proposed method reduce the fractal encoding time on the premise of guaranteeing the decoded image's quality.

The rest of the paper is organized as follows: Section 2 describes some of the recent related works, Section 3 describes the Mathematical background, and the proposed methodology is described in section 4. Experimental results of the proposed methodology are explained and discussed in section 5. Finally, conclusion is provided in section 6.

2. RELATED WORKS

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

Shiping Zhu,Liang Yu,Kamel Bellouata[13] proposed an adaptive threshold quad tree fractal compression approach, compared with fixed square segmentation compression approach, it has a greater flexibility. It divides the image block which has high details into smaller sub-block, and for the image block with low details, divides them into larger sub-block. By doing so, it can reduce the number of image blocks which need to match and shorten the encoding time.

Jinjiang Li, Da Yuan, Qingsong Xie, Caiming Zhang[14] proposed a method which applies ant algorithm to fractal compression, and implements the automatic classification for image block. When matching, it can use heuristic information and substitute global search with local research. By the comparison of average brightness between images block and sub image block.

B.Hurtgen, C.Stiler[15], divides sub-block into 15 categories, further, by sorting the image block's variance, every category can be classified into 24 sub-classes. So, total image blocks can be divided into 360 categories, when matching, we search in the same category.

Pedro F. Felzenszwalb and Daniel P.Huttenlocher[21], proposed a fast image segmentation algorithm, by comparing the characteristic difference between regions and interior domains, it can judge whether there is a boundary between the two regions. Compared with traditional image segmentation algorithm, this algorithm can obtain images' global visual features.

Sofia Douda, Abdallah Bagri, Amer Abdelhakim El Imrani[22] 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, Nisar Ahmed and Shaik Mahaboob Basha[23] 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[24] 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[25] 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[26] 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[27] 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[28] 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[29] proposed the method in which particle swarm optimization methods 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.

Deepthi Narayan, Srikanta Murthy K., and G. Hemantha Kumar[30], compared the existing segmentation approaches in terms of image features, similarity measurement & segmentation algorithm in order to improve the segmentation quality. They proposed the use of weighted Euclidean distance in order to compute the edge weight for RGB color images and also modified the segmentation algorithm slightly so that more prominent edges are selected.

Hai Wang[31], proposed based on adaptive threshold quad tree fractal compression approach, we consider image's semantic characteristic, and apply graph-based image segmentation to fractal image compression, separating the initial image into many logic areas, then encoding each area with fractal image compression method.

Zhi-liang, ZHAO Yu-li, YU Hai[32], proposed an efficient fractal image compression based on pixel distribution and triangular segmentation. The fractal image compression algorithm requires a great deal of time to complete the encoding process. In order to solve this problem, an efficient fractal image compression based on pixel distribution and triangular segmentation they proposed in this paper. Exploiting the characteristics of centroid uniqueness and centroid position invariance in discrete particular system, the matching between range blocks and domain blocks was implemented. In addition, dividing original image into isosceles triangle segmentation could reduce the number of domain blocks, and raise the efficiency of fractal coding.

Yuli Zhao, Zhi-liang Zhu, Hai Yu[33], proposed a new fractal color image coding algorithm based on correlation between RGB components and isosceles triangle segmentation is presented. Isosceles triangle segmentation instead of square segmentation is utilized to provide improved efficiency.

3. MATHEMATICAL BACKGROUND

3.1. Self-Similarity

Subsets of fractals when magnified appear similar or identical to the original fractal and to other subsets. This property is called self-similarity and it makes fractals independent of scale and scaling. Thus there is no characteristic size associated with a fractal. A typical image does not contain the type of self-similarity found in fractals. But, it contains a different sort of self-similarity. The figure 1 shows the regions of Lena that are self-similar at different scales. A portion of her shoulder overlaps a smaller region that is almost identical, and a portion of the reflection of the hat in the mirror is similar to a smaller part of her hat.

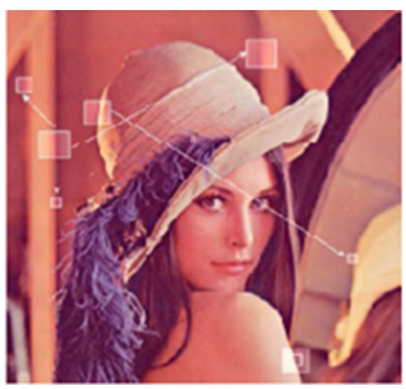

Figure 1: Self Similarity in Lena

The difference here is that the entire image is not self-similar, but parts of the image are self-similar with properly transformed parts of itself. Most naturally occurring images contain this type of self-similarity. It is this restricted redundancy that fractal image compression schemes attempt to eliminate.

3.2. Iterated Function System and Attractor

According to great mathematician Cauchy "A convergent sequence converges to a unique value."A sequence defined by $f(n) = n/2$. It is obvious that these sequences will converge to zero whatever may be the initial value of n. On the same lines it can be told that a contractive mapping converges to a unique fixed point irrespective of the shape and size of initial image fed to be contracted.

If such mappings are applied to an image then the final image that we get is called Attractor. Like the unique value of a sequence, the shape of attractor is independent of the shape of initial image but is dependent upon their position and orientation.

It reduces the initial image by half.

It places the three copies of the image in a triangular configuration.

There is a provision of giving the output of one copy operation as the input for the second copy operation *i.e*. machine can function in an iterative fashion. Figure 2 show the contracting transformations by iterated function system.

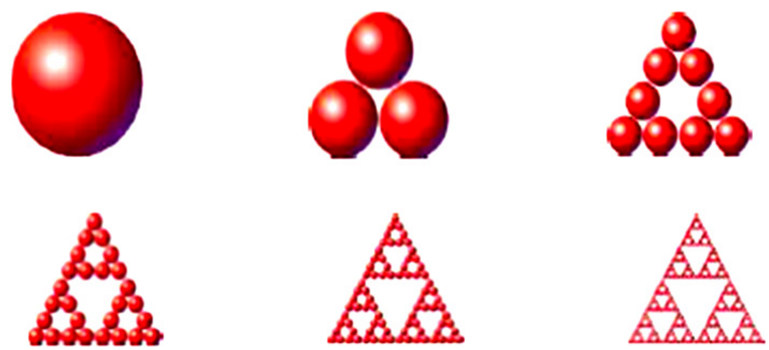

Figure 2: Contracting transformations by Iterated Function System

An Iterated Function System (IFS) is a collection of contractive mappings . Let IFS be denoted by W and the collection of transforms by w_1, w_2, w_3.......................,w_n. (1)

$$W(X) = w_1 (X) \cup w_2 (X) \cup w_3(X).......\cup w_n(X) \quad (2)$$

Where X is the grayness level of the image upon which the transform is applied.

If w's are contractive in plane then W will be contractive in space. Let X_w be an attractor resulted by the repeated applications of W on an initial image, then after applying further transformation it will converge to X_w only.

