Fast Search Approaches for Fractal Image Coding: Review of Contemporary Literature

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Abstract

Fractal Image Compression (FIC) as a model was conceptualized in the 1989. In furtherance, there are numerous models that has been developed in the process. Existence of fractals were initially observed and depicted in the Iterated Function System (IFS), and the IFS solutions were used for encoding images. The process of IFS pertaining to any image constitutes much lesser space for recording than the actual image, which has led to the development of representation the image using IFS form, and how the image compression systems has taken shape. It is very important that the time consumed for encoding has to be addressed for achieving optimal compression conditions and predominantly the inputs that are shared in the solutions proposed in the study, depict the fact that despite of certain developments that has taken place, still there are potential chances of scope for improvement. From the review of exhaustive range of models that are depicted in the model, it is evident that over period of time, numerous advancements have taken place in the FCI model and is adapted at image compression in varied levels. This study focus on the existing range of literature on FCI and the insights of various models has been depicted in this study.

***Index terms*—**

1 I. Introduction ractal Image Compression (

) FIC as a model was conceptualized by Barnsley [1] and over a period of time, the first of its kind of such a model implementation is carried out by Jacquin in 1992 [2]. The underlying concept that has supported in development of an effective model is on the basis of partitioned iteration function system (PIFS), where the self-similarity property has been adapted for achieving the desired compression [3].

In 1982, Mandelbrot a reputed mathematician has proposed the conceptual development of Fractal [4], which was used by Barnsley [1] in introducing the model in the year 1988, which was advanced and realized to the implementation levels in further stages by Jacquin [2], by providing practical coding algorithm designed on the basis of PIFS.

There shall be much of redundant information in majority of natural and also the artificial objects, in the form of repeated patterns called as fractals [5], which normally occur in all levels and could be envisaged as virtually identical, in various positions and sizes. Existence of fractals were initially observed and depicted in the Iterated Function System (IFS) [6], and the IFS solutions were used for encoding images. The process of IFS pertaining to any image constitutes much lesser space for recording than the actual image, which has led to the development of representation the image using IFS form, and how the image compression systems has taken shape. FIC (Fractal Image Compression) is certainly an effective method of portraying the nature images in a loss image compression. In the FIC method, rather than adapting the pixels method, the fractals are adapted for improving the system, and in fractal image, the image comprise contractive affine mappings for the entire image.

In a conventional approach of fractal image compression developed on the basis of collage theorem, in which the estimation of the distances between the image that are to be encoded and the fixed point of a transform for an image is estimated as collage error. But the crux for effective image compression is that the collage error should be very much minimal as possible. [7], [8]. Even in the process of retrieval, the method of self-similarity model has been very effective. However, one of the key challenges in the process fractal image compression method is the time consumed for the encoding purpose.

Profoundly, the method of fractal image compression is adapted in the process of image signature solutions [9] and texture segmentation process [10]. Also in the process of image retrievals [11,12] and the distinct methods like MR and ECG based image processing [13], too the method of Fractal Image Compression models are adapted, But the issues pertaining to lengthier encoding time is turning out to be a major setback in the model.

For instance, in the process of encoding, it is very essential to evaluate the high volume domain blocks for similarity evaluation with range blocks, and in the scenario of range blocks that are of improvement in the area of reducing the encoding time, which can facilitate in improving the system efficiency.

In terms of reducing the encoding time, there are numerous models that were proposed earlier. For instance, the concept of image redundancies is efficiently used by focusing on block of self-affine transformations, which could lead to fractal image compression solution (FIC). Numerous methods have been targeted in terms of addressing the conditions of encoding time, but one of the common ways that has been envisaged in the process is about the classification of blocks to a varied sets having range and domain blocks for the same set selected for matching.

The impact of such process is about reducing the encoding time, but the quality of the image might be jeopardized in such conditions. Reducing the size of a domain pool could be another significant method adapted in several ways. In a model proposed in [15] the domain blocks with little entropies shall be deleted from the domain pool [14], and in additional to the size of domain pool, as computational cost of matching a range block and also the domain block has significant in the encoding time. Such costs have been reduced by focusing on approximate optimum values for contrast scaling factor rather than search for it. A new model of [14] has been proposed in the combination of aforesaid points, and the new fractal image coding that is proposed has been one of the most effective methods resulting in much lesser encoding time.

Fractal coding is considered to be one of the most effective codec methods, and there are many academic researchers focusing on the process for more designing the models that could achieve more effective compression ratio, high levels of decoding speed, independent resolutions etc. [16], [17], [18]. In the other dimension, it also focus on other kind of image processing applications, which has image retrieval [19] solutions, elimination of image noise [20] [21] and the digital water marking solutions [22] [23].

