International Journal on Emerging Technologies **1**(1): 53-56(2010) **ISSN : 0975-8364**

Review of a novel technique: fractal image compression

Vijayshri Chaurasia and Ajay Somkuwar

Department of Electronics & Communication, Maulana Azad National Institute of Technology, Bhopal, (MP) INDIA

(Received 15 Dec., 2009, Accepted 23 Feb., 2010)

ABSTRACT : 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. This review represents a study of most significant advances made at all the four levels in the field of fractal image compression since 1990.

Keywords : Range blocks, Domain blocks, Fractal, Image compression and Speed-up

I. INTRODUCTION

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]. The usual approach of fractal image compression is based on the college theorem, which provides distance between the image to be encoded and the fixed point of a transform, in terms of the distance between the transformed image and the image itself. This distance is known as college error and it should be as small as possible. A.E. Jacquin gave first publication on Fractal image compression with partitioned IFS (PIFS) in 1990 [1], [4], [5]. In Jacquin's method the image is partitioned in sub images called as 'Range blocks' and PIFS are applied on sub-images, rather than the entire image. Locating the range blocks on their respective position in image itself forms the entire image. Temporary images used to form range blocks are known as domain blocks.

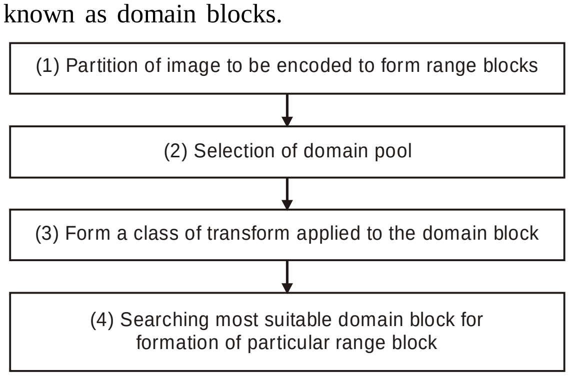

Fig.1. Decision making levels in fractal encoding.

The overall process of fractal image encoding includes four levels of decision making one-by-one as shown in the Fig.1. 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. Some speed-up schemes are discussed in section VI. Finally conclusions are made in section VII.

II. RANGE BLOCK FORMATION

In any Fractal compression system the first decision is to choose the type of image partition for the range blocks formation. A wide variety of partitions have been investigated. Fixed size square blocks are the simplest possible partition [1]. They are easy to implement but its performance decreases for images with varying "activity" 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 [12]. Two approaches are used for Quad-tree partitions [6] and Horizontal-Vertical (HV) partitions [7]. Two innovative techniques are also proposed, Polygonal blocks of different shapes [11], [12] and Irregular partitions [9]-[12]. A Quadtree partition provides best rate distortion as compared to fix-size block, polygonal and HV-partitions. 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 there is between domain and range blocks. With further advancement a new partition scheme based on Delaunay Triangulation have proposed [8], 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 support, 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. DOMAIN POOL SELECTION

Domain pool selection is the second level of decision. This choice depends on the type of partition scheme used.

Since domain blocks must be transformed to cover range blocks. The domain pool in fractal encoding is similar to the codebook in vector quantization (VQ) [13], referred as virtual codebook or domain codebook [5]. Global domain pool was the first and simplest type of domain pool [1,14]. In it a fixed domain block is used for all range blocks of image, or for particular class of range blocks in the image. Global domain pool provides satisfactory experimental results. With more advance applications of fractal compression many researchers observed in the experiments that, results are much better when spatial distance between range block and respective domain block is less. Then domain pool is generated by following a spiral search path outward from spatial position of range block [15]. Another way used to generate domain pool is masking of range block. The mask is centred at range block [16]. This is known as local domain pool. A more advance type of domain pool is the synthetic codebook [17], here the domain pool is extracted from low resolution image approximation rather then images itself. Sometimes a combination of domain block mapping and fixed VQ-codebook is used; it is called as hybrid codebook [18] and provides much better results.

IV. SELECTION OF TRANSFORMS

Transforms are applied on domain blocks to form range blocks and determines the convergence properties of decoding. The partition scheme used and the type of domain pool used restrict the choice of transforms. All the transform used for this purpose should be contractive in nature. 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] :

$$\tau_i = \Sigma_{i \in c} \tau_i = \Sigma_{i \in c} T_i \rho_i \quad ...(1)$$

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 in a deterministic way. They are also called as isometries [1]. The generally used operators are orthogonal reflection about desired axis. These transform also perform some gray scale operations. Above explained scheme is universally accepted for fractal transformation. Affine transforms other than isometries have also been considered, and generalized square isometries constructed by conformal mapping from a square to a disk gives improved performance over the conventional square isometries.

