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A Review on Fractal Image Compression

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Abstract- fractal image compression is an emerging technique based on the representation of an image by a series of repeated transforms. It is a lossy method for digital image compression. It exploits the property of self-symmetryof natural images in order to compress a digital image and use affine transforms to serve it mathematically. The main goal of fractal image compression algorithms is to reduce computation time required to compress digital images. This paper presents a comparative analysis of popular fractal image compression techniques.

Key words- fractals, IFS, affine transformation, FIC, self-similarity.

I. INTRODUCTION

The theory of fractal was coined by IBM mathematician Benoit Mandelbrot. He discovered some interesting facts about natural objects such as mountains, clouds, coastlines and trees that these structures cannot be described by conventional geometry. These natural objects can only be described by Euclidean geometry or Fractal geometry. Fractals are the geometrical objects which has property of self-similarity.There are three main things that are required to create fractals namely: a set of transformations, a base from which iteration starts, and a condensation set. An image having high redundancy needs a large storage facility and also requires relatively high bandwidth channels to send the image across the network. By applying compression to images transmission time and required storage space can be reduced.

The principle of fractal image compression was given by M. Barnsley in 1988 [1]. He uses some mathematical functions and a series of affine transformations to provide fractal image compression in his theory. Affine transformation is a combination of some geometrical operations like translation, rotation, scale change etc. The image which we will get after applying affine transformation is an approximation of the original image. The main goal of compression algorithms is to increase compression ratio and minimize the time required in compression. There are mainly two types of compression: lossless compression and lossy compression. In lossy compression some information of the image get lost in compression and an approximate copy of the original image is generated. The information is lost due to some redundancy in the original image. This type of compression is used where the exact copy of the original image is not mandatory. Fractal image compression is also a lossy compression method.In this paper, we will study the techniques of fractal image compression and also discuss some basic concepts which should be keep in mind while applying this technique and some speed up techniques for encoding.

II. FRACTAL IMAGE COMPRESSION

Lossy image compression by Partitioned Iterated Function System (PIFS) is known as Fractal Image Compression. A. E. Jacquin first publishes a research paper on fractal image compression and introduces the phenomenon of PIFS in image compression in 1990. The image is portioned in small images is, called as range blocks and PIFS is then applied on those small images rather than the entire image. Fisher et al. give a new height to the research in fractal image compression by reducing the number of comparisons involved in compression [6].

Figure 1 represents the entire process of fractal image compression. First, in the fractal image compression the image is partitioned into a number of small sub blocks in order to form range blocks. Then domain blocks are selected. This depends on the type of partition scheme used. Then the set of transformation are selected and applied on domain blocks towards range blocks and determines the convergence properties of decoding.

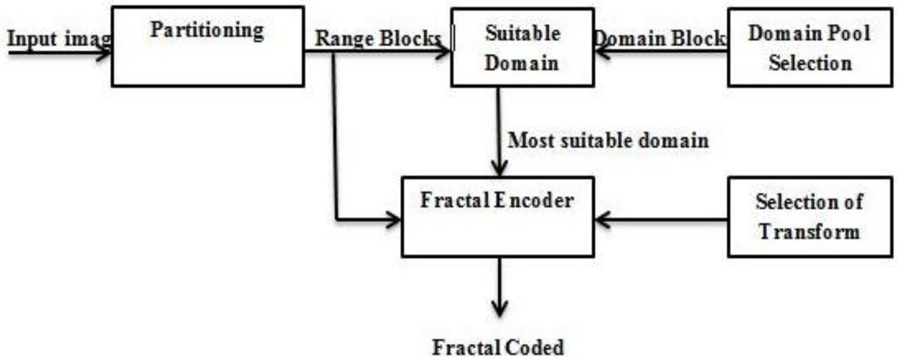

Figure1: Block diagram of fractal image compression

Fractal image compression has the following properties.

1. This technique is resolution independent.
2. Compression ratio is high as compare to the other compression techniques.
3. Fast image decoding.

