Fractal Image Compression Techniques

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Abstract:
Image compression is an essential technology in multimedia and digital communication fields. Fractal image compression is a potential image compression scheme due to its potential high compression ratio, fast decompression and multi resolution properties. Fractal image compression utilizes the existence of self symmetry of images. Since Bransley gave the concept of fractal image compression in 1988, fractal image compression has obtained recognition and has become one of the most popular coding methods in the recent years. However the high computational complexity of fractal image encoding greatly restricts its applications. Several techniques and improvements have been suggested to speed up the fractal image compression. This paper presents a review of the techniques published for faster fractal image compression.

Keywords:
Image Compression, Fractal image compression, Image partitioning

I. INTRODUCTION

Most of the existing image coding algorithm is based on the correlation between adjacent pixels and therefore the compression ratio is not high. Fractal coding is a potential image compression method, which is based on the ground breaking work of Barnsley and was developed to a usable state by Jacquin[1-4]. Its essence is that correlation not only exists in adjacent pixels within a local region, but also in different regions and local regions with global regions. The fractal-based schemes exploit the self-similarities that are inherent in many real world images for the purpose of encoding an image as a collection of transformations. The process of fractal image coding is finding an optimal contractive transformation whose attractor closely approximates the original image. Thus a digitized image can be stored as a collection of IFS transformations parameters and is easily regenerated or decoded for use or display. The storage of the IFS transformation coefficients results in relatively high compression ratios and good reconstruction fidelity, which is superior to conventional image compression schemes. For conventional fractal compression schemes, an image is partitioned into domain blocks and range blocks, the self similarities exploiting between these two kinds of blocks in the spatial domain is computationally expensive, usually hundreds of seconds is used to encoding an image, which restricts the application of fractal image compression. In the forthcoming sections we describe different speeding up techniques based on the different steps involved in fractal image compression including partitioning of image to be encoded, selection of domain blocks, and selection of transforms. Some other researchers have combined fractal with other algorithms such as fuzzy classification [5], neural network [6], genetic [7], simulated annealing (SA) [8], wavelet [9], etc. Reducing the encoding time based on computation of the gray level difference and normal variance of domain and range blocks [a] and DCT [b] have also been proposed.

II. IMAGE PARTITIONING TECHNIQUES

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 [10]. 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 [11]. Other portioning techniques like quad-tree partitioning [12], Horizontal-Vertical partitioning [13], irregular partitions [14], Delaunay triangulation[15] and Adaptive Quadtree partitioning have been proposed. A Quadtree partition provides best rate distortion as compared to fix-size block, polygonal and HVpartitions. 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. Delaunay Triangulation partition provides a reduced number of blocks as compared to square partitions and, thus minimizes the number of mappings at a rate 0.25 to 0.5 depending on the nature of image. In adaptive quadtree partition method, the image is divided into four sub blocks with equal size which are joined by four nodes and these sub blocks are judged to be subdivided or not according to their statistical properties.

III. IMPROVEMENTS IN SELECTION OF DOMAIN BLOCKS

The second level in fractal image compression is the selection of domain pools, wherein the choice depends on the type of partition scheme used since domain blocks must be transformed to cover range blocks. Global domain pool was the first and simplest type of domain pool [16]. In it a fixed domain block is used for all range blocks of image, or for particular class of range blocks in the image. This class addresses the range blocks some/equivalent value of any image parameter or range blocks of any particular region of 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. This requirement restricts the region of domain pool about the range block. The domain pool is generated by following a spiral search path outward from spatial position of range block [17]. In the local domain pool method [18], domain pool is generated by the masking of range block. The mask is centred at range block and is dense near the centre and becomes shallower progressively as we move towards edges. In Synthetic codebook [19], the domain pool is extracted from low resolution image approximation rather then images itself. In hybrid codebook [20] a combination of domain block mapping and fixed VQ-codebook is used and provides much better results.

