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Review on Fractal Video and Image Compression Techniques

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Abstract— *Compression of images process is a step in the image processing. It is concerned with the transmission and storage of digitally created images. Fractal coding is a potential image and video compression approach with good reconstruction fidelity and relatively large compression ratios, because of its simplicity and great performance; fractal image compression (FIC) is a particularly popular approach in image compression applications. However, it has a significant disadvantage in the form of a long encoding time. This is because encoding any small bit necessitates a massive similarity search in the original data As a result; the FIC search time is reduced while the quality of the reconstructed images is maintained acceptable level in many introduced paper and other still a study topic in progress. Fractal images are images that are self-similar in that each individual part is the same as the total. This paper will discusses many attempts for more author that working on image and video compression using fractal compression technique based on various approach and with each discuss focuses on the main parameter of compression such compression ratio (CR), peak signal to noise ratio (PSNR) and encoding time, as well as the details of data set the used for testing also writing with each technique to creating fractal video and image compression.*

Index Terms— *FIC, Video compression, parallel processing, Iteration Function System (IFS), Image processing.*

I. INTRODUCTION

With the ever-increasing demand for digital image (gray or color), video sequences, computer animations, and multimedia technology, data compression has become a major challenge. Due to the high cost of storage space and enormous channel bandwidth, data compression remains a major issue (transmission times). Compression of video and images is a sort of data compression in which the original data is encoded using a limited number of bits. The purpose of compression is to minimize duplication in an image or video so that it may be stored or transmitted more efficiently.

The FIC method is simple and has unique qualities such as resolution independence and a high compression rate[1]-[2] [3]. It is one of the most effective image compression methods. FIC has been employed not only for compression of regular images but also for compression of magnetic-resonance-imaging (MRI) [4], [5]and hyperspectral kinds [6],[7].

There are two types of image compression: lossy and lossless. The reconstructed image is numerically identical to the input image under lossless compression, whereas the restored image in lossy compression has significant degradation. However, this approach delivers higher compression ratios than lossless compression. One of the lossy compression techniques used in digital photos is fractal image compression. It takes advantage of the

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natural affine redundancy seen in most video and images to achieve high compression ratios and rapid decompression. The trait of self-similarity is used to encode an image that is modeled as a set of fractals. Fractal image compression has various advantages, such as resolution independence, quick decoding, and a high compression ratio, but it takes highly encoding time.

The basis for fractal Compression is the collage theorem [8]. According to the collage theorem, a new set (attractor) W(S) is defined by the union of n number of subimages, each of which is generated by applying a contractive affine transformation wi on S as per (1).

$$W(S) = \cup_{i=1}^{n} W_i(S) \qquad (1)$$

Accordding to this transform the distance between any two locations on the converted image will be less than the distance between the same points on the original image, that is ensures contractive transform [9]. As a result, when a digital image is described as a set, it can be partitioned into non-overlapping blocks called range blocks (R). Under an affine transform, the purpose of the encoding is to find a best matching block for each range block, designated as domain blocks (D). To satisfy the contractivity property, the domain block should be larger than the range block to which it maps. For a range block (Ri) with n pixels, each with intensity (ri) and a decimated domain block (Dj) with n pixels, each with intensity (di), the Root Mean Square RMS E(Ri,Dj) metric is used to calculate the distance as per (2). The goal is to minimize the error.

$$E(R_i\,, D_j) = \sum_{i=1}^{n} (s.d_i \; + o - r_i) \qquad (2)$$

The coefficient s denotes the contrast factor, with |s| < 1.0 indicating that the transformation is contractive in the luminance dimension, while the coefficient o denotes the brightness (offset). The parameters s and o, index of the best matching domain, and symmetry index must be included in the encoded bit stream. The most significant disadvantage of sequentially coded range blocks is the time spent searching for a matching domain block, which increases encoding time.

The benefit of splitting an image in this way is that the smaller range blocks are less complex, allowing for simpler local IFS to describe them. The original image's Partitioned Iterated Function System is formed by the union of these simplified local IFS codes (PIFS) [8]. Color image processing has become more significant as multimedia technology has advanced. In an RGB color space, a true color image is represented by 24 bits per pixel, with each component taking up 8 bits. However, in practice, a variety of color image representation approaches are used [10]. In most cases, the red, green, and blue color components are compressed independently using a gray-level fractal image coding process and treated as a single gray-scale image.