Among the very popular approaches towards fractal video sequence coding, in the first model, the extension of still-image related scheme to threedimensional blocks of video are adapted. Despite the fact that in such model the data compression is effective, still the quality levels are not up to standards as severe blocking artifacts are envisaged in the process.

The other model adapted in the combination of intra-frame and the motion-compensated ways of interframe fractal coding is the second popular model adapted. Significant method like hybrid circular prediction mapping and the non-contractive inter-frame mapping (/) CPM NCIM [24] in which the fractal video coding is combined with usually adapted motion estimation and motion compensation (/) ME MC based algorithm.

In such a model, (/) ME MC it focus on high temporal correlations amid of adjacent frames. The key difference in the process is about how CPM shapes up. CPM has to be contractive to the iterative decoding process for convergence, but NCIM need not be contractive in such instances due to the fact that the decoding of NCIM has been on decoded, frame sand is non-iterative. In the current solutions, the CPM frames are decoded using 6 iterations, and majorly the NCIM frames are usually coded with earlier reference frame. Both inter/intra coding and the three dimensional fractal block coding techniques are resulting of resolutionindependent model in the spatial domain. NAL indicates the bit stream which is formed on the basis of representation of coded pictures and also the associated data taking place from the coded video sequence.

The kind of digital developments that are taking place and the volume of image creations and image processing that is taking place, it is imperative that there are significant developments that are taking place in the process and still the issues of reducing the encoding time is not addressed effectively in the system and there is profound scope for research in such models. However, to ensure that the study has reviewed in-depth about various kinds of challenges envisaged in the process, extensive review of literature is carried out to understand the scope and efficacy of the existing systems, and the areas in which there are significant chances of development.

2 II. Review of Literature

Numerous research studies has been carried on the image processing and in many of such image related studies, Fractal image compression (FIC) has been the centric point. In many of the earlier studies, there are significant inputs related to how some of the classification methods were normally adapted, in which the preprocessing step primarily constitutes classification of ranges and domains. However, one of the key factors to be taken in to consideration is about how at every search only, only domains that has similar class has been assessed. [25], [26], [27], but the domain pool reduction is other effective technique that was proposed for reducing the encoding time. Predominantly the method in which the location of search space to the blocks for which the spatial location is close to the range location [28], [29] has been predominantly used in the process.

Wavelet transformation is the other solution that is adapted, in which the original image is decomposed to various frequency sub-bands for extracting the attributes from the wavelet coefficients related to varied sub-bands. Distribution of such wavelet coefficients shall be resourceful in multi scale classification of a document image which is context based [30]. In order to surface data by using the wavelet transform coefficients, from the triangular mesh, fast and efficient algorithm was adapted [31], as it directly identifies the local area complexities for an image and divides the square cells on the basis of complexity. In [32], the authors have focused on the model of hybrid image classification method which focuses on combining the wavelet transform, artificial neural network and rough set approach. In another study, Zou and Li have proposed the method of wavelet coefficients for low-pass bands [53], and such an approach is dependent on the distribution of histograms for wavelet coefficients.

In the recent studies, adaptation of PSO to the fractal images compression model has been proposed. In the proposed application, PSO based Huber FIC (HFIC) [34], shall be robust against any kind of outliers in the image and shall support in reducing the encoding time. Also, there are many other methods like image correlation, spatial correlation method which denotes the neighbor blocks that usually have some similar properties for edge relation, which can support in reducing the encoding time.

In other dimension, if one block has some kind of vertical edge, either the upper or lower block shall have similar kind of vertical edge, and using such properties the searching space shall be reduced, thus resulting in much faster encoding speeds. In [35], the authors have focused upon SC-GA method in which the combination of spatial correlation and also the genetic algorithm towards improving the encoding speed has been proposed. Also, the proposed model shall support in improving the quality of image retrieved. In [36], a direct allocation method has been proposed for predicting best Dihedral transformation which is based on lowest three DCT coefficients. The drawbacks of such methods are about comparing the DCT coefficients for a given range block and domain block as per the current search entry. Also, some of the content-based query was also developed in which the fractal properties of images were considered [37].

The other way of decreasing the encoding time is by focusing on stochastic optimization methods which could be adapted using GA (Genetic Algorithm). There are many prevalent methods of reducing encoding time that has been proposed on GA based solutions. [38]. Idea of special correlation for an image shall be used in methods, while the chromosomes in GA comprise all range of blocks that could lead to high encoding speed. Some of the other researchers also found improvements using the tree structure search methods for the search process and also using the parallel search methods [39] [40] for improving the encoding speed.