An affine mapping scheme is as well applicable on nonrectangular partitions [8,11]. These affine transforms require that the vertices of transformed domain blocks should match to the vertices of the range blocks. Another approach is wavelet-Based-Fractal-Transform (WBFT) [2], it links the theory of multi-resolution analysis (MRA) with iterated-function-system (IFS) [1, 2]. It provides a local time frequency analysis on the image as well as an iterative construction of the same image using IFS and fixed-point theory. Transform (1) could be extended by using multiple fixed blocks *i.e.*, fixed blocks with constant gradient in the horizontal and vertical directions respectively. Further extensions are possible by including blocks with quadratic form and also by adding cubic blocks. Second order transform provides best results in a rate distortion sense. Another transformation used in fractal encoding is Discrete-Cosine-Transform (DCT) [19]. DCT basis vector is superior then polynomial transform, since they form an efficient basis for image blocks due to existence of mutual orthogonality.

V. SUITABLE DOMAIN SEARCH

After selection of suitable partitioning, domain-pool and transformation, 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 :

(*i*) Domain Classification Based Methods.

(*ii*) Feature Vector Based Methods.

VI. SPEED-UP TECHNIQUES

A. Boss, fisher and jacob's scheme

In 1992 R.D. Boss, Y. Fisher and E.W. Jacob proposed a speed-up-technique based on domain classification [1,7], 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*) $A_1 \geq A_2 \geq A_3 \geq A_4$

(*ii*) $A_1 \geq A_2 \geq A_4 \geq A_3$

(*iii*) $A_1 \geq A_4 \geq A_2 \geq A_3$

This is called as canonical ordering of sub-blocks and defines 3 major classes. In addition, there are 24 different possible orderings of the variances that defines 24 subclasses for every major class. In this way the total domain and range blocks are represented in 72 classes. In coding process any range block is compared with the domain blocks, which belongs to the same category only.

B. Hurtgen and stiller's scheme

B. Hurtgen and C. Stiller gave another technique based on domain classification in 1993 [17]. In this method also, 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 then the overall mean, and '0' if it is lower or equal to the overall mean. In this way every block is represented by four bits, which could be arranged in 16 possible ways. Since combination containing all 1's will be always empty hence the blocks are divided in 15 major classes. Along with it, there are 24 subclasses of each major class 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 [24], 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 [22]. In this process all the blocks are classified into three classes as in Fisher's scheme. 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. For a given range block a cluster from the same class is searched with minimum RMS error corresponding to a contractive map. Then an optimal domain-range pair is chosen from selected cluster corresponding to contractive map. It is suitable only for small range blocks.

E. B. Rejeb & W. Anheier's scheme

It is an extension of Boss, Fisher & Jacob's Scheme, proposed by B. Rejeb and W. Anheier in 1997 [21]. The domain pool is initially scanned once in order to discard domains that are similar to other domains with nearly the same variance or unlikely to be used. They proved in their experiments that, for a speed-up factor of 2 the compression ratio is reduced about 0.8% and the quality is 0.23% improved.

F. MIMD architecture based scheme

J. Hammerle and U. Andreas have suggested a domain classification based speed-up method using MIMD-Architecture in year 2000 [27]. 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
(*i*) 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.

G. Genetic algorithm based scheme

S.K. Mitra, C.A. Murthy and M.K. Kundu proposed this scheme in 1998 [26]. Genetic algorithms (GA) are defined as mathematically motivated search techniques that try to emulate biological evolutionary processes to solve optimisation problems. GA's use multiple search points, instead of searching one point at a time. GA's could be used to find near-optimal solutions without going through an exhaustive search. This scheme could reduce the number of domain search up to a factor 21.

H. DCT inner product 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. Furthermore, the complexity of DCT inner product is reduced by using only the low band data for MSE computations. This method experimentally reported 6 times reduction in encoding time than that of baseline method with maintaining almost similar image quality.

I. Adaptive approximate nearest neighbour search scheme

C.S. Tong and M. Wong gave a technique in 2002, based on Nearest Neighbour Search [25]. 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 transform parameters.

Furthermore, an adaptive scheme is derived for the approximate search parameter to further enhance the performance. The data points are stored in KD-tree and quad-tree partitioning is used. 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.

J. DRDC technique

R. Distasi, M. Nappi and D. Riccio, in year 2006 gave a new scheme, Deferring Range/Domain Comparison (DRDC) technique for speed-up fractal coding [28]. It is a range-domain approximation error based approach, which reduces the complexity of image coding phase by classifying the blocks according to an approximation error measure. Scheme also uses KD-tree data structure to keep track of approximation error.

In this scheme first average of all the ranges of the image is computed, which is called as preset block. The coding process is divided in two phases. In first phase domain codebook is created. In this phase, all domains are compared with preset block, and approximation error is computed and stored in a KD-tree. In second phase, range blocks are encoded. In this phase, all ranges to be encoded are compared with preset, and the approximation error is computed and served as search key for locating the best fitting domain for the given range.

VII. CONCLUSION

This paper has surveyed most significant advances in different steps of fractal image compression. At every step of process lots of schemes are available but large encoding is still a drawback of this technique. In this paper we have also reviewed noteworthy speed-up techniques for fractal image compression. Feature vector schemes provide more flexibility as well as faster performance as compared to domain classification methods. The feature vector techniques accompanying predefined data-structures provide much better performance with some restriction in area of application.

