Contemporary Bench Mark Techniques in Fractal image Compression-A Survey

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ABSTRACT
Fractal Image Compression (FIC) is a extremely improving modern technique in the field of data and image compression; it is based on representing an image with affine contractive transform using features of self-similarity found in the image. This technique in recent time has achieved intense recognition because of its desirable advantages like very high compression ratio (C.R), high decoding speed, far above the ground bit-rate, very aggressive rate-distortion and non dependency on resolution. FIC principle is also useful in content based retrieval of an image where digital picture archives are organized by their visual content. However, the long encoding time, complexity involved in search process and parameters of quality decoding issues are being explored by new contemporary hybrid methods in fractal coding some of latest methods are discussed in this paper. These new contemporary bench mark methods target to improve key issues of reduction of encoding time and maintain the fidelity of an encoded or reconstructed image. A detailed investigational survey on important methods used in fractal image compression to improve on its limitations are made in this paper with reasonable conclusions and approaches to overcome them. 

Keywords : Fractal, Image compression, PSNR, Compression ratio, Evolutionary Algorithms, IFS & Parallel processing

1. INTRODUCTION
The idea of fractal was initiated by Fisher [1] as a substitute to the Euclidean geometry which involved with shapes naturally existing in nature. In recent times, this theory of applying fractals has been growing popularly in the area of computer vision and graphical image analysis using an iterated function system (IFS). IFS are being used successfully to generate and represent fractal images of both man made and naturally available. Barnsley et al were the first to conceptualize FIC technique using IFS [1], Jacquin [2] proposed gray scale compression of images in real time named fractal block code(FBC) which had innovativeness of capturing and exploiting image redundancy and self similarity which did not exist in traditional techniques of image compression. Normally, fractal code uses only few bits to represent an original image leading to very good C.R but sometimes they exhibit inefficiency in image compression metrics at specific image regions like PSNR etc. To utilize the advantage of FIC technique and limit its disadvantages some hybrid methods are developed which form the bench mark techniques in FIC leading to overall improvement in compression metrics.

A FIC method utilizes redundancy in various regions of image representing them by fractals instead of pixels. Each fractal is identified by its distinct IFS called Partitioned Iterated Function System (PIFS) from a set of affine transforms. The important objective of fractal code is to extort the regions or fractals in the image which can be approximated and be represented in the form of mathematical transforms. Fractal code for image proposed by Barnsley and Jacquin resulted in the various studies of IFS development based compression techniques with fractals as the basic idea in the recent past.

Barnsley [3] modelled real life image coding using IFS by a method of deterministic object based on fractals, resulting in a group of contractive transforms. Here IFS and collage theorem were used to introduce FIC for the first time which became the foundation for all techniques based on fractal compression. This technique approximated a real image by just storing required transform parameters instead of entire image.
reducing drastically memory storage requirement. The challenging task in FIC is finding a proper transform parameter which approximates attractor value for the original image. Jacquin [2] implemented for the first time an automated fractal compression technique for a monochromatic digital image. Here the encoding is based on approximation of smaller blocks of the image from the larger blocks using certain operations. The small blocks were named as range blocks and larger blocks were named as domain blocks. Separate transformation for every range block was obtained. This process used vector quantization for classifying the range domain blocks.

Advantages of FIC are fractal parts of image are stored in the mathematical form instead of bit maps. Hence decompression of it can have high or low resolutions of the original image. FIC as compared with JPEG has the ability to scale images without distortion.

Limitations or major concerns in FIC are as it based on self-similarity present in the image, images with arbitrary content do not have good compression. Randomness feature of image exhibit very less similarities within variable image sizes leading to further distort compressed image. Due to extensive search between image blocks, it shows high encoding complexity than decoding resulting in more compression time.