To remove spatial and temporal redundancy, video sequences are compressed using intra frame coding and inter frame coding, respectively. Block matching motion estimation is used in many motion compensated video coding standards. Most video codecs have two types of frame data: intra-frames and predicted frames. Intra frames are full images that have been compressed in some fashion and can be reconstructed without requiring the use of other frames. A predicted frame only contains information about the differences between the previous and current frames; to build the entire frame, the prior frame must be available, which can be built from predicted frames.

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The contain of the paper is organized in the following: in (section **II**), discusses the historical basis of fractal geometry as well as how it might be used to encode images. In (section **III**), we discuss the literature review for various ways of gray scale and color image and video sequence compression. While in (section **IV**) we will discuss the result of the literature review table then convert it into 2-D curve.

II. FRACTAL GEOMETRY

The usage of fractal geometry in multimedia can be extremely beneficial, and this was initially accomplished utilizing the IFS (Iterated Function System) and Hutchinson's [9] Theorem. A mathematical function that describes complicated geometrical sets and pictures is known as an (IFS). In computer graphics, the IFS are used to compress images and data. The practice of representing information with fewer bits is known as digital compression.

Fractal image compression process is based on the concept that all images include affine redundancy, which means that under certain affine transformations, the same image can be encoded with fewer bits. There are various factors to consider while selecting a compression algorithm. These factors include the degree of compression, the speed with which the operation is performed, and the size of the compressed file compared to the quality of the decompressed image.

In 1975, Benoit B. Mandelbrot, a French mathematician, created the term fractal. Fractal comes from the Latin word fractus, which meaning "broken" or "irregular and fractured." In reality, Mandelbrot's foundational book "The Fractal Geometry of Nature", published in 1977, is widely credited for establishing fractal geometry. Mandelbrot set is a type of geometry created by Mandelbrot. According to this definition, A fractal is a rough or shattered geometry shape that can be broken down into smaller parts [9]

Another sort of fractal with a similar shape is the Iterated Function System, or IFS, which was coined by John Hutchinson to characterize fractals in 1981. Fractals can be seen all over the place in nature. A series of affine transformations that transfer a plane to it is known as an iterated function system. *Fig. 1* depicts numerous iterations of this method on various tree fern inputs.

IFS, according to Barsney, can be used to encode digital images. With the use of a photocopy machine that compresses the image three times, the IFS may be clearly understood and *Fig. 2* illustrates this. The smiling is a photo copy machine that duplicates the original image and produces three more reduced copies. This procedure can be repeated indefinitely.

All of the copies appear to be convergent on the original image. Because the copy process decreases the input image, when we repeatedly run the output back as input, the copies of any original image will shrink to a point; there will be more and more copies, but each copy will get smaller and smaller. As a result, the original image is unaffected by the initial image. In truth, the original image's appearance is solely determined by the position and orientation of the copies.

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FIG. 1. AN IFS-CREATED FERN.

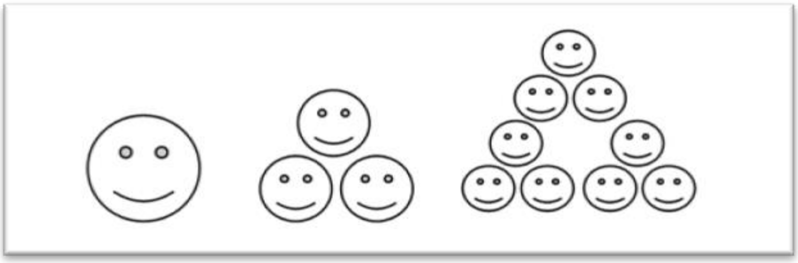

FIG. 2. ITERATION FUNCTION SYSTEM (IFS) PROCESS TO CREATE THE IMAGE.

III. LITERATURE REVIEW

There is no specific feature can be considered as a universal indicator for acceleration video and image compression. A lot of studies have been presented in the field of fractal compression. Some of these studies will be present in this section only those have focused by researchers and which have reasonable accuracy.

