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A Survey on Fractal Image Compression Techniques

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Abstract: Fractal Image Compression (FIC) is a lossy compression technique, where we can obtain a large amount of compression by representing the image as a contractive transform. The main drawback of FIC is its complexity in encoding and lack of speed. At the same time it has several advantages such as, zooming the image without degrading the quality due to its resolution independent nature. FIC have a good trade off between the compression ratio and PSNR when comparing with other standard image compression techniques. In order to improve the performance of the fractal image compression several methods are adopted. This paper is a study of various fractal image compression methods.

Keywords: Fractal encoding, Image compression, PSNR, Compression ratio, Discrete Cosine Transform, Discrete Wavelet Transform.

I. INTRODUCTION

The demand of multimedia applications has increased over the years. This has resulted in image and video compression becoming an important issue in reducing the cost of data storage and transmission. Some of the familiar compression standards used now are JPEG (Joint Photographers Expert Group) and GIF (Graphics Interchange Format) although there recently researches are going to find even more efficient compression standards. The main objective of image compression is to efficiently produce the image having less number of bits in order to reduce storage space and increase the transmission speed without compromising image quality.

There are two types of image compression, Lossy as well as Lossless. In lossless compression, the reconstructed image is numerically similar than that of the original image. Where as in lossy compression the reconstructed image contain some degradation. But this provides greater compression ratios than lossless technique.

The simplest way of storing image is pixel by pixel, but it is complicated. Larger image required more space to be stored. Instead of storing the pixel values directly different encoding schemes are adopted. These coding schemes include Huffman Coding and GIF. Both of these are lossless schemes. Other algorithms cause the image to lose data, but they result in less storage space. These algorithms include Fourier Transform, Cosine Transform, JPEG and Fractal Image Compression.

JPEG stands for Joint Photographers Expert Group. This group was formed in 1980 which is a DCT-based image compression method used for still image compression. It has both lossless as well as lossy modes. JPEG is the most used format for storing and transmitting images in Internet. Although the use of JPEG standard has been very successful in several years, but it has some properties to improve. A fundamental shift in the image compression approach came after the DWT became popular, and it is adopted in the new JPEG 2000 standard. Another alternative method used to incur high compression ratio is Fractal Image Compression.

This scheme was proposed by Arnaud Jacquin[1] and promoted by M. Barnsley[2]. It is based on the iterated function systems which utilize the self-similarities within the image. Basically it works by partitioning an image into blocks called range and domain and using Contractive Mapping to map range blocks to domains. But the encoding of this method is more time consuming because of finding the most suitable range-domain pair. But the decoding is more simple than encoding. Due to this unsymmetrical nature this compression not widely used. But now a day several methods are proposed to improving its performance.

II. DIFFERENT FRACTAL IMAGE COMPRESSION METHODS

As said earlier the main drawback of fractal image compression technique is the high encoding time required. Different methods are using now a days in order to solving this problem.

A. Classification Method

It includes Block classification [3], Domain range pixel value difference [4], soft computing techniques [5].

i. Block Classification

In order to reduce the searching time during the matching process in the quadtree partition method, the sub blocks are classified in each level. For the range blocks, they are classified directly. For the domain blocks, they are transformed by spatial scaling and spatial position transformations before classifying.

The classification method is described below.

Firstly, divide each sub block into four equal parts, and calculate the mean value and the variance of each part. Then, according to the mean values, the sub blocks are classified into 3 main classes.

Class 1:1 2 3 4 μ ≥ μ ≥ μ ≥ μ ;
Class 2:1 2 4 3 μ ≥ μ ≥ μ ≥ μ ;
Class 3:1 4 2 3 μ ≥ μ ≥ μ ≥ μ ;

Finally, according to the descending order permutation of the variances (1 δ, 2 δ , 3 δ and 4 δ), each main classes are divided into 24 auxiliary classes. In this way, each sub blocks are divided into 72 classes.

