A Novel Study of Image Compression Using Error Based Technique

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Abstract— A literature survey was done to study different techniques of Image compression, performance improving techniques. Fractal image compression is advantageous technique but leads to complexity which is overcome by error based technique. We obtained self similarity in image by partition a given image into non overlapping, called range blocks and form a domain pool containing all of possible non overlapped blocks called domain blocks. We have proposed a method to reduce the complexity of the image perform range/domain comparisons with respect to a preset block by using binary search tree.

Keywords— Fractal image compression, classification, feature vector, approximation error, range block , domain block, present block.

I.   INTRODUCTION

Digital image compression technique boardly classified in two as: still image compression and motion image compression .Still image further classified into lossy compression technique and lossless compression technique .Lossless technique is used to recover original image perfectly. Lossless image is further classified based on encoding techniques as: Huffman coding, Arithmetic decomposition, Lempel Ziv and Run length .Lossy provides high compression ratio. Lossy classified as: Prediction based technique, Frequency based technique, and Importance oriented technique and Hybrid technique.

Fractal image compression is a lossy compression technique developed by Barnsley and Jacquin, in which an image is compressed by storing it as a transformation. The transformation function used in fractal image compression is chosen in such a way that its unique fix point is a close approximation of the input image. Compression occurs because storing the details of the image transform (also known as encoding) takes up much less space than the original image. Decompression (or decoding) involves applying the transform repeatedly to an arbitrary starting image, to arrive at a (fractal) image that is either the original, or one very similar to it.

Fractal theories are totally different from the others. M. Barnsley introduced the fundamental principle of fractal image compression in 1988 [2]. Fractal image compression is also called as fractal image encoding because compressed image is represented by contractive transforms and mathematical functions required for reconstruction of original image. Contractive transform ensures that, the distance between any two points on transformed image will be less then the distance of same points on the original image [2]. These transforms are composed of the union of a number of affline mappings on the entire image, known as iterated function system (IFS) [1], [2]. Barsnley has derived a special form of the Contractive Mapping Transform (CMT) applied to IFS's called the College Theorem [1,2].

Fractal Image compression is a very advantageous technique. It is based on affine contractive transforms and utilizes the existence of self-symmetry in the image. The total process involves four levels of decision making and various techniques are available at every step as shown in fig 1. In author represents a study of most significant advances made at all the four levels in the field of fractal image compression since 1990.
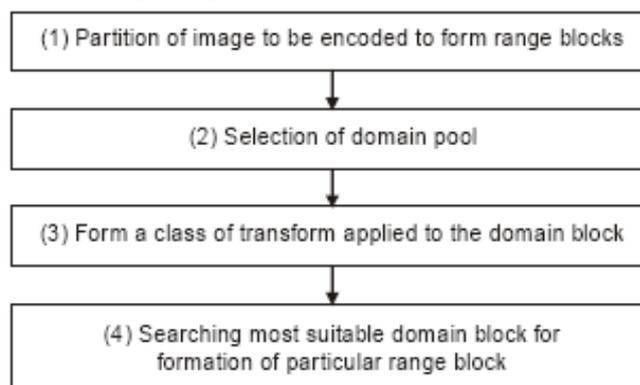

Fig. 1 Decision making levels in fractal encoding.

The rest of the paper is organized as follows. In section II, we discuss different type of partition schemes. Then in section III, we describe features and types of domain-pool selection. The transformations used are explained in section IV, while in section V, suitable domain search is explained. Lastly some speed-up technique discussed in section VI with our error based technique idea to speed-up compression in section VII. Finally conclusions are made in section VIII.

II. FORMATION OF RANGE BLOCK

The basic scheme of fractal image compression is to partition a given image into non overlapping blocks of size rxr, called range blocks Fractal compression system the first decision is to select the type of image partition to form the range blocks formation. A number of varieties of partitions have been investigated. Fixed size square blocks are the simplest possible partition [1]. They are easy to implement by using probabilities. But its performance speed decreases for images with varying levels of different range blocks. The solution of this problem is to use some adaptive scheme for block size so that large blocks are assigned for low detail region and small blocks for significant detail region. Further two approaches are:

A. Quad tree partition
Provides best rate distortion as compared to fix-size block, polygonal and HV-partitions.

B. Horizontal-Vertical (HV)
Although irregular partitions performs much better then the fix-size and Quad-tree partition, but some sort of interpolation is required here because no pixel-to-pixel correspondence between domain and range blocks.