L. E. George and A. M. Kadim, 2011[11]used color images were compressed using a rapid compression based on vector quantization approach using block indexing technique. The color image blocks are utilized to create the codebook using an affine transform. The image blocks are classified using block descriptors derived from the DCT coefficients, and the compressed color image must have more contrast areas than a codebook in order to nearly clear the blocks. In comparison to the usual scheme, the proposed solution reduced coding time by 17.2 percent. When DCT coefficients are used to filter the picture blocks, the matching process becomes faster.

S. Zhu, Y. Hou, Z. Wang, and K. Belloulata, 2012 [12] They explored a method where fractal video sequences are coded in the context of region-based functionality to speed up the encoding process. The standard CPM/NCIM technology is enhanced first, and then fractal video coding is improved using an unique hexagon block-matching motion estimation approach. The images in the video sequences are encoded region by region using a previously created segmentation map. Its efficiency and correctness are demonstrated by the experimental findings. In compared to CPM/NCIM technology, the suggested technique takes less time to encode and provides a higher compression ratio and quality.

A. G. Baviskar and S. S. Pawale, 2012 [13] Presented a strategy For fractal image compression, an effective domain search strategy based on feature extraction was presented, which improved compressed image quality while reducing encoding and decoding time. A

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modest number of features are computed for each image block, including mean, standard deviation, skewness, and kurtosis. Rather than employing individual pixels to distinguish and compare the range and domain images, these attributes are used to compare the domain and range blocks. When the smallest range blocks are used, the proposed technique provides high PSNR at the cost of fewer CR.

S. V Veenadevi and A. G. Ananth, 2012[14]introduced a new proposal method to achieve fractal image compression, Using a threshold value and Quadtree decomposition, the original image was divided into non-overlapping parts. For image encoding and decoding, a threshold value and Huffman coding are used, these methods were used to compress satellite images. The results show a considerable improvement in the calculated CR and PSNR values.

S. B. Dhok and R. E. Chaudhari , 2013[15] presented A new full search based on motion estimation algorithm using FFT that uses a circular cross-correlation algorithm as the full search block matching criteria. The correlation based similarity metric is used to obtain the mean subtracted normalized correlation coefficient between a range and a domain block. In comparison to a standard full search block matching approach with similar decompressed video quality for the same compression ratio, the suggested algorithm achieves a faster processing speed.

C. Rawat and S. Meher, 2013[16] presented a simple method for improving compression quality by using DCT theorem and fractal image compression techniques. The color image is compressed using DCT, and fractal compression is utilized to avoid repeating coding of comparable blocks. The Euclidean distance measure is used to find equivalent blocks. The original image is divided into a total of (8x8) non-overlapping blocks. The DCT is utilized for all blocks of the image, and then the DCT coefficients are quantized. The zero values are eliminated using a zig-zag approach on the block values, which improves compression quality and extracts nonzero data. The fractal image compression process is used in this stage. Finally, Huffman encoding is used to compress the image.

U. Nandi, S. Santra, J. K. Mandal, and S. Nandi, 2015[17] created a new rapid classification strategy with quadtree partitioning technique and DCT for image compression . The compression ratio and peak signal to noise ratio (PSNR) of the fractal image compression approach are maintained by this classification procedure, but the compression time is greatly reduced.

S. B. Dhok and R. E. Chaudhari, 2016[18]established a new coding approach based on Quadtree decompositions to enhance the searching speed by managing the upcoming divisions of the block using domain block motion compensated prediction error as a threshold In the frequency domain, cross correlation is achieved via FFT, which uses a single computational process for all domain blocks rather than individual block-by-block calculations, employing three level quadtree partitions and quick NCC computation as matching criteria. By introducing rotation and reflection DFT features to the IFFT of zero padded range blocks, the encoding time is significantly reduced. It was more adaptable to the scene contents than the fixed block size approach. From a human perception standpoint, the suggested technique improves the subjective visual quality of decoded video and achieves a high compression ratio.