Section 2 presents a base line algorithm for FIC. Section 3 section conducts detail literature investigations on existing benchmark models in fractal compression. Section 4 & 5 discusses contemporary evolutionary methods and parallel algorithms for FIC in. Section 6 presents, research issues found in FIC and finally section 7 deals with summary & conclusions.

2. BASELINE FRACTAL IMAGE (FI) ENCODING ALGORITHM.

In a general basic model of FI, encoding is done such that the given image is divided into non overlapping equal size square blocks called as range Blocks. A transformation parameter is established for each and every range block or Block range. Figure 1 shows comparison search of domain range blocks. Figure 2 Illustrates diagram for Fractal coding process and figure 3 illustrates Flow diagram for baseline fractal compression Algorithm

![Diagram](image1)

Figure 1 Domain and Range search indication

The FI coding tries to locate a group of contractive transformation that maps domain cell against a group of range cells that strips the image. The fundamental steps in fractal coding are as stated below

- First the entire original image to be compressed is divided to square block cells which do not overlap each other called Range cells (R) or Block ranges
- Next image is now partitioned into a series of overlapping non uniform size large number of blocks called Domains (D) or Block domains (Block Domain) generally at least size double of range block.
- Match the transformations that are most similar to the Block ranges recognized by adjusting contrast, Range Block brightness through affined transformations
- Encode the image with information of every range cell location and domain map to its range and transformation parameters S & O

$$S = \frac{\sum_{i=1}^{n} D_i S_i}{\sum_{i=1}^{n} D_i}$$

(1)

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\[ O = \frac{1}{n} \left[ \sum_{i=1}^{n} R_i - s \sum_{i=1}^{n} D_i \right] \]  

For every R block, the greatest matching D block should be found by relative changes of W from equation (3).  

\[
W \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} a & b & 0 \\ c & d & 0 \\ 0 & 0 & S \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} + \begin{bmatrix} c \\ f \\ o \end{bmatrix}
\]

In above relative changes \( w, s \) manages image contrast, \( c \) manages Range Block brightness. The eight transform matrices as \( a, b, c, d, e, f \). These eight matrices represent their dihedral form stages as identity, +90º rotations, +180º rotations, -90º rotations, mid-vertical axis reflection, mid-horizontal axis reflection, first diagonal reflection and second diagonal reflection.

**3. BENCHMARK MODELS IN FRACTAL IMAGE COMPRESSION**

**3.1 Block Partitioning Based Methods**

In FIC system the Important and foremost criteria is to decide or select the partition method for image Range Block formation [4]. A vast range of partition methods are available in contemporary literature few of the important ones are discussed here. The simplest partitioning is the square size blocks of non varying size [4]. Another popular approach is of quad tree where in degree of similarity is tested after dividing image into 4 equal size blocks of square shape. Hexagonal spiral architecture are some of the other techniques. Compare to above mentioned literature a Quad-tree(QT) based block partition performs with better rate distortion. Non equal partitioning exhibits better metrics compared to fixed squared and quad tree, but pixel correspondence with Block Domain and Range Blocks is complex requiring interpolation. In quad tree approach encoding time is enhanced based on Range Block, gray scale difference and its ratio. Using QT satellite images are compressed with Huffman code obtaining a better C.R and PSNR in urban images than compared to rural as rural images have less fractals or similarities. A non overlapping Block Domain with QT is proposed with

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**Figure 2 Illustrative Diagram for FIC coding**

**Figure 3 Flow diagram for baseline FIC**

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four contrast scaling values in .In Quad tree (QT) [3] a circular array is utilized for re composition of sub blocks from least level to highest level of fractals as a pipelined method using processors yielding better results for complex gray shade images than conventional QT. A new approach of combining QT and Quad decomposition is introduced for gray shade and edge image blocks [4].