3.3. Partitioned Iterated Function System (PIFS)

Fractal image compression uses a special type of IFS called a partitioned iterated function system (PIFS). In figure 3 shows the Partitioned Iterated Function System. A PIFS consists of a complete metric space X, a collection of sub domains $D_i \subset X$, i = 1, 2,.....n, and a collection of contractive mappings

$$\tilde{w}: D_i \rightarrow X, \quad i = 1,2, ...n. \quad (3)$$

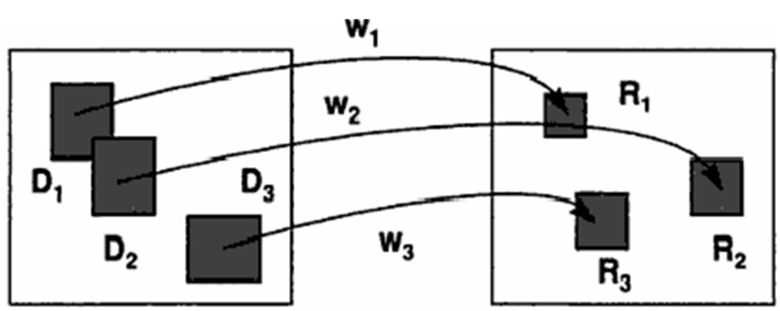

Figure 3: A Partitioned Iterated Function System

3.4. Contraction Mapping

A transformation $f : X \rightarrow X$ on a metric space (X, *d*) is called a contraction mapping if there is a constant s, $0 \leq s \leq 1$, such that

$$(f(x_1), f(x_2)) \quad \leq \quad sd(x_1, x_2) \tag{4}$$

for all x_1, x_2, ….., X. The constant s is called the contractivity factor for *f*. Figure 4 shows an example of a contraction mapping *f* acting on a set of points in R^2.

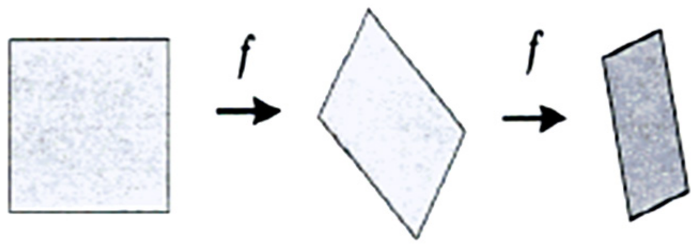

Figure 4: A contraction mapping *f* acting on a set of points in R^2

The above figure depicts a transformation that is applied more than once. That is, once $f(x)$ is computed for a point x, the value $f(f(x))$ is computed by applying f to the result. The transformations obtained by applying f over and over again in this way are called iterates off.

Let $f : X \rightarrow X$ be a contractive mapping on a complete metric space(X, *d*).Then f possesses exactly one fixed point

X_f € X, and for any x € X, the sequence $\{f^{on}(x) : n = 1,2,,....\}$ converges to x_f, that is,

$$\lim_{n \to \infty} f^{on}(X) \quad = \quad x_f \text{, for all } x \; \varepsilon \; X. \tag{5}$$

If W is a contraction on F(image space),then according to the theorem W has a unique fixed point f_w € F satisfying

$$W(f_w) \quad = \quad f_w \tag{6}$$

Iteratively applying W to any starting image f_0 will recover the fixed point f_w.

3.5. The Collage Theorem

Barnsley (1993) has derived a special form of the contraction mapping theorem applied to IFS's on H(X), *h*) called the Collage Theorem. For a grayscale image f, we can find a contractive transformation W such that

$$d_2(f, W(f)) \quad \leq \quad \varepsilon,$$

then

$$d_2(f, f_w) \quad \leq \quad \frac{\varepsilon}{1 - \varepsilon} \tag{7}$$

Where s is the contractivity factor of W, f_w is the fixed point and ε be > 0. This means we can start with any image g and iterate W on g to get an image that is close to f.

$$W^{on}(g) \quad \rightarrow \quad f_w \approx f. \tag{8}$$

The Collage Theorem brings us one step closer to fractal image encoding. Decoding consists of iterating W on any starting image *g* to reform *g* to recover f_w.

3.6. Affine Transformation

The transformations used by Barnsley for his IFS's are the affine transformations. An affine transformation T: $R^2 \rightarrow R^2$ is a transformation of the form.

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

$$W\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} e \\ f \end{bmatrix} \quad (9)$$

Where *a, b, c, d, e, f* Affine transformations can accomplish rotation, translation and contraction. Let $\tilde{w}_i(x, y)$ be an affine transformation on $I^2 \rightarrow I^2$, then

$$\tilde{w}_i(x, y) = A_i\begin{pmatrix} x \\ - \\ y \end{pmatrix} + b_i \quad (10)$$

for some 2 * 2 matrix A_I and 2 * 1 vector b_i

Let $D_i \rightarrow I^2$ be some sub domain of the unit square I^2, and let R_i be the range of $\tilde{w}_i$ operating on D_i, that is $\tilde{w}_i(D_i) = R_i$.

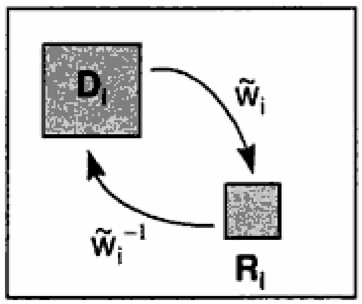

Figure 5: Spatial affine transformation and its inverse

We can define w_i : F → F operating on images $f(x,y)$ by

$W_i(f)(x, y) = s_i f(\ \ (x, y)) + o_i$ provided $\tilde{w}_i$ is invertible and (x, y) € R_i, s_i controls the contrast and o_i controls the brightness. A spatial affine transformation and its inverse system are shown in figure 5.

3.7. Basic Fractal Image Encoding Approach

The basic ideal of fractal image compression is as following: divide initial image into small image blocks with non-overlapping (Rang block, R block for short). For each R block, find an image block (Domain block, D block for short) which is the most similar to current R block under a certain transform, that is, use some image blocks' transformation to splice the initial image, and make the spliced image similar to the original image as much as possible[31].

Suppose the image which to be encoded is 256*256 size with 256 gray shade and R block is a 8*8 size block, so the whole image can be divided into 1024 R blocks, all the R blocks composite R pool. Suppose D block is four times larger as R block, so the number of D block is (256-2*8 + 1)2 = 58081, all the D blocks composite D pool. For each R block, find a D block from D pool which is the most similar to it.

The concrete steps are as following:

1. Shrink D block to the size of R block, marked D' block, and the specific shrinking method is four neighborhoods regional method
2. Transpose, turn D' block. Specifically, we can choose eight affine transformations which proposed by Jacquin, and the corresponding transformation matrix.
3. Compare each R block with all D' blocks in D pool, and obtain the most similar D' block. The similarity can be measured with average variance MSE, if we see each R block and D block as vectors.
4. For each R block, record the corresponding compression affine transformation W. All compression affine transformations constitute the whole image's fractal code.

The whole above process is described in figure 6.