Algorithm

Step 1. Set the maximum and minimum recursion depth and the error threshold
Step 2. The adaptive quadtree partition is performed on the image. The domain blocks and the range blocks in each level are classified.
Step 3. Each range blocks are compared with the domain blocks which have the same class as the current range block. If the error is below the given threshold, record the corresponding parameters; otherwise, jump to Step 2.

ii. Domain Range Pixel Value Difference

A comparison for best match is performed between the domain and range blocks only if the range block pixel value difference is less than the domain block pixel value difference.

Algorithm

Step 1: Construct the domain pools corresponding to each quadtree partition levels
Step 2: Calculating the block pixel value difference of all domain blocks Maximum value of pixel (Pmax) - Minimum value of pixel (Pmin).
Step 3: Classify and sort the domain in each domain pool in ascending order of the pixel value difference.
Step 4: Search for a best match between a range and domain belongs to the same class.

iii. Soft Computing Techniques

Here classifying the domain pool using Artificial neural network classifier. A domain range match produces long encoding time. In order to reduce this encoding time , best matching domains for each range can be selected from same class. This classification is based on back propogation algorithm and the input which is given to the classifier are two features, standard deviation and skewness both are extracted from the domain cells.

B. Search Strategies

i. Particle Swarm Optimization

Particle swarm optimization method [6] performed under classification and Dihedral transformation to reduce the amount of MSE computations . Here only four MSE computations out of eight are computed and therefore only half of the computation time is required. For each range block . use particle swarm optimization as the searching strategy in the domain pool. For the block matched process, considering two factors which are block type and region. Firstly as each particle lies in the domain pool, just consider the block whose type is the same as that of the range block. Then, using the region type to decide the Dihedral transformation Tk . If the domain and range block are located in the same region then ,Tk: k=0-3. Otherwise we perform Tk: k=4-7. Fig.1 shows the flowchart of this search strategy.

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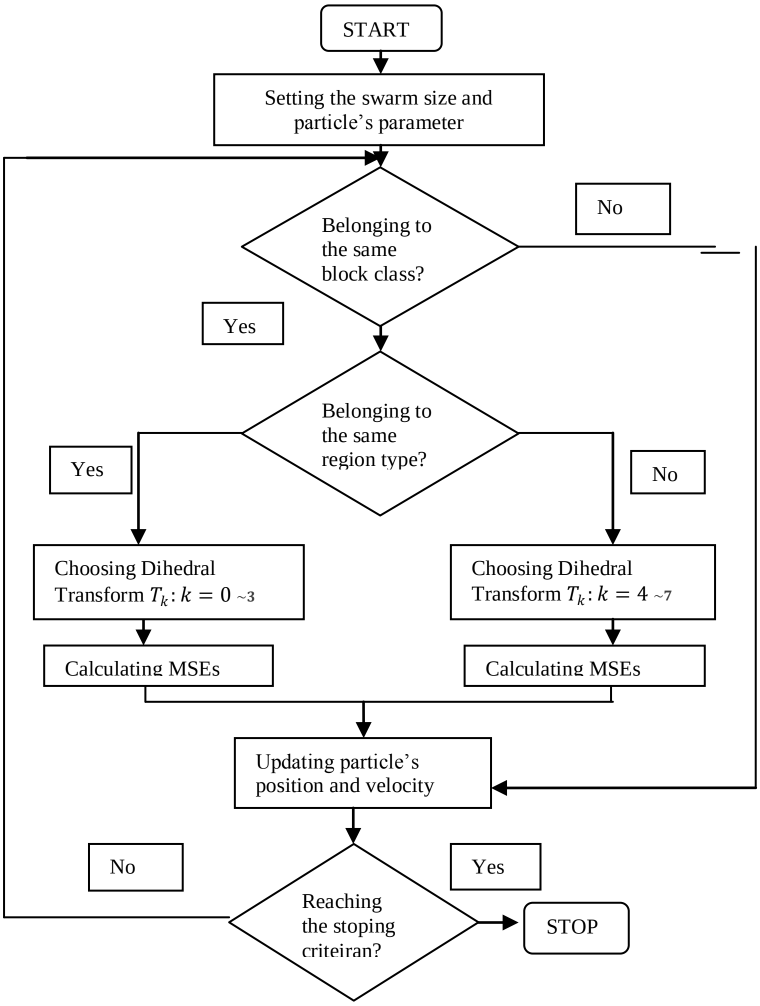

