

SURVEY OF FRACTAL IMAGE COMPRESSION TECHNIQUES

¹T.Janani, ²Shennes Mathew, ³S.Deepa

^{1,2,3}Assistant Professor, Department of ECE, Karpagam College of Engineering

Abstract: Image compression is a method by which we can reduce the space for storing images, video which will be helpful in transmission performance. There are many applications which require image compression such as multimedia, internet, remote sensing etc. This paper presents analysis of fractal image compression (FIC) techniques, fractal compression is a lossy compression methods for digital images, based on fractal. The method is appropriate for natural images and textures. FIC is an image coding technology based on the self-similarity of image structure and broadly used in image de-noising, image encryption etc. In this context, the review summarises the major FIC method spanning across different FIC technique.

Keywords: Fractals, Iterated Function System (IFS), Image Coding, PSNR

1. Introduction

Image compression deals with minimizing number of bits used to represent a digital image without destroying the quality of image. Data compression has become a vital concern for information transmission and storage [3]-[5]. Large amount of data cannot be stored if there is a low storage capacity, hence compression plays a very vital role in transmission and storage. Basically there are two types of compression methods [6]

1. Lossless compression method
2. Lossy compression method

In lossless compression methods the reconstructed image after the compression method is applied, is identical to that of the original image i.e. there is no loss of information in the image. It is broadly used in the field of medical image processing, where each minute information details is very important.

In lossy compression method, the reconstructed image after applying compression methods contains quality degradation relative to the original image, but to an acceptable level. In general lossy compression method is widely used because higher compression ratio can be achieved compared to lossless compression method [3]. The rest of this paper is organized as follows. The concept of fractal image compression is briefly summarized in section 2. The property called iterated function system is explained in section 3. In

section 4 we focus on the property of self-similarity. In section 5 various Fractal compression techniques are discussed. Finally the conclusion of various methods is drawn in section 6.

2. Fractal image compression

Fractal Image Compression (FIC) was first proposed by Michael Barnsley in 1987 [1], who introduced basic principle of FIC. FIC is a technique which is used to encode the image in such a way that it reduces the storage space by using self-similar portion of the same image. FIC is a lossy compression technique for digital image, based on fractals.



Figure 1. Example of fractal fern

In certain images, some parts of the image resemble the other parts of same image, these self-similar parts are called fractals and these fractals are used in order to compress image. Fractal algorithms convert these parts (referred as fractals) or geometric shapes into mathematical information which is also called as 'fractal codes' which are later used to reconstruct an image. One of the images is converted into fractal code it become resolution independent. In the below Figure1 we can observe that whole image is repeated pattern of the part of the same image.

2.1 Merits and Demerits of FIC

When compared to other compression method which is used for compressing different kind of images, FIC has some main advantages and drawbacks.

Merits

- Achieves high compression ratio
- Fast decoding

- Resolution independent
- Mathematical encoding frame

Demerits

- Encoding speed is slow

3. Iterated Function System (IFS)

According to Michael Barnsley, an image can be represented as a set of mathematical equations and this idea of taking an image and express it as an IFS code forms the basis of FIC, but this found impractical because of its complexity, an improvement is made to it by Arnaud Jacquin [2], by using partitioned iterated function system (PIFS). PIFS consists of metric space X , a group of sub domain D_i , $i=1, \dots, n$ and a group of contractive mappings W_i : $D_i \rightarrow X$, $i=1, \dots, n$. The images with the IFS are called affine transformations.

In IFS mapping, coefficient will represent a data of block of the compressed image. Thus a digitized image can be stored as a collection of Iterated function system (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.

4. Self- similarity property

Self- similarity is one of the basic properties of fractal image. An object is said to be self-similar if it looks “roughly” the same on any scale. Figure1 shows an example of fractal. But all image doesn't contain this type of self-similarity found in fractals, rather it contains different sort of similar portions [8], [9]. Self-similar portion in the Lena image it shown in the below Figure2. A part of her shoulder overlaps smaller regions which is almost similar, and piece of the reflection of the hat in the mirror similar to the smaller part of the Hat [7]. In this kind of image only a part of image is self-similar where as in Figure1 entire image is self-similar.



Figure 2. Displaying self-similarity different locations

General Fractal Encoding Procedure

Step 1: Read the binary image.

Step 2: Convert it into grey level image.

Step 3: Divide the image into small square blocks without overlapping called as range blocks.