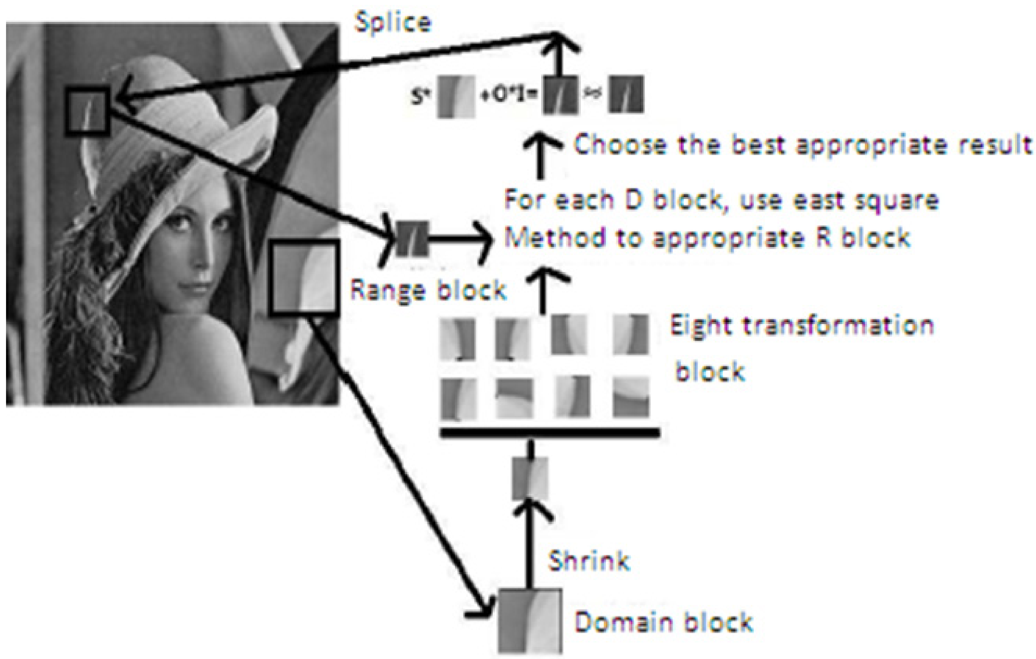

Figure 6: Show the schematic diagram of the fractal encoding process [31]

3.8. Basic Fractal Image Decoding Approach

The fractal decoding process is relatively simple, that is, for all R blocks, act the corresponding affine transformation on any one initial image, iterate for several times(commonly ten times) , according to fixed point theorem, this iteration process would converge to a fixed attractor, and this attractor is the decoding image. Adaptive threshold quad tree fractal compression approach is the same as the basic fractal image encoding method, the main difference is, when doing image match, we don't find the global best-match block in D pool, and instead, we use an adaptive threshold to judge whether the current R block matches D block, if the two's match error MSE is smaller than threshold, we can consider that current D block matches R block, otherwise, the two are not matching.

3.9. Some Discussion on Typical Fractal Compression Approaches

Basic fractal image compression approaches do not consider the image's content, and divide images into regular square image block. When image block has a larger size, it can affect the recovered image's visual effect, and reduce PSNR. But when image block has a smaller size, it can increase D blocks' amount, thus increase the encoding time and reduce compression ratio. Inspired by this, it is very natural to think that use some statistic information of image block (such as gray average, variance, fractal dimension) to speed the matching process to reduce time complexity.

Based on this idea, some typical approaches are proposed in reference[13-15]. But there exist some disadvantages in above three approaches: firstly, they only consider some statistic information of image block, and neglect the image block's semantics and the semantic relationship between block and block. For example, the image block from the image's background has little probability of matching the image block from image's main content; secondly, once an R block can't find the best-match D block in its own search space, it can't expand its search to his adjacent search space; therefore, the decoding image has poor quality.

4. PROPOSED METHOD

Reference[21] proposed a graph-based image segmentation algorithm, and this algorithm overcomes the shortcomings of traditional image segmentation algorithm, i.e., excessive segmentation over image. At the same time, this algorithm can adjust its segmentation scale according to different images, thus, it can achieve better content-based image segmentation. In the fractal encoding process, most blocks which come from different image's contents have different textures, so blocks come from different image contents can't be the best-match block for each other in most cases, but for the blocks come from the same image content, they can easily match each other well. An example is shown in figure 7.

From figure 2, it can be seen that, blocks come from region 1 can easily find its best-match block in region 1, the situation for blocks come from region 3 is the same as that in region 1, but blocks come from region 1 can hardly find its best-match block in region 3.

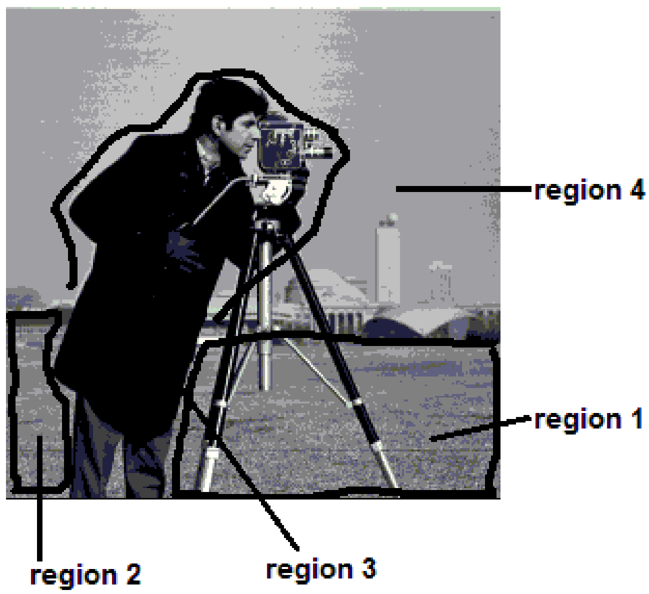

Figure 7: Schematic diagram of image content segmentation

Inspired by this fact, Hai Wang[31] combined graph-based image segmentation algorithm and adaptive threshold quad tree fractal compression approach together, and proposed a new fractal image compression approach: used graph-based image segmentation approach to segment image at an appropriate segmentation scale, separate the original image into many different logic areas according to image content, and construct the corresponding search space for each logic area. Then encode each logic area using adaptive threshold quad tree approach. When the encoding for all logic areas in the whole image is finished, the whole image's encoding is completed.

But after[31] separate the initial image into several different logic areas, it is difficult to encode the irregular shape with fractal compression approach; in this paper they adopted the following method:

After the initial image is separated into several different logic areas, they can set a same label for all pixels located in the same logic area, by doing so; they indicate that all those pixels are in the same logic area. When encoding, they can also set a label for each image block, and the label for image block is the equal to the labels of pixels located in the block, if there are several different pixels with different labels in one block, they can set the block's label as anyone of them, all the image blocks with the same label constitute a search space. As shown in fig 8, image block B can be either partitioned into the search space which A located in or partitioned into the search space which C located in.

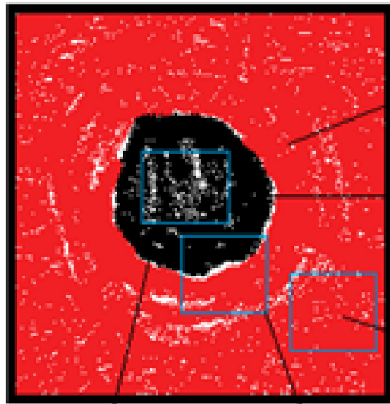

Figure 8: Schematic diagram of setting image block's label

When encoding with adaptive threshold quad tree approach, for each R block, they don't need to find its best-match block within the entire image, but find it within the local search space which R block located in, thus, used local optimum to replace global optimum.