Fig. 1. Flow chart

ii. Range Exclusion

This technique [7] reduces the number of range blocks required in matching process by extracting mean and standard variance features that characterize the range images. The mean value of range gives the measure of average gray level of range (Mr); standard variance (Vr) value of range defines the dispersion of its gray level from the mean. Variance has been used to check whether the range area is homogenous region or contains details. After partitioning, the contents of each range will be checked before starting the search operation to decide if it is a homogenous region (flat) or not. In homogenous region the value of variance is about zero while it is increase in the areas with more details. The flat region means that all pixels of this region have the same value or are close to each other. During the matching process, the homogeneous ranges will be excluded. So, the matching operation will be limited on the detailed regions and which results in reduction of computation time.

iii. Domain Pool Reduction

Reducing the no. of domain pools used for matching based on the entropy of each domain block. Domain blocks having high entropy ie more information content than a threshold value is used for matching [8]. Entropy can be calculated by using (2)

$$P_i = \frac{q_i}{\sum_{j=1}^{K} q_j} = \frac{q_i}{n^2} \qquad (1)$$

$$\text{Entropy} = -\sum_{i=1}^{K} P_i \, \text{Ln}(P_i) \qquad (2)$$

C. Hybrid Methods

The hybrid method includes combination of fractal image compression with transform coding techniques such as DCT [9], DWT [10]. The basic idea of combining different compression techniques in a way that advantages of both

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schemes are preserved. With the emerging of fractal image compression many hybrid schemes based partially on fractal coders have been proposed.

i. Fractal Coding with DCT

The Discrete Cosine Transform is first performed on the image to be compressed. The transform coefficients are then encoded using fractal block coding, producing a set of affine transformations of which the DCT representation is an approximate attractor. Two approaches are here. First apply DCT on the entire image and then partition it into range blocks. But drawbacks of this methods are transforming an entire image is a very lengthy process. Second, the quantization error on each coefficient is difficult to relate to the distortion actually perceived by the eye.

The conventional way to address these problems is to partition the image into small blocks and apply DCT to these blocks of the image, which become the range blocks for the fractal encoding stage. First, it takes less time to transform a large number of small blocks than to transform a large block having an equivalent number of pixels. Partitioning an image into blocks also helps in controlling distortion. For each range block, the set of domain blocks is obtained by performing the DCT transform on blocks of image, which are as equal size as of range block. The next step in the coding process is the fractal encoding for each range block. For each range block, a search of the entire set of domain blocks is performed to find the domain block that is the most similar to the range block.

In the decoder, first fractal parameters should be decoded. Then inverse DCT is applied to decoded parameters and decompressed image is obtained.

ii. Fractal Coding with DWT

The Discrete wavelet transform (DWT), which utilizes the technique of sub band coding, is found to afford a fast computation of wavelet transform. It is easy to implement and also reduces the computation period and necessary resources. In wavelet transforms the signals are examined carefully using a set of basis functions which are related to each other by simple scaling and translation operations. The signals to be analyzed are passed through filters with different cutoff frequency at different scales. When a signal passes through a filter its splits into 2 bands, lower and higher frequency sub bands where these procedures are repeated for only the low frequency sub bands to obtain a multilevel wavelet decomposition of an image[10].The fundamental idea of fractal coding is to decompose an image into segments using the standard image processing techniques such as color separation, edge detection, and spectrum and texture analysis. Each such segment is then looked up in a library of fractals. The library essentially contains codes called iterated function system (IFS) codes ,which are a compact set of numbers. A set of codes for a given image is determined using a systematic procedure. When the IFS codes are applied to a set of image blocks, an image which is a very close estimation of the primary is obtained. This scheme is highly effective for compressing images.