III. BASIC TERMINOLOGY OF FRACTAL IMAGE COMPRESSION

1. Self-Similarity:

There are many regions in natural images which are similar to each other and thus introducing redundancy in images. This property is called self-similarity. This property makes fractals independent of scaling. Every image does not contain the type of self-similarity exhibits by the fractals. The entire image could not be self-similar but parts of the image could be the same. The compression ratio depends on type of redundancy involved in the image [2,3].

2. Iterated Function System and attractor:

Iterated function system (IFS)became popular; Barnsley and his colleagues in the Georgia University first observed the use of IFSincomputerized graphics applications. Theyfound that IFS was able to cress color images up to 10000 times. The compression contained two phases. First, the image was partitioned to segments that were self-similar as possible. Then each part was described as IFS with probabilities. The key to compression was the collage theory, which gave a criterion to select the parameters in the transformation. Image decoding was done by iterative repeat of the transformation. While the decoding was done automatically the encoding required human iterations,atleast in the image segmentation. In 1989, Jacquin proposed afull automatic algorithm for fractal image compression based on Affine transforms that work locally rather than globally. If above mentioned mapping is applied on an image then the final image that we will receive is called Attractor. The shape of the attractor is independent of the shape of initial image but is dependent upon their position and orientation [2].

3. Encoding:

The image is portioned into non-overlapping square blocks (range blocks) of size B*B and larger overlapping square blocks (domain blocks) of size 2B*2B. After that the domain pixels are arranged in groups of four in order to find the average so that the domain could be reduced to the size of range blocks. Affine transformation of pixel values is found so that the mean square error difference can be minimized. If the resulting mean square value is above a threshold and if the depth of quad tree is less than the predefined maximum depth the range is partitioned into four quadrants and the process is repeated. If the mean square error value is below a threshold the affine transformation is stored for encoding.

4. Decoding:

In decoding the quad tree partition is used to find out all the ranges in a given image. For each range R_i the domain D_i is reduced by two in each dimension by averaging non-overlapping groups of 2*2 pixels. The decoding step is iterated until the fixed point is approximated.

IV. POPULAR FRACTAL ALGORITHMS

Fractals are used to describe attractor's texture and other chaos related geometric objects. Chaotic attractors are defined as attractors with fractal structure or fractal's geometric property. So we can clearly see the relation between chaos and fractals "Fractals can help detect chaos". Fractal approximation uses the shape information of gray surfaces, i.e., the IFS encodes an input image based on the idea of self-similarity. Thus, the existence of similar gray surface patterns is important to encode an image by fractal coding. In the method fast coding algorithm using the pixel wise IFS, because the scaling factor is calculated pixel wise, an input image having the weak self-similarity is effectively encoded by fractal mapping.

In addition, this method can find optimal parameters without the search process. Thus, it is faster than other methods requiring expensive search time. Further research will focus on the investigation of the quantization problem, optimization, and applications of the PIFS to moving image sequences [4, 5].

In specifying fractal sets, various approaches are used that are mainly based on iterative procedures. For example, as a result of geometric transformations, fractal sets arise such as the Sierpinski napkin and the Koch snowflake. Universal means are iterated function systems (*IFS*s) defining a set as a fixed point of a transformation; according to the collage theorem each bounded set can be rather well approximated by an *IFS* attractor. Moreover, for specifying sets with a regular structure, various schemes such as hierarchical iterated function systems (*HIFS*s) constructions controlled by graphs, and also weighted finite automata can be used. At first sight, all these constructions are close to the concept of a finite automaton since, to specify them, the transition diagram of a classical finite automaton can be used. Nevertheless, the process of their operation more corresponds to that of a finite discrete network in which each node first summarizes its inputs and then processes the obtained sum and transfers the results to other nodes. In the case of *HIFS*s and constructions controlled by graphs, the resulting set is determined using a fixed point of a system [6].