3.2 Block Classifying Based Methods

Image classification is the common technique used for reducing range block search complexity wherein the Range Blocks and Block Domains are separated into groups by their similar features. In the approach suggested entropy based domain pools [5] are formed, the domain blocks are separated in 2 pools one with odd position and other with even position Block Domain. First search is performed for even pool of Block Domains and then entropy difference between domain and range is calculated. If it found less than threshold, the search is stopped else a even position search is started. By this approach image quality slightly reduces but speed up factor compared to full search increases by eight times [5]. A Graph-based segmentation is applied to separate input image into areas of image content with search space construction. Adaptive threshold QT is used for encoding a logic area and a DCT block is employed for edge classification either in horizontal or vertical direction. Here structure similarity (SSIM) index is utilized to decrease computation complexity as compared to MSE. This method encodes faster by a factor fifteen compared to full search. Other method using diamond shape domain pool reduction adaptive partitioning method reduces range block partition and classification based on mean and variance [5].

3.3 Block Transform Based Methods

These methods propose as Lossless acceleration based on codebook coherence of FFT image partition and fast convolution Q.T partition uses down sampling by zero padding to Range Blocks. This transform method can decrease the time complexity of FI coding and is well applied for lossless applications of image compression.

FFT based block match transform is used for hadamard product by decimating blocks to vector using suitable scanning and circular shift techniques. Troung proposed hadamard transform [6] for reducing MSE calculations and applying on image compression reduced PSNR by 1.5 to 2.5 decibels. Applying DCT transform-inner product method [6] redundant computation is removed when simultaneously implemented for eight fractal orientations. This method improves nearly 6 times quicker than baseline FIC method without change in its image quality. An optimized Block Domain search in frequency domain of Fast DCT coefficient-based metric operation is proposed by converting uniform size square shape blocks into one dimensional array for calculating DCT. Another wavelet transform proposed by Haar is used for sub-tree quantization where in fractal coder analyzes using Haar wavelet coefficients [6] to map similar regions in an image. Pure-Fractal and Wavelet-Fractal compression is related to DNA micro array images exhibiting larger degree of self-similarity.

3.4 Block Feature Extraction Methods

Feature extraction adaptive pixel value difference method works for best domain range comparison match only if range pixel value is within the domain pixel value difference. In another method normal variance of Block Domain is more than that of Range Blocks with fixed block size. Both of these methods have less coding time with good image quality after reconstruction. A method for medical and satellite image is proposed on entropy difference of range domain blocks with a pixel value difference. A fractal encoding algorithm for an adaptive search is proposed for range check with Block Domain to meet condition of adaptive search shown in equation 4 with a tolerance factor of θ. For these methods in every Range Blocks the nearest allocation for the simultaneous quantization of a neighbour Block Domain is obtained achieving better scaling and affine parameters.

\[ |\text{std}(R_i) - \text{std}(D_i)| \geq \theta \cdot \text{std}(R_i) \] (4)

3.5 Nearest Neighbour Based Search Techniques

Multidimensional FIC nearest neighbour search method operates on a logarithmic time scale as compared to baseline linear search. It is used to improve coding speed and can easily be integrated with existing classification methods. Another method for neighbour prediction algorithm based on sub blocks uses variable
size Range Block based on the mean value of domains relevant with four neighbouring blocks. Alternatively block ranges are decomposed again into 4 quadrants based on QT decomposition principle. Inter block correlation is other technique for neighbour search using four domain blocks as good candidates for the input Range Blocks having high correlation. Else, a local variance method is used to locate the best match domain block for a faster search.

3.6 Other Hybrid Block Based Methods

Other hybrid Range Block methods for fractal grey scale compression are Quantum Evolutionary Algorithm (QEA) proposed based on local operator search. Here convergence of population with a simulated annealing is adopted for a local optimal solution. Particle Swarm Optimization (PSO) technique is used for matching Block Domain search by classifying range domains into 3 regions by their third level DW coefficient. Another popular scheme is reconstructing an original image by hard threshold and then dividing them into non-overlapping ranges of small size and domains with large size.