The block diagram of the this method is shown in the figure 2 . Image adjustment is performed to boost the intensity of the image after which the image is resized to its original size. The sub band image is compressed by using fractal algorithm. During decoding fractal codes are iteratively applied to any absolute image of the assonant size. By using all the true details of the sub bands five wavelet sub trees are built. Non overlap range block $R_H(X, Y)$ and overlapping domain block D_H are built using equations (3) and (4). For each range block the assonant fractal algorithm is utilized to find the best matched domain block with a negligible MSE.

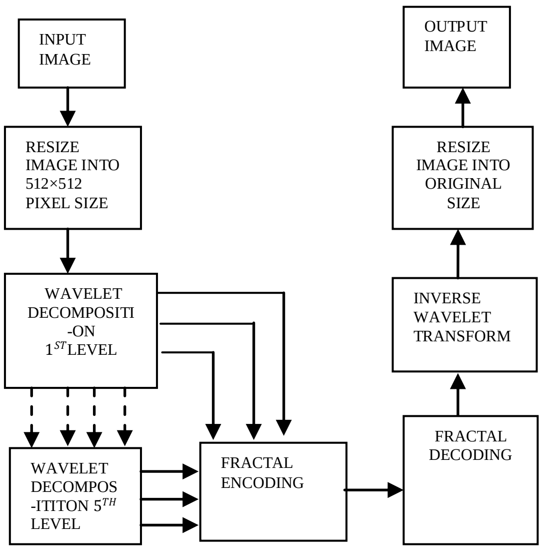

Fig. 2. Block Diagram for DWT based FIC.

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$$E(R_{Hi}, D_{Hi}) = \frac{1}{n}\sum_{i=1}^{n}(s.d_{hi} - r_{hi})^2 \qquad v = N\varepsilon N \quad (3)$$

$$s = \frac{\sum_{i=1}^{n} d_{hi}\, r_{hi}}{\sum_{i=1}^{n} d_{hi}^2} \quad (4)$$

III. PERFORMANCE EVALUATION PARAMETERS

So many parameters are used to calculate the performance of compression. The most frequently used are compression ratio (CR), compression time, mean squared error (MSE) and peak signal to noise ratio (PSNR).

Compression Ratio: Ratio of uncompressed file size to the compressed file size.

$$CR = \frac{\text{Uncompressed file size}}{\text{Compressed file size}}$$

Compression time: Nothing but time taken for Compression and decompression. Which are considered separately. The algorithm is said to be time efficient when it takes less time for both compression and decompression.

Mean square error: MSE is the cumulative difference between the compressed and original image. Image quality improves with smaller value of MSE.

$$MSE = \frac{\sum_{M,N}[I_1(m,n) - I_2(m,n)]}{M \times N}$$

M and N represents the number of rows and columns in the input image.

Peak signal to noise ratio: PSNR is a measure of peak error between the original and compressed image. Higher the PSNR value, better the image quality. Where R is the maximum pixel value of the image.

$$PSNR = 10\log_{10}\left[\frac{R^2}{MSE}\right]$$

TABLE I Summarizing the advantages and disadvantages of various methods.

Method	Advantage	Disadvantage
Classification		
Block classification	Increased compression ratio	Effecting PSNR
Domain range pixel value difference	Muti resolution property	Computationally difficult
Soft computing techniques	Computation time reduces	Must provide more inputs for training
Search strategy		
Particle swarm optimization	Coding efficiency	Effecting reconstructed image quality.
Range exclusion	Encoding speed	PSNR decreases
Domain pool reduction	Fast encoding	Effecting reconstructed image quality
Hybrid method		
Fractal coding with DCT	Improved encoding time	Tiling Effect
Fractal coding with DWT	Fast encoding, No frequency distortion compare with other standards	Less PSNR compared with BFIC.

IV. CONCLUSION

We have reviewed and summarized various methods used for reducing the encoding complexity of fractal image compression. To conclude, all these techniques are useful in their related areas and new methods are developing which gives better compression ratio as well as lesser encoding time. This review paper gives clear idea about different methods that are used for reducing the encoding complexity. Based on review of different methods and their Compression algorithms we conclude that all these algorithms depends on quality of image, amount of compression and speed of compression.

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