They obtained valid shorter encoding time on the premise of guaranteeing the recovered image quality. Compared with compression approaches they proposed in reference[13-15], their improved approach has following advantages: firstly, divide the image blocks into several different search space according to the image content, and overcomes the disadvantage that searching within the global search space in reference[14]; secondly, adaptively segment the image at an appropriate segmentation scale according to the image content, then divide all image blocks into several classes, and this overcomes the disadvantage that dividing all image blocks into a fixed kinds of categories in reference[15], for the image blocks with rich texture, their improved approach can speed up the encoding process more obviously; thirdly, for the classifications proposed in reference[13, 15], those image blocks come from the adjacent class might have totally different textures, so once they can't find their best-match block in the search space which they belonged to, they couldn't expand their search into the adjacent class thus the recovered image has poor quality. But in paper[31], by the processing method of image block which is at the junction of different image contents, the image block can be divided into several different classes, once an R block can't find its best-match D block; it can expand its search to its adjacent class, so the decoded image has a higher quality.

Based on adaptive threshold quad tree fractal compression approach[31], they considered image's semantic characteristic, and apply graph-based image segmentation to fractal image compression, separating the initial image into many logic areas, then encoding each area with fractal image compression method. Their proposed approach can improve the recovered image's quality and compression ratio significantly, but encoding time lowering was very nominal.

To reduce the encoding time and increase the compression ratio and PSNR without degrading the image quality we proposed a new method, fractal image compression based on graph theory and isosceles triangle segmentation. Our proposed method has three steps as, first: input image segmentation based on graph theory[31], achieved better content-based image segmentation, in this technique we find the different region in figure 8, separate the original image into many different logic areas according to image content, and construct the corresponding search space for each logic area. Second: segmented image partitioned based on isosceles triangle segmentation.

In this isosceles triangle segmentation the domain blocks and range blocks are divided into isosceles triangles rather than rectangles figure 9 shows the range bocks, domain bock and range and domain bock segmentation approach[33]. This segmentation method is in favor of approaching the diagonal edge and using the self-similar relationship of the image which helps reconstruct the edge information of original image.

From figure 9 (*a*), hypotenuse length of non-overlapped range blocks $R_1, R_2, \ldots, R_n$ is 4, and $R_1, R_2, \ldots, R_n$ cover the whole image.

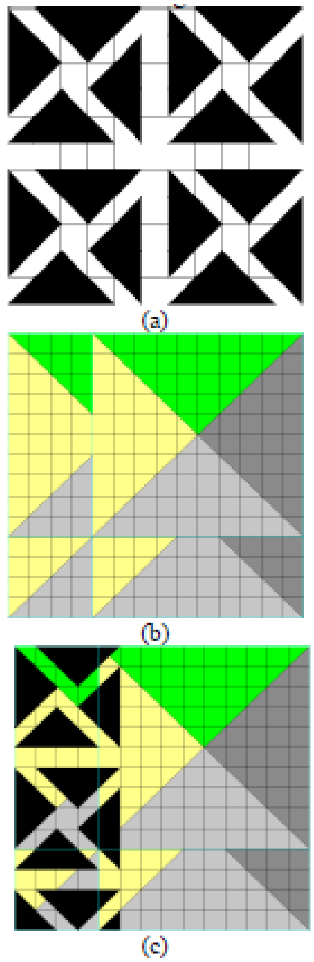

Figure 9: (*a*) is range block segmentation, (*b*) is domain block segmentation, (*c*) is segmentation scheme of range blocks and domain blocks [33]

Figure 9 (*b*) and figure 9 (*c*) are the overlapped domain block segmentations with hypotenuse length of 10. Step length of domain blocks is L. In other words, number of pixels between two adjacent domain blocks is L. The pixel number of domain blocks is four times more than that of range blocks. The step length of domain block would influence the efficiency and image quality of fractal coding directly. The shorter the step length, the more matching times between domain blocks and range blocks is needed. However, over-length step may result in mismatching between blocks leading to the reducing of the image quality.

For finding the best matching domain block, every domain block needs to do shrink transformation, isometric transformation, brightness transformation and brightness excursion as shown in figure 10. The most similar domain block of current range block is found after comparing range blocks with transformed domain blocks. Then record the corresponding coefficient of affine transformation. It is the coefficients which construct fractal code of current range block.

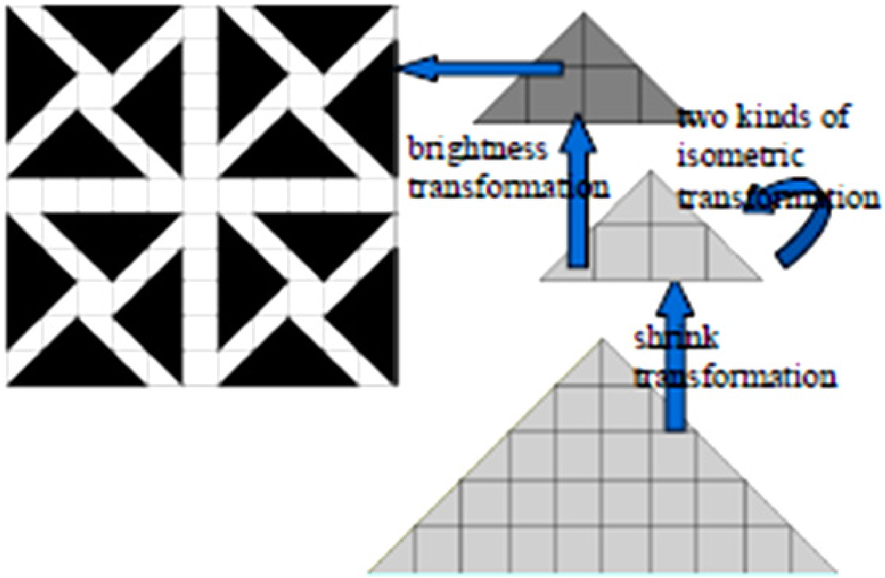

Figure 10: Matching process between domain and range blocks [33]

In third used fractal based image encoding for getting the higher compression ratio and PSNR and decreasing the encoding time based on self- similarity. Figure 11 shows the overall encoding process.

Proposed algorithms encoding steps as following:

Step 1: Segment the initial image with graph-based image segmentation algorithm, and set label for all pixels;

Step2 : Divide initial image into different R blocks with non-overlapping, each R block is 8*8 size, and set label for each R block, classify R block based on isosceles triangle segmentation rather than rectangles;

Step 3: Divide image into different D blocks allowing some overlapping, the size is four times as R block, and set label for each D block, classify D block based on isosceles triangle segmentation rather than rectangles;

Step 4: Shrink D block to R block's size;

Step 5: Calculate D block's variance, and for D blocks in the same class, sort them according to their variance;

Step 6: Choose one R block; calculate its variance and matching threshold;

Step 7: In the search space where R block located in, find a D block which has the closest variance to current R block;

Step 8: Define a searching window; the ratio between the number of blocks which located in the searching window and the number of total blocks is W%, and half of blocks in the searching window have a larger variance than the D block mentioned in step 7, others have a smaller variance.

Step 9: In the searching window, after affine transformation and gray migration, find the best-match D block;

Step 10: Calculate the matching error between best-match D block and R block, if the error is larger than threshold 'bias', divide R block into four sub-blocks, add them to the corresponding search space according to their labels, and slide certain steps, divide some new D blocks, add them to corresponding search space according to their labels too. If the error is smaller than threshold bias, storage affine transformation parameters; now, calculate the variance of range and domain blocks by the equation below. The variance of block I is defined as,

$$\text{Var(I)} = \sqrt{\left\{\frac{1}{n*n}\left(\sum_{i=1}^{n*n} X_i^2\right) - \left(\frac{1}{n*n}\left(\sum_{i=1}^{n*n} X_i\right)\right)^2\right\}}$$

Where n is the size of the block and X_i is the pixel value of the range blocks.