C. Delaunay Triangulation
This partition provides a reduced number of blocks as compared to square partitions and, thus minimizes the number of mappings. The triangulation are computed on a set of points distributed on the image. This technique is fully flexible and efficiently coded, in this way it reduces complexity at a rate between 0.25 to 0.5 depending on the nature of image.

III. SELECTION OF DOMAIN POOL

Domain pool selection is on secondary level. Domain pool selection depends on the type of partition scheme used. Domain blocks must be transformed to cover range blocks. The domain pool is similar to the codebook in vector quantization (VQ) referred as virtual codebook or domain codebook [5].

Global domain pool was the first and simplest type of domain pool. Global domain pool content a fixed domain block is used for all range blocks of image. Global domain pool provides satisfactory experimental results. With this results are much better when spatial distance between range block and respective domain block is much lesser. Then domain pool is generated by following a spiral search path and masking of range blocks. The mask is centered at range block which is known as local domain pool. A more advance type of domain pool is the synthetic codebook [6] in which here the domain pool is extracted from low resolution image approximation rather than images itself.

IV. SELECTION OF TRANSFORMS

The Transforms are applied on domain blocks to form range blocks and determines the convergence properties of decoding. Each of transform can skew, stretch, rotate, scale and translate any domain image. The general form of transformations suggested by Jacquin is given as sum of elementary block transformations [3, 4] :

$$^\tau i = \Sigma i \in c \ ^\tau i = \Sigma i \in c \ ^T i^\rho i \qquad ...(1)$$

Where ρi represents a discrete spatial contraction operator, which maps a domain cell (D_i) to the range cell (R_i). The pixel values of the contracted image block on the range block (R_i) are average value of four neighboring pixels in the domain block. T_i is a transformation, which processes image blocks. These transforms do not modify pixel values; they simply shuffle pixels within a range block. They are also called as isometries [1]. The generally used operators are orthogonal reflection about desired axis. These transform also perform gray scale operations, and universally accepted for fractal transformation.

An affine mapping scheme is applicable on nonrectangular partitions which require the vertices of transformed domain blocks should match to the vertices of the range blocks. Another approach is wavelet-Based-Fractal-Transform (WBFT) [2] and Discrete-Cosine-Transform (DCT) [7]. DCT basis vector is superior then polynomial transform, as they form an efficient basis for image blocks due to existence of mutual orthogonality.

V. SEARCH FOR SUITABLE DOMAIN

Fourth step of fractal encoding process is the search of suitable candidate from all available domain blocks to encode any particular range block. This step of fractal image compression is computationally very expensive, because it requires a large number of domain-range comparisons. The attempts to improve encoding speed are addressed as speed-up techniques and focused on two areas as Domain Classification Based Methods and Feature Vector Based Methods.

VI. SPEED –UP TECHNIQUES

A. Boss, fisher and jacob's scheme
1992 R.D. Boss, Y. Fisher and E.W. Jacob proposed a speed-up-technique based on domain classification [1,8], which had improved the compression speed approximately by a factor 8. In this method, a square domain/range block in

subdivided in four quadrants *i.e.*, upper left, upper right, lower left and lower right. These quadrants are numbered sequentially and their average pixel intensities A_i and the corresponding variances V_i are calculated ($i = 1, ..., 4$). These sub-blocks are oriented according to their average intensities; they will follow one of the three ways :

$$(i)\ A_1 > A_2 > A_3 > A_4\ (ii)\ A_1 > A_2 > A_4 > A_3\ (iii)\ A_1 > A_4 > A_2 > A_3$$

This is called as canonical ordering of sub-blocks and defines 3 major classes. There are 24 different possible orderings of the variances that defines 24 subclasses for every major class so that total domain and range blocks are represented in 72 classes. The same category range block is compared with corresponding domain block.