Among the other methods that were discussed in the earlier models, the accelerated encoding technique presented focus on reducing the huge encoding time. As per the Fisher's classification method [41], the image blocks shall be categorized in to 72 classes which are very complex. In their study Wu et.al [42] depicts the method of fractal image method which is based on intelligent search for standard deviation. In comparison to the other models [43], the method is a significant improvement towards attaining significant loss in terms of reconstructed image quality. Also, Lin et.al [44] in their study proposed a search strategy which is dependent upon the edge property, as its superior performance of the Duh' method is evident from the experimental results provided in the solutions. Zhou et.al [45] has supported in image blocks modeling based on unified feature, however the compression ratio is not so desirable in the proposed method.

In the recent past, many other methods that are based on evolutionary strategies have been proposed. To support in improving the encoding time largely some of the studies that are largely based on no search strategies [46], [47]. Wang et. al [46] has developed a no search image coding method which works on fitting plane which in comparison to Furao's method [47] and Wang method [48], the ration levels of compression, quality and encoding time appear to be very effective.

Also, the method of PSO (particle swarm optimazation) which is focused gradually has been focused upon the model. Many of the research scholars have combined upon the PSO algorithm and the fractal image compression coding methods. Tseng et.al [49] has proposed a fractal image coding method based on visual based PSO. Also in the other model by Rinaldo [50], and from Shapiro [51], it has been observed that that the self-similarity for the images is based on wavelet transform. Lin et.al [52] has also proposed a method adapting the PSO for classification based on third-level wavelet coefficients. Such methods always reduce the searching space, however, it requires huge amount of computations and the compression ratios which are small. Also, in [53], another level of speed-up technique has been introduced.

With the emergence of SDS (Suitable Domain Search) methods that are adapted, there are many methods that are adapted, for instance wide variety of techniques have been proposed for fastening the SDS and towards cumulatively addressing the Speed Techniques [54]- [72]. Such techniques include few of the significant models like block reduction techniques [54]- [63], and methods like inventive domain search techniques [64]- [72].

Duh et.al [57], has also introduced the kind of adaptive fractal coding which is relying upon DCT coefficients. The thresholds in the process has been determined an exquisite manner and the results depict that the model is very effective in terms of speedup ratio denoted as 3, however the results also depict that the encoding time is still high and the compression ratio is small. In simple terms, the objective of the studies has been about reducing the time, either by limiting the required time for SDS by reducing the time required for computation, or by addressing the issues of complexity of computation. In the recent past, many speedup techniques have been proposed on diverse approaches which came in to picture.

Jaferzadeh et.al in [20] has proposed a method of block classification acceleration mechanism for addressing the issues of FIC. In the proposed model fuzzy c-mean-clustering approach has been adapted for categorizing the image blocks and further compared such models with novel metric which is designed on discrete cosine transform coefficient. In the method reported, a speedup of 45 with 1db has been evaluated for compromising in the image quality. Using the Pearson's correlation Coefficient method, Sorting Based block classification scheme has been developed by Wang et.al [63]. It has produced the speed ratio till 10 with little loss in the image quality.

Wang Xing-Yaun et.al also has proposed the other model of swarm optimization and hybrid quad tree partition based [71] FIC technique, which has reduced the compression time to the range of 3 to 4 and there is improved levels of compression ratio, but there is significant reduction in the PSNR.

In a similar kind of study, Songlin Du et.al also has proposed a method as Quantum-Accelerated FIC system [72], in which the time consumption has been impacted by using Grover's quantum search algorithm QSA [73] [74] and on the basis of reported square -root speedup there is very little loss in the quality of the images. The framework of parallel processing which is adapted in the methods [75]- [77], for achieving High Efficiency Video Compression (HEVC). The common phenomenon of parallel processing is adapted for speed enhancement in the FIC system.

Though there is some advancement, the requirement of time turns to be a snag in the compression method adapted and deduction in terms of varied levels of computational expenses for FIC which is still an unwrapped issue that could be adapted. Such a new image features are adapting the speedup technique which is proposed to further reduce the level of compression time by focusing on reducing the amount and also the complexity towards addressing the SDS, in terms of maintaining the quality and compression ratio when compared to the BFIC method.

In the fast FIC schemes, the classification process is also applied in order to classify the domain blocks in to various classes, and each of the matching block is searched using several classes that are associated with the blocks. Despite the fact that there are many schemes that are proposed for speeding up the encoding in FIC, the time consumed is still on higher side.