Step 11: For all R blocks, repeat Step 6-10;

Step 12: Write out the compressed data in the form of a local IFS code;

Step 13: Apply a fractal compression algorithm to obtain a compressed IFS code.

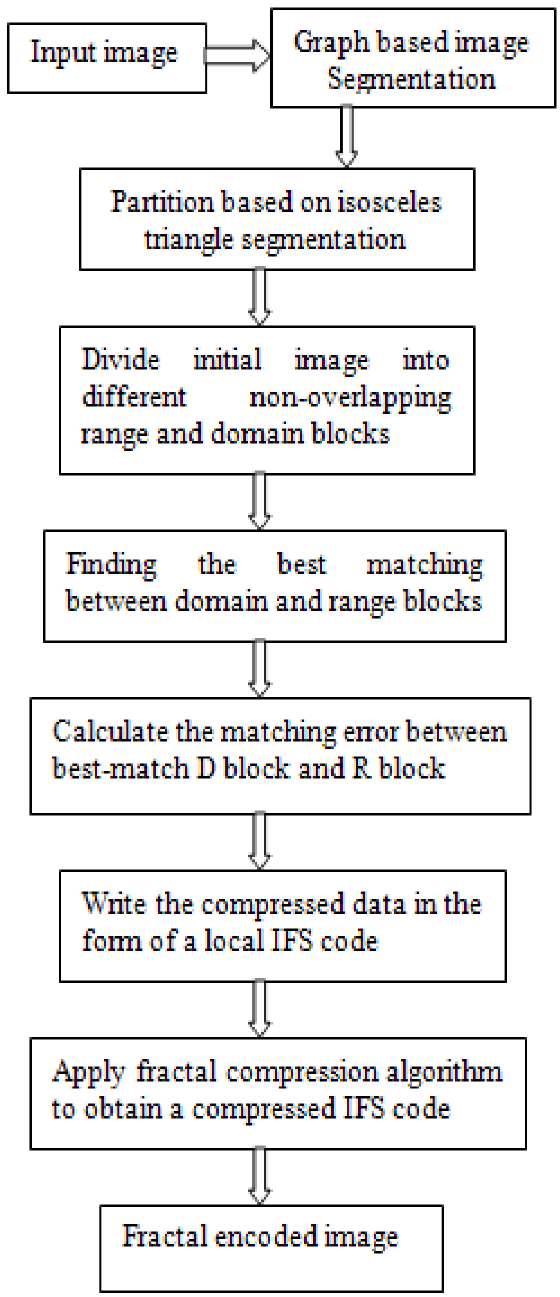

Figure 11: Fractal based encoding process

5. IMPLEMENTATION, RESULTS AND DISCUSSIONS

In this section the method is implemented, tested and the simulation results are verified. The experiments are carried out in the Pentium IV (3.06GHZ, RMA 512MB) system under Windows XP operating system. We implement our proposed approach using Matlab 13b. Typical results with six color images (namely, A street scene, a baseball scene, an indoor scene, Lena image, Leopard image and Tower image) of size 256 × 256 × 3 are presented here.

Image compression is based on fractal coding is lossy compression method. The quality of image is measured by Peak Signal to Noise Ratio (PSNR).

$$\text{PSNR} = 10\log \frac{255^2}{\left(\frac{1}{\text{M X N}}\right)\sum_{i=1}^{M}\sum_{j=1}^{N}(x_{i,j} - \grave{x}_{i,j})^2} \tag{11}$$

Where, M X N is the size of the composite image, and $x_{i,j}$ and $\grave{x}_{i,j}$ are values of the original image and reconstructed image at position (*i, j*). Naturally higher PSNR value indicates much better image quality. And execution time of the program to calculated using tie-toe code of Matlab toolbox.

Compression ratio (CR) is a measure of the reduction of the detailed coefficient of the data. In the process of image compression, it is important to know how much detailed (important) coefficient one can discard from the input data in order to sanctuary critical information of the original data. Compression ratio can be expressed as:

$$\text{CR} = \frac{\text{Decompressed image data size}}{\text{Original image data size}} \tag{12}$$

Where CR = Compression Ratio.

The quantization table (Q) and the scaling factor (SF) are the main controlling parameters of the compression ratio. Each element of the transformed data is divided by corresponding element in the quantization table (Q_{matrix}) and rounded to the nearest integer value by using round function in MATLAB. This process makes some of the coefficients to be zero which can be discarded[34].

In order to achieve higher compression ratio, the quantizer output is then divided by some scalar constant (SF) and rounded to nearest integer value. This process yields more zero coefficients which can be discarded during compression[35]. The Compression ratio (CR) can be varied to get different image quality. The more the details coefficients are discarded, the higher the CR can be achieved. Higher compression ratio means lower reconstruction quality of the image.

Figure 12 (*a*), (*b*), (*c*), (*d*), (*e*) and (*f*) show the original color images of A street scene, a baseball scene, an indoor scene, Lena image, Tower image and Leopard image respectively. Figure 12 (*g*), (*h*), (*h*), (*i*), (*j*), (*k*) and (*l*) show the segmented images. In figure 12 (*m*), (*n*), (*o*), (*p*), (*q*) and (*r*) show the decompressed images in our proposed method.