Step 4: Introduce large square blocks, with overlapping called as domain blocks. The size of domain block is double the size of range block.

Step 5: For each range block find the matching domain block which closely resembles range block with respect to some metric and accordingly parameters are computed.

Step 6: Write out compressed data in the form of local IFS code.

Step 7: Apply data compression algorithm to obtain a Compressed IFS code.

5. Fractal Image Compression Techniques

The significant computational requirements of the domain search resulted in lengthy coding times for early fractal compression algorithms. The design of efficient domain search techniques has consequently been one of the most active areas of research in fractal coding, resulting in a wide variety of solutions. The various techniques in the literature related to fractal image compression (FIC) are reviewed to improve the efficiency of FIC.

A. Invariant representation

The search for the best domain block for a particular range block is complicated by the requirement that the range matches a transformed version of a domain block; the problem is in fact to find for each range block, the domain block that can be made the closest by an admissible transform. The problem may be simplified by constructing an appropriate invariant representation for each image block. Transforming range and contracted domain blocks to this representation allows direct distance comparisons between them to determine the best possible match [15].

Invariant representations for the single constant block transform utilise the DCT (or another orthogonal transform) of the vector followed by zeroing of the DC term and normalisation [16]. This representation can decrease the time required for an efficient domain search, and allows the utilisation of a distance measure adapted to the properties of the human visual system.

In [10], FFT based fractal image coding with variable quadtree partition is used. This algorithm is applied to the approximation subband and three detail subbands of the wavelet transformed image. Quadtree partitioned wavelet subtree is constructed after wavelet decomposition of fractal decoded approximation subband image. The self-similarities existing in wavelet subtree are exploited by predicting the coefficients at

finer scale from those at coarser scale using affine transformation.

In conventional fractal coding algorithm the main drawbacks are high encoding time, blocking artifacts at low bit rates. These twin drawbacks can be avoided if fractal transformation is in the wavelet domain. Many authors combined wavelets with fractal coding to obtain high quality for compression at low bit rate. The objective of combining wavelet and fractal coding is to increase the encoding speed and high compression ratio than pure fast fractal algorithm. Wavelet transform perform decomposition of image signals into multi resolution with set of tree structured coefficients. These coefficients have the same spatial location with different resolution and orientation. In wavelet transform based fractal coding, the high frequency coefficients of one level is predicted from the next level subband coefficients because they are highly correlated. Fast fractal encoding, normalized cross correlation with mean square error (MSE) as matching criteria is applied to only low frequency components using quadtree partition. Other wavelet coefficients are predicted using non iterative fractal coding with variable size subtree representation.

This helps to improve the visual quality without blocking artifacts at low bit rates than JPEG. Regarding speed, the proposed method presents an average 92% reduction of coding time comparing to the fast fractal image coding. But the main drawback in proposed method is that, for high bitrates, the visual quality is poor as there is blocking artifacts.

B. Fitting Plane

In [11], based on Wang's fitting plane-based fractal image coding using least square regression (LS-FPFIC), Jian Lu, Zhongxing Ye and YuruZou proposes an efficient Huber fitting plane-based fractal image compression method (HFPFIC). In the HFPFIC, by building Huber fitting planes for the domain and range blocks, a new matching error function is proposed to avoid that the corrupted data is present as the independent variable in the Huber regression model, and a weighted operator is utilized to eliminate the influence of outliers on evaluating the matching error. Since the Huber fitting planes for all domain blocks are calculated in advance before the matching process is carried out, the number of robust regression-iterations for full search HFPFIC is considerably reduced when comparing to the other full search robust FIC methods.

Furthermore, this paper proposes a normalized median absolute deviation about the median(MAD) decomposition criterion used as adaptive quadtree partitioning scheme, which works very fast and achieves very nice partitioning results both for noiseless and salt & pepper noisy images. In order to relieve the high computational complexity, the no-search scheme is utilized to accelerate the encoding

process. The results show that, especially for the noisy image corrupted by salt & pepper noise, compared with conventional robust fractal image coding methods, the proposed algorithm can save the encoding time and improve the restored image quality efficiently. It is shown that, when applying the Huber fitting plane (HFP) technique to encode the corrupted image directly, it can achieve good image quality and extremely fast encoding speed.

Though FIC methods achieved robustness against the outliers caused by salt & pepper noise they do not show significant improvement in image quality for Gaussian and Laplace noises. However, these robust FIC methods are not quite satisfactory. Besides the high computational cost, the domain block containing hidden outliers under the samples is used as the independent variable in the robust regression model, which may negatively influence the performance of the robust estimator for the computation of the fractal parameters.