In the case scenario of processing with encoding time to process a 512 $\times$ 512 image comprising 4 $\times$ 4 range blocks, the processing time as per the DRDC scheme that is proposed by Riccardo Ditasi et.al [78], could take approximately 20 seconds and for processing the 256x256 image, the processing time as per DUFC model of Yi-Ming Zhou et.al [79] shall be more than 2.8 seconds.

Despite the fact that such schemes need not be compared for analysis, without evaluating under similar test conditions, still the results depict the fact that there is significant need for increasing the speed of encoding in FIC. Also, some of the schemes like variance-based block sorting scheme that is proposed by He et al [80] and the model of Fisher's 72 classes' scheme [81] clearly denote the fact that the process is more effective in terms of encoding, but the reconstructed image quality in such schemes shall be very complex in terms of preserving them. Such conditions clearly denote the fact that FIC scheme is very essential towards speeding up the encoding in more effective ways and in terms of preserving the reconstructed image quality for better outcome.

Also in some of the studies, the researchers have proposed on varied range of color image compression techniques, and some of the key solutions pertaining to such kind of color image compression have been discussed in the following sections. Shiping , Zhu Liang , Yu Kam lBellouata [82] in their study has proposed the method of adaptive threshold quad tree fractal compression model that has some fixed square segmentation approach with greater flexibility. It also divides the image block with high details in terms of smaller sub-block and also for the image block that has low details, which divides them in to some of the larger sub-blocks. By such a process, it is evident that the number of image blocks that are needed to match and shortening of the encoding time has to be focused upon.

Jinjiang , Li Da , Yuan Qingsong , Xies Ca iming Zhang [83] , in their study proposed a method that focus on ant algorithm for fractal compression and works on implementing the automatic classification towards an image block. In the instances of matching, it can make use of heuristic information and also the substitute global search that works with local research. In terms of comparison of average brightness for the image block and also the sub image block.

B.Hurtgen, Castile proposes the model in which the Stiler classifies the sub-block in to 15 categories, and further by focusing on sorting the image block's variance, each of the categories shall be classified in to 24 sub-classes. Hence, in total the image blocks shall be classified in to 360 categories, whilst matching the fact that the search is carried out in same category.

Pedro F. Felzenszwalband Daniel P. Huttenlocher, [84] has focused on the method of fast image segmentation algorithm which has the characteristic Sofia Douda, Abdallah Bagri, Amer Abdelhakim EI Imrani [85] hasproposed a new method that is developed on the basis of DCT coefficients. In such a method, the domain blocks that have low activity are always discarded from the domain pool. Also, the activity of blocks is depending on the horizontal and vertical DCT coefficients. Ruhiat Sultana, Nisar Ahmed and Shaik Mahaboob Basha [86] in their study discussed about an advanced fractal image compression algorithm which is based on quad tree that is constructed to search attractor either from the big domain block, and if the domain block is not able to trace any similar kind of block in the range, the most similar range block shall be searched for and it estimates the correctional value towards constructing the fictitious range block.

GoharVahdati et al [87] discussed a fractal image compression method developed on the basis of spatial correlation and hybrid particle swarm optimazation along with GA. There are two significant stages in the algorithm, where the first stage focus on local optima that is used for spatial correlation between neighboring blocks, and in the instances of local optima not being satisfied, the second stage of algorithm is adapted to evaluate similarities between the whole images.

Kharate and Pail proposed that the compression ration which is adapted for and the quality which has improved considerably from the entropy adapted for enhancing the run-length towards encoding, which is predominantly on the wavelet packet best tree. Also, in the process of decomposing a tree, the method has to focus on minimization of time complexity for wavelet packet decomposition. Some of the sub bands comprising significant information on the basis of threshold entropy shall be envisaged from the implementtation of the algorithm.

D. Venkatasekhar and P. Aruna [88] has proposed an effective Genetic Algorithm, which is used for finding the best block in terms of replacement, as the fractal image is carried out very easily. In the proposed model, Genetic Algorithm comprising Huffman coding shall be used for fractal image compression. Khalil [89] has implemented a Run Length coder that is made simple and more effectively. If the proposed algorithm has worked on quantized coefficients for the DCT in several concurrent tokens get existed.

Vijaya-Prakash and Gurumurthy [90] discussed a technique which could support in improving the data compression process. A new model of DCT and Quantization architecture has been designed to address the image compression, which could be adapted by deploying the DCT. Once the compression is achieved by performing quantization for the DCT data coefficients. Yih-Lon Lin and Wen-Lin Chen [91] has proposed a method in which the swarm optimization is adopted for classification and also towards Dihedral transformation for speeding up the fractal image encoder. Using the PSO algorithm, the best match solution for the search space is adapted, and in the process, similarity measures that are essential for performing only when the domain and range blocks are considered to be same type.