The issue of how to effectively partition images in FIC is shown by varying range blocks effectively into minimum and maximum size block ranges. Obtained results are better in terms of C.R and PSNR for reconstructed images compared to basic and existing FIC methods [7]

4. HYBRID RANGE BLOCKS AND EVOLUTIONARY COMPUTING APPROACHES IN FIC

Chakrapani et al. [8] proposed a technique of back propagation for FIC which basically follows a neural network approach. The major drawbacks of traditional FIC are exhaustive search and more computational involvement. This method uses global search providing trained artificial intelligence for feature extraction improving C.R and C.T. The feature extraction technique used in a neural network method decreases the problem of dimensionality enabling the given image to be trained separately from the sample or test image resulting in less computational time and less number of computations during its search procedure. The important improvement of proposed neural method is its capability to adapt itself for a trained data. It can adapt during its training phase itself as per the distribution of features observed.

The critical issue of more MSE computations, high encoding search time in existing FIC is dealt [9] with proposed method using evolutionary algorithm of Cuckoo search. The proposed method here uses Cuckoo search technique with Levy flights to reduce maximum number of iteration search per Range block, resulting in decrease of encoding time both for CPU and GPU. Obtained results show that even for proposed optimized search, this method maintains PSNR value comparable to full search baseline FIC. [9]

4.1 Hybrid Range Blocks Artificial Neural Network approach

The primary aim of hybrid Range Block size FIC using Artificial Neural Network (ANN) approach is to build up a neural network which can classify the domain block objects of grey image with improved coding time and image quality. As FIC is based on self-similarity attempting to find contractive transforms which map domain blocks to range blocks ANN uses this clustering of domains as an initial step. Matching of domain- ranges takes longer time for encoding so an efficient algorithm must be used to properly classify image into domain range blocks and decrease their searches. In this hybrid Range Block size method domain range matches are made for domain blocks belonging to the similar range class. Feature extraction is made from classification technique to identify the blocks of domain whose feature vectors are within threshold level of range blocks classified.

4.2 Hybrid Range Blocks Genetic-Simulated Annealing Approach (HGSAA)

HGSAA utilizes FIC hybrid Range Block size method with simulated annealing of GA avoiding a premature convergence of strings. The Domain range mapping process of Range Block complexity in encoding is avoided here using GA technique and SA (Spiral Architecture) approach. GA provides optimized solution in many applications performing its fundamental five operations of initialization, fitness choice, cross over and mutation. GA at first generates chromosome populations and finds genes in a chromosome with the best and fittest. Generally strings of symbol are used to search for the best. Secondly, the production process is
carried for the strings creating a pool for mating. Lastly crossover and mutation phases are carried with strings with their existing probabilities and termination criterion with at least 424 fitness functions attained.

4.3 Hybrid Range Block size Genetic-Neural Approach

This hybrid Range Block size approach is utilized in FIC method for dropping computational time and boosting C.R. Once fractal coding of image is complete feature vector extraction starts for the given classifier domain blocks. Utilizing this classification long time of encoding reduces with less number of range domain search computations. More advanced classifying methods utilize predefined class sets for allocating classifier for each domain to any of the available classes.

4.4 Genetic Algorithm with Schema Theory Approach

Genetic algorithm (GA) method is hybrid Range Blocks with schema theory for FIC with an aim to decrease time required to find a replacement block to the given original image. This approach uses the mixture of person knowledge and search by GA and schema theory. The primary motivation for this hybrid Range Block algorithm is based on natural properties, where a high fitness object is used for its replacement with existing one. Here each block has a permutation by a factor of 425 for locating its best match in its adjacent blocks. It is covered by crossover and mutation mechanisms of schema theory resulting in diversity of population.