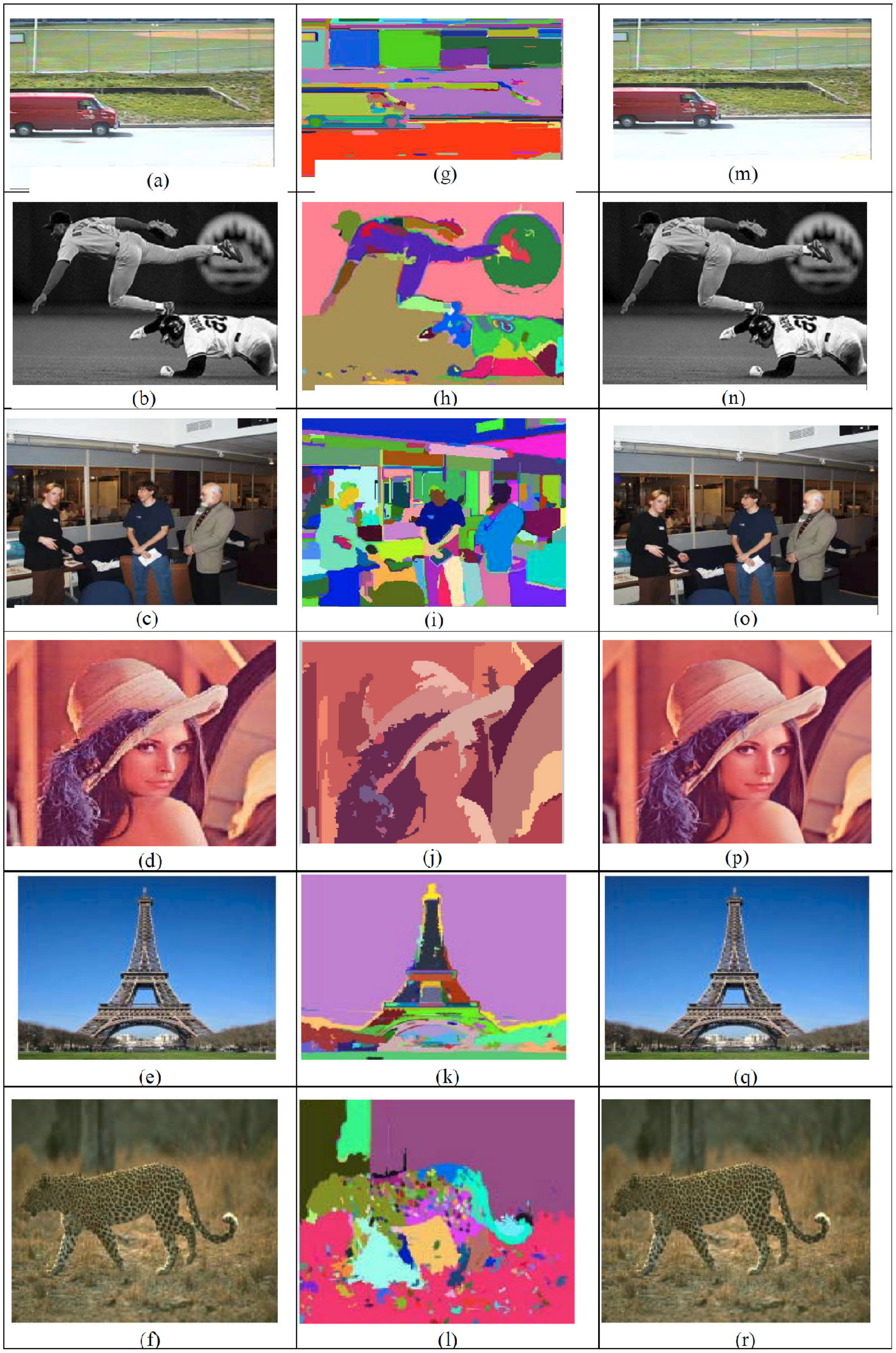

Figure 12: (*a*), (*b*), (*c*), (*d*), (*e*) and (*f*) shows the original images of A street scene, a baseball scene, an indoor scene, Lena image, Leopard image and Tower image and (*g*), (*h*), (*i*), (*j*), (*k*), and (*l*) show the segmented images and (*m*), (*n*), (*o*), (*p*), (*q*), (*r*) show the decoded images

In the experiment, it also be implement the approaches proposed in reference[13-15, 31, 33] under the same experimental environment, and run every compression approach 30 times, record their encoding time, recovered images PSNR, compression ratio every time, then calculate the average value for those 30 groups' data, we get those six compression approaches. Table 1 shows the comparison between references[13-15, 31, 33] and proposed method with respects to PSNR (dB), encoding time (sec) and compression ratio (CR).

Table 1
Comparison Between B.Hurtgen [15], Shiping Zhu [13], Jinjiang Li [14], Yuli Zhao [33], Hai Wang [31] and Proposed Method with respect to PSNR, Encoding Time and Compression Ratio

Test images	*B. Hurtgen [15]*			*Shipping Zhu[13]*			*Jinjian Li [14]*			*Yuli Zhao [33]*			*Hai Wang [31]*			*Proposed method*		
	PSNR (dB)	*Time (sec)*	*Compression ratio*	*PSNR (dB)*	*Time (sec)*	*Compression ratio*	*PSNR (dB)*	*Time (sec)*	*Compression ratio*	*PSNR (dB)*	*Time (sec)*	*Compression ratio*	*PSNR (dB)*	*Time (sec)*	*Compression ratio*	*PSNR (dB)*	*Time (sec)*	*Compression ratio*
A street scene	30.9	2.2	8.9	32.8	3.4	9.0	32.6	3.2	9.2	35.16	42	4.88	34.9	2.3	12.2	37.05	2.1	27.9
A baseball scene	31.01	2.4	8.8	32.6	3.7	8.9	32.4	3.1	9.0	35.12	42	4.88	34.9	2.4	12.3	39.01	2.0	29.7
An indoor scene	30.8	2.3	8.7	32.4	3.7	9.01	32.5	3.2	9.4	35.19	43	4.84	34.5	2.4	12.01	39.01	2.0	33.12
Lena	31.01	2.3	8.8	31.8	3.3	9.1	32.8	3.2	9.3	35.11	41	4.89	34.8	2.5	11.7	38.11	2.1	31.02
Tower image	31.02	2.1	8.9	32.9	3.3	9.3	32.7	3.4	9.5	35.18	40	5.03	34.9	2.3	12.3	37.9	2.2	30.11
Leopard image	30.8	2.1	8.8	32.7	3.4	9.0	31.6	3.3	9.1	35.19	42	4.88	34.9	2.3	12.1	39.43	2.0	34.2

Table 1 represents some compared data on PSNR, coding time cost, compression ratio using the method proposed in this paper and B.Hurtgen[15], Shiping Zhu[13], Jinjiang Li[14], Yuli Zhao[33] and Hai Wang[31]. From table 1, it has been shown that: compared with other approaches, proposed compression approach can reduce the encoding time greatly, at the same time; there are also marginal increases in recovered image's quality, PSNR and compression ratio. Isosceles Triangle Segmentation based range block and domain blocks need less times of similarity matching, and the matching effect at edge is much better than square blocks. As a result, method proposed in this paper has better image quality and improved time efficiency compared with other methods[13-15, 31, 33] .

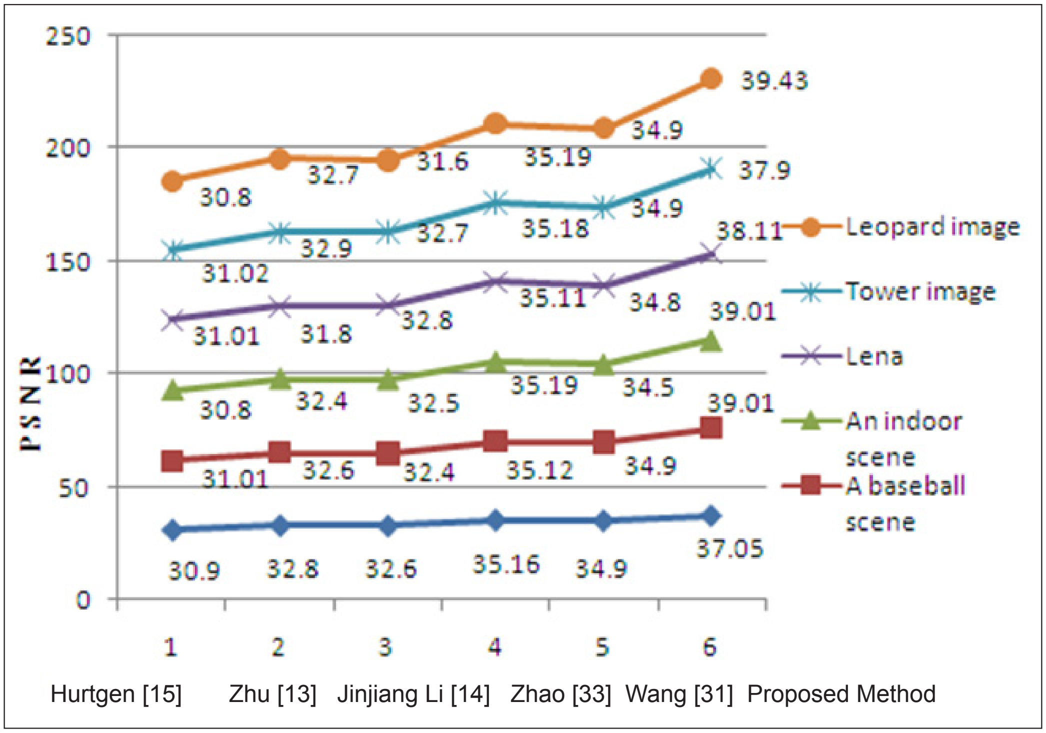

Figure 13: Comparison of PSNR between B.Hurtgen [15], Shiping Zhu [13], Jinjiang Li [14], Yuli Zhao [33], Hai Wang [31] and Proposed method