V. Chaurasia, R. K. Gumasta, and Y. Kurmi, 2017 [19]performed a mechanism method in which domain pool size is optimized by changing the overlapping of domain blocks. The number of domain blocks formed in domain partitioning is represented in terms of image size, range size. It is directly proportional to image size while indirectly

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proportional to range size. Proposed method with optimized domain pool size gives high quality image with reasonable encoding time.

K. Jaferzadeh, I. Moon, and S. Gholami, 2017 [20] proposed an approach to make FIC a faster technique making use of local features so as to reduce search space. A new local binary feature is introduced. Extracted feature is used to calculate distinction among range and domain blocks by using Hamming distance method instead of least-square method. A superior feature extraction can make a distinction between one block from other non-similar blocks. By skipping irrelevant range-domain blocks matching, it increases the searching speed while maintaining the quality of the decompressed images.

A.M. H. Y. Saad and M. Z. Abdullah, 2018 [21] proposed approach using deep data pipelining to implement FIC. In this approach an image is partitioned into non-overlapping range and overlapping domain blocks where domain block comprises four range blocks. Also two same processes can be applied immediately using two units as a processor. Later time for encoding is reduced by added the innately more extent of relationship amid pixels into vicinity places and best matching domain block search is done in the nearby blocks only. Proposed method based on pipelining strategy encoded a large size image very fast with reasonable PSNR and CR.

R. Gupta, D. Mehrotra, and R. K. Tyagi, 2018 [22] Presented method to improve encoding time and decoding image quality, edge based- FIC approach along with nearest neighbor technique. In this k-nearest neighbor search method is used for range and domain block pool searching then that's gives Acceptable decompressed image is achieved using nearest neighbor technique.

A. Banerjee, U. Biswas, and M. K. Naskar, 2019 [23] they presented approach using quadtree partitioning in which original image is divided into even part and odd part respectively. One part is divided using quadtree decomposition of a range of thresholds. Then complete encoding of fractal codes is done using Huffman coding. This proposal suggested scheme reduces time complexity, as well as, gives increased CR and acceptable PSNR.

A.-M. H. Y. Saad, M. Z. Abdullah, A. M. A. Nayef, and A. S. H. Abdul-Qawy, 2020 [24] they investigated a new method where fractal technique's search time was reduced as compared to a full-fledged dynamic search approach .The dynamic search begins with the domain block that is closest to the range block that needs to be encoded and expands until it finds a suitable matched domain block or the search window covers the entire image. The empirical data reveal that the provided search approach can cut the search time in half when compared to the existing methodology.

A.M. H. Y. Saad, M. Z. Abdullah, N. A. M. Alduais, and H. H. Y. Sa'ad, 2020[25] studied The impact of applying a spatial dynamic search approach rather than a matching threshold strategy on the typical full-search FIC algorithm's search problem. Different image sizes and types are evaluated, as well as range block and partitioning step sizes and quantization settings. The dynamic search approach starts with the nearest domain block and carries on until it discovers an accepted matched block or covers the entire image when the matching threshold technique is employed. It might be claimed that the proposed technique favors close image blocks over distant image blocks.

Few state-of-the-image and video compression techniques, based on fractal image compression, which used in the past ten years, are mention in Table I this table explains the dataset utilized the technique which used image and video details for each technique, and the results which include the aim of each work; it is contain the values of compression ratio (CR), peak signal to noise ratio (PSNR) and Encoding time of each approach.

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TABLE I. LIST OF FRACTAL COMPRESSION TECHNIQUES THAT USED OVER THE PAST 10 YEARS WITH THEIR IT'S DETAILS, RESULTS AND PUBLISHER DEPENDING ON THE REFERENCES.