With the help of the concept of the address of a point of an *IFS* attractor, a surjection from [0:1] onto the attractor is naturally constructed. In fractal image compression, the encoding step is computationally expensive. A large number of sequential searches through a list of domains (portions of the image) are carried out while trying to find the best match for another image portion. Our theory developed here shows that this basic procedure of fractal image compression is equivalent to multi-dimensional nearest neighbor search. This result is useful for accelerating the encoding procedure in fractal image compression. The traditional sequential search takes linear time whereas the nearest neighbor search can be organized to require only logarithmic time. The fast search has been integrated into an existing state-of-the-art classification method thereby accelerating the searches carried out in the individual domain classes.

In this case we record acceleration factors 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. Furthermore, as compared to plain classification our method is demonstrated to be able to search through larger portions of the domain pool without increased the computation time[1].

A set of algorithms has been developed to model acoustic backgrounds with specific discrete features. Fractal background images arc generated using a midpoint displacement method, a technique in which a two-dimensional surface is recursively subdivided by analyzing four corners and adding a random variable to determine new points. By altering only a few parameters a large variety of fractal backgrounds may be produced [9].

Natural topographical features such as ripples and shadows, and man-made topographical features such as tracks, roads, and structures can be simulated in shape, Size, texture, and intensity. When appended to a fractal base, the total image will resemble a geographic region. The collective set of features used in simulation is contingent upon the type of image being represented like radar, acoustic, or photographic.

The two dimension features of particular types of images specify the resolution, range and environment that is being simulated. The distinctive visual and statistical attributes of a specific image set can be replicated in a synthesized image. Selected images are presented with a variety of features.

In the study given by [Rashiq et.al] we use the frequency-domain approach and introduce a novel method to capture the fractal behavior of Internet traffic in which we adopt a random scaling fractal model to simulate the self-affine characteristics of the Internet traffic. In this we utilize the self-affine nature of Internet traffic in order to disguise the transmission of a digital file by splitting the file into a number of binary blocks (files) whose size and submission times are compatible with the burst lengths of Internet traffic. We examine two different time series. The Sizes series consists of the actual packet sizes as individual packet arrives, and the inter-arrival series consists of timestamps differences between consecutive packets [7, 8].

Study carried by Mandelbrot who was best known as the founder of fractal geometry, which impacts mathematics. It is admittedly the first broad attempt to investigate quantitatively the ubiquitous notion of roughness. Nature is filled with complex geometrical shapes such as branching patterns of rivers, biological shapes, seashore lines, and even the curves of currency exchange rates. The common feature in such complex shapes: is self-similarity. Mandelbrot discovered that the self-similarity is the universal property that underlies such complex shapes, and he coined the expression 'fractal' to describe them. Furthermore, he illustrated its properties mathematically and founded a new methodology for analyzing complex systems.

There are typically four techniques to generate fractals: escape-time fractals (also known as 'orbits' fractals), iterated function systems, random fractals, and strange attractors. In 2002, Rani introduced superior iterations in the study of fractals. The new iterative approach to study fractal models, which was found superior to the conventional iterative approach.

The paper C.J. Robertson, describes the simulation of naturally occurring topographical Features using fractals. Features are indicated on an image array by position, shape, and intensity. The shape is indicated by a "skeleton" outlining the contour of the feature. The fractal image is created using a recursive subdivision method, also known as midpoint replacement, in conjunction with the "skeleton" of the feature.

The fractals described in the paperwere recursively generated using a variation of the popular midpoint displacement method. Unlike most other application as of this method, this one does not require the displacement to be Gaussian or to have variances a function of distance. In fact these sets were generated using uniformly distributed displacements of constant variance. The fractal dimensions of the resulting sets are clearly a function of the variance of the displacement, but as in many cases, the actual Hausdorff dimension is difficult to calculate [10].

V. CONCLUSION

We have described a number of fractal image compression algorithms in this paper. The fractal theory exploits the property of self-similarity in the natural images and other images, in order to find the compression. Fractal image compression technique is better from other image compression techniques in terms of resolution because this technique is independent of resolution means the image can be expend to any resolution.The main problem with this technique is that it's encoding time, because it takes too much time to encode an image. A number of algorithms were proposed up to now to increase the speed of encoding process and those algorithms are doing very well so, in near future it would become a popular technique for image compression.

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