B. Hurtgen and stiller's scheme

B. Hurtgen and C. Stiller gave another technique based on domain classification in 1993 [6]. The range and domain blocks are subdivided in four quadrants. The average intensities of four quadrants of any block are calculated and compared with the average intensity of overall block. Each quadrant is assigned a bit, which is '1' if its mean is higher than the overall mean, and '0' if it is lower or equal to the overall mean. Likewise every block is represented by four bits, arranged in 16 possible ways and there are 24 subclasses according to the ordering of variance as in Fisher's method. In this way all the blocks are classified in 360 classes.

C. Nearest neighbour search scheme

D. Saupe and U. Freiburg give a scheme based on feature extraction in 1995 [1], they have shown that the fractal image compression is equivalent to the multidimensional nearest neighbor search. Then searching optimal domain-range pairs is equivalent to solving nearest neighbor problems in a suitable Euclidean space of feature vectors of domains and ranges. The data points are given by feature vectors of the domains and query point by feature vector of range. Multi-dimensional nearest neighbor searching is a well known data structures and algorithms for them operate in logarithmic time. This approach provides an acceleration factor from 1.3 up to 11.5 depending on image and domain pool size with negligible or minor degradation in both image quality and compression ratio.

D. Cluster based scheme

C.J. Wein and I.F. Blake proposed a speed-up technique based on clustering, in 1996 [10]. A number of clusters are generated for each class, equal to the square root of the number of blocks in that class. The clusters are formed with the use of KD-tree and nearest neighbour algorithm.

E. MIMD architecture based scheme

J. Hammerle and U. Andreas have suggested a domain classification based speed-up method using MIMD-Architecture in year 2000. In this method fractal encoder is implemented by parallel processing and apiece is assigned to each processor element (PE). MIMD architecture preserves sequential coding quality in process. They suggested four classes of algorithms:

(*i*) Class A: Parallelization via ranges (*ii*) Class B: Parallelization via domains
(*iii*) Class C1B: Fixed distribution (*iv*) Class C2B: Adaptive distribution

Significant amount of speed-up is provided by this method, C2B algorithm is proved to be most efficient in time improvement and C1B shows the best scalability.

S.K. Mitra, C.A. Murthy and M.K. Kundu proposed this scheme in 1998 [11]. Genetic algorithms (GA) are defined as mathematically motivated search techniques which solve optimisation problems. GA's use multiple search points, instead of searching one point at a time which find near-optimal solutions without an exhaustive search. This scheme could reduce the number of domain search up to a factor 21.

F. Genetic algorithm based scheme

T.K. Truong, J.H. Jeng, I.S. Reed, P.C. Lee and A. Li gave a speed-up method in year 2000. In this scheme Discrete Cosine Transform (DCT) is used to reduce the time requirement of appropriate domain search. These computations show a high amount of redundancy in frequency domain; hence they transformed the problem to frequency by using DCT. Then all the redundant computations are eliminated by proper arrangement and resulted in 6 times reduction in encoding time than that of baseline method with maintaining almost similar image quality.

G. Adaptive approximate nearest neighbour based scheme

C.S. Tong and M. Wong gave a technique in 2002, based on Nearest Neighbour Search. It is an extension of Saupe's method. In this the range-domain matching problem is converted to Nearest Neighbour Search problem and then approximated by orthogonal projections and pre-quantization of the fractal transforms parameters.

The data points are stored in KD-tree and quad-tree partitioning. It improves fidelity and compression ratio, while significantly reduce the memory and time requirement as compared to Saupe's method. Experimentally, improvement of 0.08% up to 2% in quality, 8% up to 40% in compression ratio is reported. It reduces the time requirement by a factor 3 up to 9.

VII. ERROR BASED SCHEME

From the above all factal image compression scheme, we develop one technique as Error Based Technique. The major problem with fractal-based coding techniques is that of complexity at the encoding stage. To speed-up the coding

phase of fractal image compression and to reduce the computational cost of exhaustive search. We will apply a new classification method for fractal image compression called DRDC differing range domain block comparison based on an approximation error measure in feature vector [12]. The fundamental idea of this algorithm consists in deferring the comparisons between ranges and domains, utilizing a preset block.