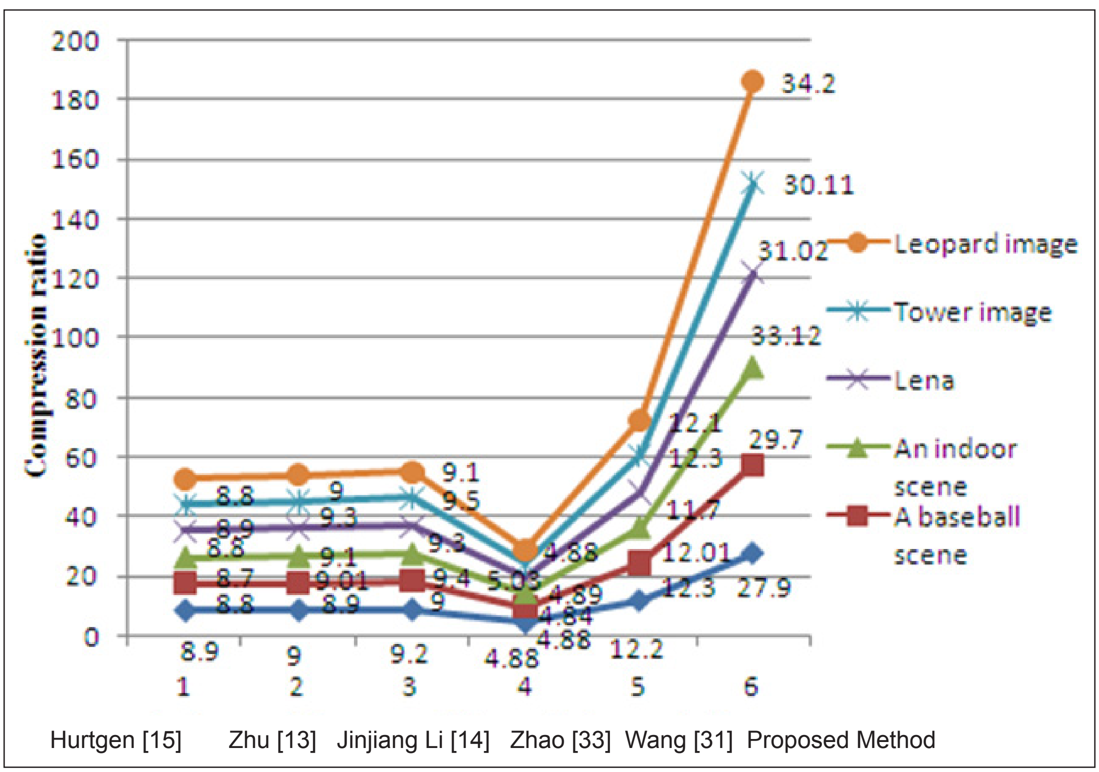

Figure 14: Comparison of compression ratio between B.Hurtgen [15], Shiping Zhu [13], Jinjiang Li [14], Yuli Zhao [33], Hai Wang [31] and proposed method

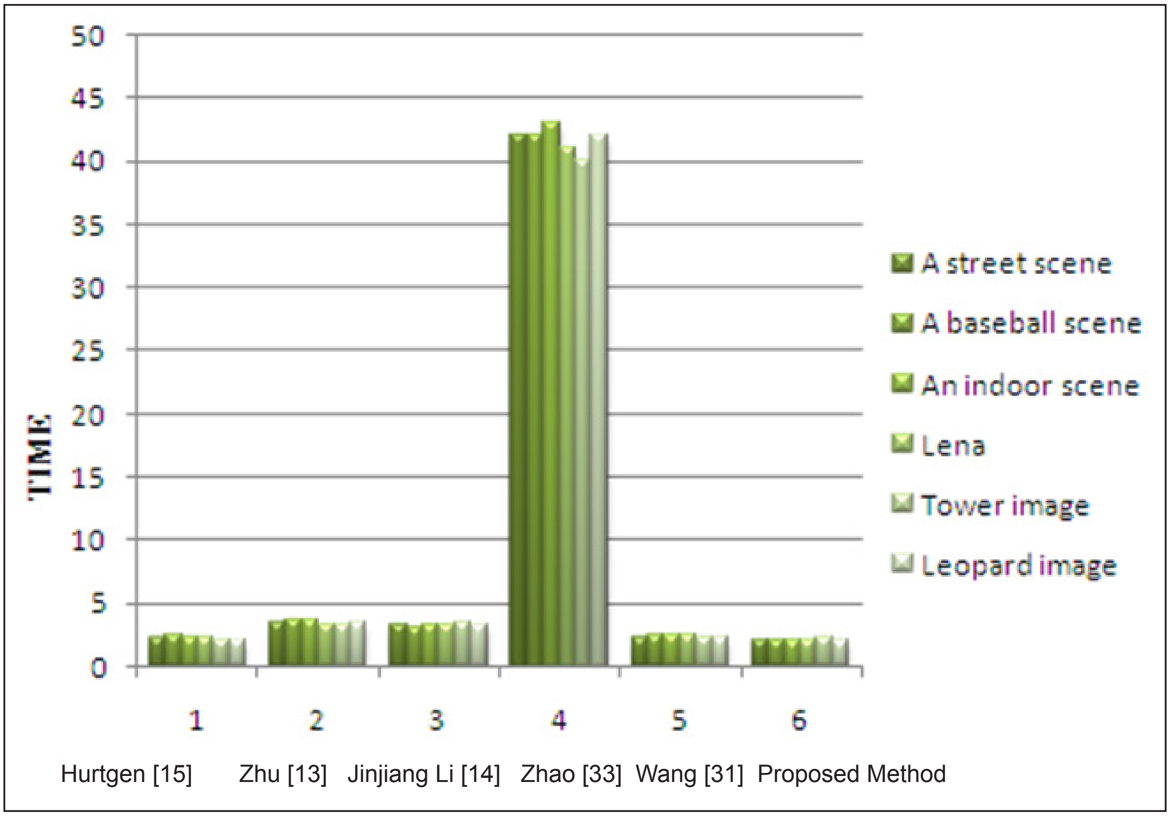

Figure 15: Comparison of TIME between B.Hurtgen [15], Shiping Zhu [13], Jinjiang Li [14], Yuli Zhao [33], Hai Wang [31] and proposed method.

In figure 13 shows the comparison of PSNR between[13-15, 31, 33] and proposed method respectively. From the comparison graph it has been noticed that value of PSNR increased in proposed method compared to others approaches. Figure 14 shows the comparison graph of encoding time and it has been seen that in proposed approached need less encoding time compared to others methods. And lastly in figure 15 shows the compression ratio is increased in proposed methods.