4.5 Particle Swarm Optimization with Genetic Algorithm approach

This method proposes a PSO hybrid Range Block with a GA approach for reducing compression time and improves C.R. This FIC technique uses spatial correlations of images to find best match in the domain pool. Here compression takes place in two steps first making spatial correlation using a local optimal solution next if local does not satisfy then entire image similarities are considered for optimal search. It is observed that some neighbour block domains do not exist when applicable. More gaps between the local and global optimum solution is avoided through pre defined threshold by a baseline method. This algorithm is activated when the gap exceeds minimum threshold level. This proposed method of PSOGA first selects the best match where MSE value is less than threshold T for recorded fractal code.

5. FRACTAL IMAGE COMPRESSION BY PARALLEL ALGORITHMS

A more number of schemes are found in literature for parallel execution encoding of FIC. These algorithms have more computational cost when used with FIC by an order of $O(I^4)$ for $I \times I$ pixel image. It has an advantage of speeding up compression process and as decompression is already faster it does not affect much in it. Some of these techniques describing parallelization [10] are discussed having considerable improvement in FIC encoding time compared with baseline FIC.

5.1 Based on Classification by Granularity

A simple classification of parallel algorithm is based on either “fine grained” or “coarse grained”. But recently there exists other than these two levels one extreme proposed by using $n^2$ processors where n is image size working with a single pixel. In other method proposed [10] image is partitioned among the available processors applying sequential FIC on their own sub block image with no communication. This algorithm is highly coarse grained, but lacks quality in compressed image compared to sequential technique.

5.2 Based on Classification by Data Partition

This classification method is a popular mechanism especially for coarse grained algorithms, as presented in [10]. Here basically two main issues are considered first one is whether each processor has the enough space memory for storing entire image copy and next is whether domain pool access is with or without any communication. The first issue arises when a parallel architecture of shared memory is used or when architecture of distributed memory available is more on each processor. Most of the architectures, have emerged for scaling distributed memory resulting in adequate memory to store image of even high resolution. In FIC methods for domain classification using parallel algorithms [10] have used some processing elements.
The issue of high searching time and the computational complex search is addressed and improved in chapter 4 by implementing Spiral Architecture based Range Blocks variable range FIC. Proposed method obtains a smooth and complexity reduced search of domain range with improved C.T, C.R and PSNR. [11]

5.3 Based on Classification by Load-Balancing Algorithm

This algorithm portrays the available parallel techniques which ensure equal load distribution across accessible processing elements. This classification is based on three categories i.e pipelining algorithm, a static load balancing method partitioned on block ranges and dynamic partitioning algorithm. The architecture presented in shows each Range Blocks comparison with a dissimilar Block Domain at any stage. After the completion of comparison process Block Domains are carry forwarded to next processor which is in queue for the next comparison. After all the domain blocks pass from the pipeline range comparison stops for all blocks. A related technique is agreed and described focusing on pipeline approach design.

6. OPEN ISSUES OF FRACTAL IMAGE COMPRESSION

With all the above discussed literature survey, it is investigated that following are the open issues still existing in FIC techniques

- Partitioning or formation of Block ranges and Block domains for the given image
- Quickly Search a perfect block domain match for a similar block range
- Minimise or speed up encoding time with least possible MSE searches
- Optimize domain pool with minimum transforms to match all image block ranges to speed up the image encoding
- Apply contemporary techniques of image compression with existing FIC and Range Block size them to obtain better image compression metrics suitable for various image categories.

7. SUMMARY & CONCLUSIONS

This Survey paper has made a serious attempt to investigate the latest FIC techniques existing and their critical issues some of the conclusions made are as follows:

- The issue effectively partition images in FIC is solved by block partitioning techniques varying range blocks effectively into minimum and maximum size block ranges.
- The issue of high searching time and the computational complex search is addressed and improved by better Range Block searching methods like Spiral Architecture, Range Block size variable range FIC with improved Compression time & image fidelity.
- The issue of more computations, high encoding search time may be solved by evolutionary algorithms like PSO, GA, Ant colony Optimisation , Cuckoo search etc.

REFERENCES