IV. SELECTION OF TRANSFORMS

The third and crucial step of fractional image compression is the selection of transforms. Transforms are applied on domain blocks to form range blocks and determine the convergence properties of decoding. The partition scheme used and the type of domain pool used restrict the choice of transforms since domain blocks are mapped into range blocks using these transforms. All the transforms used for this purpose should be contractive in nature. Each of transform can skew, stretch, rotate, scale and translate any domain image. Transforms do not modify pixel values. They simply shuffle pixels within a range block in a deterministic way. They are also called as isometrics. The generally used operators are orthogonal reflection about desired axis and Rotation about centre of block, through some required degree. These transform also perform some gray scale operations like, gray level scaling, Translation and absorption of gray scale. 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. 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). 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. 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) [21]. DCT basis vector is superior then polynomial transform, since they form an efficient basis for image blocks due to existence of mutual orthogonality.

V. RANGE BLOCK FORMATION METHODS

The range block formation which is the search of suitable candidate from all available domain blocks to encode any particular range block, is computationally very expensive, because it requires a large number of domain range comparisons. In the basic approach proposed by A E Jacquin [22] each domain block is transformed by every transform in the IFS and compared with the range block to be encoded. For each comparison the college error is calculated and stored by some means. The domain block and transform corresponding to the least college error are considered as best candidate for the selected range block. This process is repeated for all range blocks. Hence this approach requires lengthy computation and consumes long time in encoding. Many methods have been proposed to reduce this time requirement. In the method proposed by R.D. Boss, Y. Fisher and E.W. Jacob [23] blocks are grouped in some defined classes. The ranges of any class are compared with the domains of the same class only, thereby reducing the total number of comparisons. The total blocks were grouped into 3 major classes and 72 subclasses according to their average intensities and variances. This resulted in improving the speed factor by 8. B.Hurtgen and C. Stiller suggested a similar technique, with 15 major classes and 360 subclasses [24], which provides better image quality. In an extension of this method by B. Rejeb and W. Anheier [25], the domain pool is initially scanned in order to discard domains that are similar to other domains with nearly the same variance or unlikely to be of use from each class of domain pool. In the clustering method proposed by C J Wein and I F Blake [26], clusters are formed with the use of KD-tree and nearest neighbour algorithm. In the Nearest Neighbour Search based scheme given by D. Saupe and U. Freiburg [27], the comparison of range blocks and domain blocks is based features rather then on individual pixels. 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. An extension of this method by C.S. Tong and M.Wong converts the range domain matching problem to Nearest Neighbour Search problem which is then approximated by orthogonal projections and pre quantization of the fractal transform parameters. This method reported an improvement of 0.08% up to 2% in quality, 8% up to 40% in compression ratio and reduced the time requirement by a factor 3 up to 9 as compared to Saupe's method.

VI. OTHER TECHNIQUES

Another method based on Genetic algorithms (GA) is proposed by S.K. Mitra, C.A. Murthy and M.K. Kundu [28]. 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 and hence decreases the compression time by a factor 21. T.K. Truong, J.H. Jeng, I.S. Reed, P.C. Lee and A. Li gave a method based on DCT Inner Product [29]. In this scheme Discrete Cosine Transform (DCT) is used to reduce the time requirement of appropriate domain search. The total system is transformed to frequency domain by using DCT for further computations. This method experimentally reported that, the encoding time is reduced about 6 times than that of baseline method with maintaining almost similar image quality. Many other methods and techniques like Ant Colony algorithm [30], Fast pyramidal domain block search algorithm [31], Adaptive Domain pool scheme [32] and Fractal Image Compression based on local extreme points [33] have also been proposed.

VII. CONCLUSION

The paper discusses various improvements for speeding up the fractal image compression has been discussed. In partitioning, irregular partitioning provides better quality as compared to rectangular partitions but they become complex. The global domain pool is very simple and easy to implement but local domain pool results better image quality. Hybrid domain pool provides much better overall performance. The transforms used in fractal coding should be contractive, polynomial transform provides satisfactory results but they become complex with increase in order, DCT basis vector is superior then polynomial transform. Feature vector schemes provide more flexibility and 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.

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