6. CONCLUSIONS

This paper briefly introduces the basic theory of image fractal compression, and discusses some typical fractal compression techniques. Based on Isosceles triangle geometry fractal compression approach and applying graph-based image segmentation to fractal image compression, separating the initial image into many logic areas, then encoding each area with fractal image compression method, better of merits have been achieved. Proposed approach can improve the recovered image quality and compression ratio significantly.

REFERENCES

[1] Radhakrishnan S. and Subramaniam J., "Novel Image Compression using Multi-Wavelets with SPECK Algorithm," *International Arab Journal of Information Technology*, vol. 5, no. 1, pp. 45- 51, 2008.

[2] Palanisamy G. and Samukutti A., "Medical Image Compression using a Novel Embedded Set Partitioning Significant and Zero Block Coding," *International Arab Journal of Information Technology*, vol. 5, no. 2, pp. 132-139, 2008.

[3] M.F. Barnsley, Fractal everywhere [M], New York: Academic Press, 1988.

[4] A.E. Jaquin, Image coding based on a fractal theory of iterated contractive image transformations [J], IEEE Transactions on Image Processing, 1(1): 18-30, 1992.

[5] M.F. Barnsley and H.Rising III, Fractals Everywhere,2nd edtion, Boston, MA:Academic Press Professional,1993

[6] B.Wohlberg and G.de Jager,A Review of the Fractal Image Coding Literature,IEEE Transactions on Image Processing,1999,8(12):234~245.

[7] L.Torres and M.Kunt.Video coding:the second generation approach.Kluwer AcademicPublisher,1996

[8] Hurd,L.P,Gustavus,M.A,Barnsley,M.F.etc.Fractal video compression. Compcon Spring '92. Thirty-Seventh IEEE Computer Society International Conference, Digest of Papers.

[9] Brijmohan, Yarish .Low bit-rate video coding using fractal compression of wavelet subtrees. IEEE AFRICON Conference, v 1, p 39-44, 2004

[10] Cochran, W.O,Hart, J.C,Flynn. P.J. Fractal volume compression. IEEE Transactions on Visualization and Computer Graphics, v 2, n 4, p 313-322, Dec 1996

[11] Y.Fisher, Fractal Image compression [J], Fractals, 2(3): 321-329, 1994.

[12] H.L. Zhao, Z. Liang, N. Y .Soma, Fractal color image compression[C], XIII Brizilian Symposium on Computer Graphics and Image Processing(SIBGRAPI'00), 185-192, 2000.

[13] Shiping Zhu,Liang Yu,Kamel Bellouata.An improved fractal image coding algorithm based on adaptive threshold for quadtree partition. The International Society for Optical Engineering, v 7129, 2008

[14] Jinjiang Li, Da Yuan, Qingsong Xie, Caiming Zhang. Fractal Image Compression by Ant Colony Algorithm. The 9th International Conference for Young Computer Scientists

[15] B.Hurtgen,C.Stiler,Fast hierarchical codebook search for fractal coding of still images[J],Proceedings of EOS/SPIE Visual Communications PACS Medical Applications'93,Berlin,1993:397~408.

[16] L.Thomas,F.Deravi.Region-based fractal image compression using heuristic search.IEEETransactions Image Processing,1995,4(6):823~838.

[17] Davoine F,Antonini M,Chassery J.Barlaud M.Fractal image compression based on delauney triangulation and vector quantization[J],IEEE Transactions Image Processing,1996,5(2):338~346.

[18] Li Wenjing,Li Wangchao.A fast fractal image coding technique[J].Proceedings of ICSP'98:775~778.

[19] Macro Polvere,Michele Nappi.Speed-up in Fractal Image Coding:Comparison of Methods[J].IEEE Transactions on Image Compression 2000,9(6):1002~1009.

[20] Raouf Hamzaoui, Dietmar Saupe, and Michael Hiller. Distortion Minimization with Fast Local Searchfor Fractal Image Compression. Journal of Visual Communication and Image Representation 12, 450–468 (2001)

[21] Pedro F. Felzenszwalb and Daniel P.Huttenlocher . Efficient Graph-Based Image Segmentation. International Journal of Computer Vision, 59(2) September 2004

[22] Sofia Douda, Abdallah Bagri, Amer Abdelhakim El Imrani, "A reduced domain pool based on DCT for a fast fractal image encoding", Electronic Letters on Computer Vision and Image Analysis, 10(1):11-23, 2011

[23] Ruhiat Sultana, Nisar Ahmed and Shaik Mahaboob Basha, "Advanced Fractal Image Coding Based on the Quadtree," Computer Engineering and Intelligent Systems, Vol 2, No.3, ISSN 2222-1719 (Paper) ISSN 2222-2863 (Online).

[24] Gohar Vahdati, Habib Khodadadi, Mahdi Yaghoobi and Mohammad-R. Akbarzadeh-T, "Fractal Image Compression Based on Spatial Correlation and Hybrid Particle Swarm Optimization with Genetic Algorithm," 22nd International Conference on Software Technology and Engineering (ICSTE), 2010.

[25] Kharate G. and Patil V., "Color Image Compression Based on Wavelet Packet Best Tree," International Journal of Computer Science Issues, vol. 7, no. 2, pp. 31- 35, 2010.

[26] D. Venkatasekhar and P. Aruna, "A Fast Fractal Image Compression Using Huffman Coding," Asian Journal of Computer Science and Information Technology, vol. 2, no. 9 pp. 272- 275, 2012.

[27] Khalil M., "Image Compression using New Entropy Coder," International Journal of Computer Theory and Engineering, vol. 2, no. 1, pp. 39-42, 2010.

[28] Vijaya-Prakash A. and Gurumurthy K., “A Novel VLSI Architecture for Digital Image Compression using Discrete Cosine Transform and Quantization,” International Journal of Computer Science and Network Security, vol. 10, no. 9, pp. 175-182, 2010.

[29] Yih-Lon Lin and Wen-Lin Chen, “Fast Search Strategies for Fractal Image Compression,” Journal of Information Science and Engineering, 28, 17-30, 2012.

[30] Deepthi Narayan, Srikanta Murthy K., and G. Hemantha Kumar, Image Segmentation Based on Graph Theoretical Approach to Improve the Quality of Image Segmentation, International Journal of Computer, Electrical, Automation, Control and Information Engineering Vol:2, No:6, pp.1803-1806, 2008.

[31] Hai Wang, Fast Image Fractal Compression with Graph-Based Image Segmentation Algorithm, International Journal of Graphics Vol. 1, No.1, pp.19-28, November, 2010.

[32] Z.L. Zhu, Y.L. Zhao, H. Yu, Efficient fractal image compression based on pixels distribution and triangular segmentation, *journal of computer applications*, (2): 337- 340, 2010.

[33] Yuli Zhao, Zhiliang Zhu, Hai Yu, Fractal Color Image Coding Based on Isosceles Triangle Segmentation, International Workshop on Chaos-Fractal Theory and its Applications 2010

[34] Rao, K.R. and Yip, P., ―Discrete Cosine Transform‖ ,Academic Press, New York, 1990

[35] Z. Wang, A. C. Bovik, H. R. Sheikh and E. P. Simoncelli, Image quality assessment: From error visibility to structural similarity, IEEE Trans. on Image Processing, vol. 13, no. 4, pp. 600-612, Apr. 2004.