In the DRDC method whole process of suitable domain search is based on approximation error. Firstly the image is partitioned in sub-images to form range blocks. Then domain blocks are selected with the double size as that of range blocks. An average block ($\bar{d}$) is computed, which is equal to the average of all range blocks (ri),

$$\bar{d} = \frac{1}{|R|} \sum_{r \in R} r$$

then a few number of features (mean, variance, skewness, kurtosis) of image blocks are extracted and feature vector (f [m, v, s, ku]) for range, domain and average blocks are formed. Further operations of desired task are performed on these feature vectors. The range-domain comparisons are done in two parts; the domain and range feature vectors are compared with feature vector of preset block separately.

The mean value of image gives the measure of average greylevel of image (m), standard deviation (v) defines the dispersion of its greylevel from mean. Skewness (s) describes existence of symmetry/asymmetry from the normal distribution in image. Skewness come in the form of negative skewness or positive skewness, depending on whether data points are skewed to the left (negative skew) or to the right (positive skew) of the data average. Kurtosis (ku) characterizes the relative peakedness or flatness of a distribution compared to the normal distribution. Positive kurtosis indicates a relatively peaked distribution where as negative kurtosis indicates a relatively flat distribution of greylevels in the image

The coding process is divided into two phases. In the first phase, domain feature vectors (*fdi*) are compared with feature vector of preset block(*$f_{\bar{d}}$*), difference between these vectors is computed, which is equal to the Euclidian distance between the vectors and the approximation error is computed and this set of error stored in a binary search tree A binary search tree, however, is a specific case of a tree. First it is a binary tree, meaning that a node can at most have 2 children. And it is a binary search tree, meaning that the child to the left of a parent is less than the parent while the child on the right is greater than the parent. Insertion, search and nearest-neighbor search operations are defined on it.

In the second phase, range feature vector (*fri*) corresponding to the ith range block is compared with average feature vector (*$f_{\bar{d}}$*), and Euclidian distance between them is calculated. And again error has been computed but it is not stored in the binary search tree. This error value is used as search key for nearest neighbor search for locating the best fitting domain for the given range. The domain block corresponding to the nearest error value shows maximum similarity with the particular (ith) range block and assigned to it for encoding. This search process is repeated for each range block. In this way the suitable domain block corresponding to every range block is searched.

Proposed Algorithm:

Step 1: Compute the preset block ($\bar{d}$), equal to the average of all range blocks.

Step 2: Extract features (Mean (*m*), Standard deviation (*v*), Skewness (*s*), Kurtosis (*ku*)) of domain, range and Preset blocks.

Step 3: Calculate Euclidian distance $\psi(f_{di}, f_{\bar{d}})$ for all domain blocks.

$$\psi(f_{di}, f_{\bar{d}}) = \sqrt{(m_{\bar{d}} - m_{di})^2 + (v_{\bar{d}} - v_{di})^2 + (s_{\bar{d}} - s_{di})^2 + (ku_{\bar{d}} - ku_{di})^2}$$

Step 4: Store these error into binary search tree.

Step 5: Calculate Euclidian distance $\psi(f_{ri}, f_{\bar{d}})$

$$\psi(f_{ri}, f_{\bar{d}}) = \sqrt{(m_{\bar{d}} - m_{ri})^2 + (v_{\bar{d}} - v_{ri})^2 + (s_{\bar{d}} - s_{ri})^2 + (ku_{\bar{d}} - ku_{ri})^2}$$

Step 6: Find the nearest value of these error by performing search operation on binary search tree.

Step 7: Assign domain block corresponding to the nearest error value in binary search tree to the desired range block.

VIII. CONCLUSION

The survey of Fractal image compression with different methods and schemes resulted in their own advantages and disadvantages .This leads to our idea of Error based approach to speed-up technique. In conventional method every range block is compared with all the domain blocks and approximation error between them is stored for each range block. Along with this search for least error is done for every range block. Whereas in this method domain feature vectors are compared with average feature vector in domain code-book formation and each range feature vector is compared once with average feature vector to form search key. We have saved the approximation error between average and domain feature vectors in binary search tree and the searching is done with deferent search keys in the same error space in binary search tree. Due to binary search tree and error vectors that help us to reduce the computational cost of exhaustive search while still preserving a good image quality.

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