REFERENCES

[1] Y. Fisher, Fractal Image Compression: Theory and Application. New York: Springer-Verlag, (1994).

[2] M. Barnsley, Fractals Everywhere. New York: Academic, (1988).

[3] A.E. Jacquin, "A novel fractal block-coding technique for digital Images", *ICASSP International Conference on Acoustics, Speech and Signal Processing*, (1990).

[4] A.E. Jaquin, "Image coding based on a fractal theory of iterated contractive image transformation", *IEEE Trans. On Image Processing*, **1**(1): (1992).

[5] A.E Jaquin, "Fractal image coding: A review", *Proceeding of tile IEEE*, **81**(10): (1993).

[6] G. Farhadi, "An enhanced fractal image compression based on Quadtree partition", ISPA03 *Proc. on Image and Signal Processing and Analysis*, (2003).

[7] Y. Fisher, E.W. Jacobs, and R.D. Boss, "Fractal image compression using iterated transforms," in Image and Text Compression, J.A. Storer, Ed. Boston, MA: Kluwer, pp. 35-61(1992).

[8] F. Davoine, M. Antonini, J.M. Chassery and M. Barlaud, "Fractal image compression based on Delaunay triangulation and vector quantization", *IEEE Trans. Image Processing*, **5**(2): 338-346(1996).

[9] L. Thomas and F. Deravi, "Region based fractal image compression using heuristic search", *IEEE Trans. Image Processing*, **4**(6) 832-838(1995).

[10] D. Saupe and M. Ruhl, "Evolutionary fractal image compression", *IEEE Int. Conf. Image Processing*, Lausanne, Switzerland, **1:** 129-132(1996).

[11] Tanimoto, H. Ohyama and T. Kimoto, "A new fractal image coding scheme employing blocks of variable shapes", *IEEE Int. Conf. Image Processing*, Lausanne Switzerland, **1:** 137-140(1996).

[12] Ruhl, H. Hartenstein and D. Saupe, "Adaptive partitionings for fractal image compression", *IEEE Int. Conf. Image Processing*, Santa Barbara, CA, **2:** 310-313(1997).

[13] B. Ramarurthi and A. Gersho, "Classified vector quantization of images", *IEEE Trans. on Communications*, **34**(11): (1986).

[14] E.W. Jacobs, Y. Fisher, and R.D. Boss, "Image compression: A study of iterated transform method", *Signal Processing*, **29**(3): 251-263(1992).

[15] J.M. Beaumont, "Advances in block based fractal coding of still pictures", in *Proc. IEEE Colloq.: The Application of Fractal Techniques in Image Processing*, 3.1-3.6(1990).

[16] B. Wohlberg and G.D. Jager, "A review of fractal image coding literature", *IEEE Trans. on Image Processing*, **8**(12) 1716-1729(1999).

[17] B. Hurtgen and C. Stiller, "Fast hierarchical codebook search for fractal coding of still images", in *Proc. EOS/SPIE Visual Communications PACS Medical Applications*' 93, Berlin, Germany, (1993).

[18] R. Hamzaoui, M. Muller and D. Saupe, "VQ-enhanced fractal image compression", *IEEE Int. Conf. Image Processing*, Lausanne, Switzerland, **1:** 153-156(1996).

[19] T.K. Truong, J.H. Jeng, I.S. Reed, P.C. Lee and A.Q. Li, "A fast encodind algorithm for fractal image compression using the DCT inner product", *IEEE Trans. Image processing*, **9**(4): 529-535(2000).

[20] S. Weistead, Fractal and Wavelet Image Compression Technique: PHI, India, (2005).

[21] B. Rejeb and W. Anheier, "A new approach for speed-up of fractal image coding", *IEEE 13th Int. National Conf. DSP proceedings*, **2:** 853-856(1997).

[22] C.J. Wein and I.F. Blake, "On the performance of fractal compression with clustering", *IEEE Trans. Image Processing*, **5**(3): 522-526(1996).

[23] G.M. Davis, "Wavelet-based analysis of fractal image compression", *IEEE Trans. Image Processing*, **7**(2): 141-154(1998).

[24] D. Saupe and U. freiburg, "Accelerating Fractal Image Compression by Multi-Dimensional Nearest Neighbor Search", Proceedings DCC'95 Data Compression Conference, J. A. Storer and M. Colin (eds.) *IEEE Comp. Soc. Press*, March (1995).

[25] C.S. Tong and M. Wong, "Adaptive approximation nearest neighbor search for fractal image compression", *IEEE Trans. Image processing*, **11**(6): 601-615(2002).

[26] S.K. Mitra, C.A. Murthy, M.K. Kundu, "Technique for fractal image compression using genetic algorithm", *IEEE Trans Image Processing*, **7**(4): 586-593(1998).

[27] J. Hammerle and U. Andreas, "Fractal image compression on MIMD architectures II: Classification based speed-up method", *Journal of Computing and Information Technology*, **1:** 71-82(2000).

[28] R. Distasi, M. Nappi and D. Riccio, "A range/domain approximation error- based approach for fractal image compression", *IEEE Trans. Image processing*, **15**(1): 89-97(2006).