C. Classification

Classification based search techniques often do not explicitly utilise an invariant representation as formalised above, but rely instead on features which are at least approximately invariant to the transforms applied. Domain and range blocks may either be classified into a fixed number of classes according to these features[12][16], a matching domain for each range only being sought within the same class, or inspection of domains may be restricted to those with feature values close to those of the range.

In [12], a novel fractal compression scheme to meet both the efficiency and the reconstructed image quality requirements is proposed. This scheme is based on the fact that the affine similarity between two image blocks is equivalent to the absolute value of Pearson's correlation coefficient (APCC) between them. Firstly, all the domain blocks are classified into 3 classes according to the classification method. Secondly, the domain blocks are with respect to APCCs between these domain blocks and a preset block in each class, and then the matching domain block for a range block can be searched in the selected domain set in which these APCCs are closer to APCC between the range block and the preset block. Since both the steps in our scheme are based on APCC which is equivalent to the affine similarity in FIC, the reconstructed image quality is well preserved. Moreover, the encoding time is significantly reduced in our APCC-based FIC scheme. The block D satisfying $|p(R,D)| \rightarrow 1$ is usually hard to search for R, it is important to choose a proper block as the preset block B to search the best approximate D.

D. Segmentation

In [13], KamelBelloulata and JanuszKonrad explore fractal image coding in the context of region-based functionality with two region-based fractal coding schemes implemented in spatial and transform domains, respectively. In both approaches regions are defined by a prior segmentation map and are fractal-encoded independently of each other. A new dissimilarity measure is proposed that is limited to single-region pixels of the range block. The computational complexity of encoding an image using the proposed method is directly related to the size of search space over which the distortion is minimized; the number of permissible domain blocks plays the dominant role. The most demanding case is when each segment of every domain block of the image is considered; the domain-block codebook is built from the whole image. This exhaustive procedure is theoretically optimal but extremely involved computationally. Moreover, it does not allow for independent decoding of regions.

In DCT-based fractal coding, boundary range blocks contain pixels from two or more objects. Thus, similarly to the spatial-domain case, independent decoding of objects is not possible. Also, the coding quality may suffer since pixels on different sides of the boundary may have different characteristics; by applying the standard DCT to such a block, spectral properties of these pixels are mixed up making the search for a good range-domain correspondence unreliable. In particular, a sharp intensity transition may cause significant spectral oscillations.

E. Feature Extraction

In [14] Riccardo Distasi, Michele Nappi, and Daniel Ricciopropose a new approach, namely deferring range/domain comparison (DRDC), based on feature vectors. The main idea is to defer the comparisons between ranges and domains. Rather, a preset block is used as a temporary replacement. The preset block is computed as the average of the ranges present in the image. The coding phase is divided in two phases.

In the first phase, where the domain codebook is created, all the domains are extracted from the image, then each of them is compared with the preset block by solving a mean square root problem. The preset block/domain approximation error is computed and stored in a KD-tree data structure. In the second phase, the ranges have to be encoded; each one of them is compared with the preset block, thus obtaining the preset block/range approximation error, in the same way as performed for domains. Using this data, it is found the domains that are likely to encode the current range with the best accuracy. This criterion proves that a generic range block is accurately coded by domains with equal or similar approximation error. In this way,

for each range we have to perform a much smaller number of range/domain comparisons, and the time spent for coding is significantly reduced.

It is evident that the proposed algorithm performs better than the baseline algorithm in terms of time and PSNR. However, one of the difficulties with fractal coding is that its faster implementations tend to be a little memory-hungry. Therefore, it is interesting to consider the methods under exam from the point of view of memory usage, showing in what circumstances the domain tree results in memory savings respect to the other spatial access methods.

6. Conclusion

The field of fractal compression is comparatively new, as it is the study of fractals. It is one of the techniques used for image compression due to considerable merits of resolution independence and rapid decoding. The main concept used in this compression scheme is to use IFS to reproduce image. In this paper many FIC techniques is reviewed and based on the experimental outcomes given by respective authors we conclude that the algorithm which satisfies, 1) less encoding time i.e., the rate of convergence for reaching best block or the speed of compression with high PSNR and 2) better visual quality after decoding, and hence the good PSNR is considered to be the best fractal compression algorithm.

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