Deepthi Narayan, Srikanta Murthy K., and G. Hemantha Kumar, [92] has focused upon comparing the varied kind of approaches that are prevalent for the image features, segmentation and similarity algorithm towards improving the segmentation quality. It has led to the development of weighted Euclidean distance for computing the edge weight for RGB color images and also the modification for segmentation algorithm is also carried out for identifying the prominent edges that are selected.

Hai Wang, [93] proposed an adaptive threshold quad tree fractal compression approach, in which the semantic characteristic is focused upon and the graphbased image segmentation for fractal image compression, and separating an initial image to many logic areas were focused upon, for ensuring better levels of fractal image compression.

, Zhi liang ? ZHAO , Yu li ? , YUHai [94] detailed an effective and efficient fractal image compression model that is based on pixel distribution and triangular segmentation. However, the fractal image compression algorithm needs an effective time to complete the encoding process, and towards addressing such problem, the scope of efficient fractal image compression that is developed and proposed based on pixel distribution and triangular segmentation has been depicted.

However, exploiting the characteristics of centroid uniqueness and also in terms of focusing on the centroid position that is invariance towards a particular discrete system, along with matching amid of the range blocks and the domain blocks has been implemented. In addition to such developments, even the original images that are processed to equilateral triangle segmentation shall reduce the volume of domain blocks and also raise the efficiency of fractal coding.

YuliZhao, Zhi-liang Zhu, Hai Yu [95], also has proposed another fractal color image coding algorithm, which focus on correlation between RGB components and also the equilateral triangle based segmentation is presented, rather than focusing on square segmentation to offer improved efficiency.

FFT based fractal image coding is proposed in [96] by Hannes, for speeding up the encoding computations. The collage error towards addressing the range Year 2016 ( ) F and domain range is measured on the basis of five different inner product operations. Every inner product implementation adapts FTT based cross correlation operation. In terms of quantized gray level transformation (s and o) there are numerous parameters that are considered for calculating the domain block for determining the collage error. In [97], the mean subtracted normalized cross correlation for FTT is presented in [97], which could support in evaluating similarity range and domain block.

Computation of energies towards mean subtracted or overlapped domain blocks are intense in terms of computation. Among the fractal image coding point of view, there are many single computation of domain image which is required for addressing all the range blocks. But in the case of frame based fractal video coding search area towards addressing all range blocks which could be very different and shall be overlapped with any other search areas

In [98], an effective model using cross-hexagon search (NHEXS) has been proposed for fractal video coding, to address the higher motion in terms of speed used for searching stationery and also for searching in quasi stationery blocks. In the first stages, it adapts search patterns that are of two cross shaped are adapted and accordingly some of the large/small hexagon-shaped patterns that comply with NHEXS towards halfway stop technique is developed, and using the modified partial distortion criterion (MPDC) for minimizing the encoding time the process is carried out. In extension to the model of NHEXS, another study [99] proposes the video sequences that are encoded by region-based approach. In the method the regions are defined as per the earlier computed segmentation map and the ones that are encoded independently for each other. Object based stereo of video compression on the basis of combinations for the shape-adaptive DCT and fractals are developed in [100]. In [101], the study has focused on models for compressing the mobile videos using fractal, where the genetic algorithm and particle swarm optimization techniques are adapted for improving the quality of video and speed up factor respectively.

To address the issues of some of low bit rate videos, effective methods like inter cube correlation search that has spatial and spatial-temporal directions are presented in [102] for the purpose of improving the coding performance. Motion and non-motion wavelet sub trees for each of the inter frame are coded independently by focusing on fractal variable tree towards set partitioning algorithm [103], [104] that has suitable low bit rate videos.

3 III. Conclusion

Review of extensive literature pertaining to how the fractal image solutions have been developed, applied in to various levels of image compression solutions, clearly indicate the fact that despite of significant developments that are taking place in the solution, there are significant challenges that are envisaged. It is imperative from the study, despite the fact that there are many studies in place related to decreasing the coding time and improving the quality of compression, and decoding, still there are numerous factors that are turning out to be major challenges that has to be addressed.

In lieu of the emerging scenarios, where thousands of images are generated in an hour and millions of images are transacted between the users, and being corresponded between the systems, the need for compression is very high, and fractal compression images model being and an effective solution, there is significant need for extensive research in terms of addressing the short comings that are envisaged in the process for improving the efficiency and performance of FCI. [1] [2]

[2]Fast Search Approaches for Fractal Image Coding: Review of Contemporary Literature

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