Reference /year	Technique used	Details	Results	Publisher
[11]-**2011**	Fast VQ with DCT Based Block Indexing techniques.	Lena image Image size= (256×256) Block size= (4×4)	CR= 7.31 PSNR= 30.09 Encoding time= 1.13 sec.	Springer
[12]-**2012**	Fractal video sequences compression coding with region-based on functionality	'mother–daughter' video Frame size=(352×288) Block size= 8×8	CR= 15.33 PSNR= 40.79 Encoding time= 0.031 sec.	Elsevier Inc
[13]-**2012**	Feature Extraction, standard deviation (sd), Mean (M), kurtosis (k) and skewness(S).	monkey.jpg Image size=(256×256) Block size= (4×4)	CR=6.8705215 PSNR=24.890816 Encoding time=66.5 sec.	Springer
[14]-**2012**	Quadtree decomposition and Huffman coding	Lena image Image size= (256×256) Block size= (4×4)	CR=2.02 PSNR=29.92 Encoding time=15.86Sec.	Academy & Industry Research Collaboration Center
[15]-**2013**	FFT based circular cross correlation algorithm.	'mother–daughter' video Frame size=(256×352) Block size= (8×8)	CR= 29.40 PSNR= 37.38 Encoding time= 10.31sec.	IEEE
[16]-**2013**	A hybrid mechanism, DCT and Huffman encoding	Lena image Image size=(1024×1024) Block size=(8×8)	CR= 11.1544 PSNR= 31.5739 Encoding time= _	Zarqa University
[17]-**2015**	DCT with Quadtree Partitioning	Lena image Image size= (256× 256) Block size= 8×8	CR= 0.8296 PSNR= 28.87 Encoding time= 60 ns	IEEE
[18]-**2016**	Fast Quadtree Based Normalized Cross Correlation Method using FFT	'Foreman' video Frame size=(352 × 288) Block size= 4×4	CR= 70.84 PSNR= 33.47 Encoding time= 2.88 sec.	The Korean Institute of Electrical Engineers

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[19]-**2017**	Optimized Domain Pool Size	Lena image Image size = (256×256) Domain step(d $_{step}$) = 8 Block size = (4×4)	CR= _ PSNR= 27.561 Encoding time= 307 sec	IEEE
[20]-**2017**	Local binary pattern Hamming distance Adaptive thresholding	Lena image Image size=(256×256) Block size=(4×4)	CR= _ PSNR=31.52 Encoding time=4.23 Sec	Springer
[21]-**2018**	Featuring Deep Data Pipelining Strategy	Lena image Image size=(1024×1024) Block size= (8×8)	CR= 34.1 PSNR= 30.3 Encoding time= 10.8ms	IEEE
[22]-**2018**	Nearest neighbor technique	Lena image Image size=(256×256) Block size= (_ X _)	CR= 10.45 PSNR= 27.42 Encoding time=14.36 Sec	Elsevier
[23]-**2019**	Quadtree Partitioning Approach	Lena image Image size= (256×256) Block size= _	CR= 7.44 PSNR=30.12 Encoding time=52.52 sec	IEEE
[24]-**2020**	Dynamic Search Approach	Lena image Image size= (256×256) Block size=(4×4)	CR=6.74 PSNR= 26.89 Encoding time= _	IEEE
[25]-**2020**	Matching Threshold Strategy with Spatial Dynamic Search	Lena image Image size= (512×512) Block size=(8×8)	CR= 21.3 PSNR= 26.5 Encoding time=0.9 Sec	IEEE

IV. DISCUSSION

From the previous sections, we see that the development of processing for both image and video on side of compression, especially in terms of compression ratio, quality of processing, and encoding time and that return to a different approach used. As per the literature review table, we can convert the different results into two curves one that describes the development of results in different years for image *Fig. 3* and the other one can describe the development of the result on different years for video *Fig. 4*.

For the curve of *Fig. 3*, we see that the parallel processing effect increases the value of compression ratio (CR) achieved to (34.1), also we observed that the minimum encoding time achieved to (60 ns) in 2015 using DCT with Quadtree Partitionin technique. In case of PSNR , we know that one of fractal compression advantage that it is kept on the quality of

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the image and the different approach get on a good PSNR and there is little difference along of the curve between them.

For the curve of *Fig. 4*, we notice that Fractal video sequences compression coding with region-based on functionality approach effect decreases the value of encoding time achieved to (0.031 sec), also we observed that the maximum compression ratio (CR) achieved to (70.84) in 2016 using Fast Quadtree Based Normalized Cross-Correlation Method using FFT technique. Also, the curve shows that all approach gives good PSNR and no big difference between the point of the result.

So, our proposal methodology according to this result in the future will work according to develop this result and try to get the best encoding time with suitable CR and PSNR.

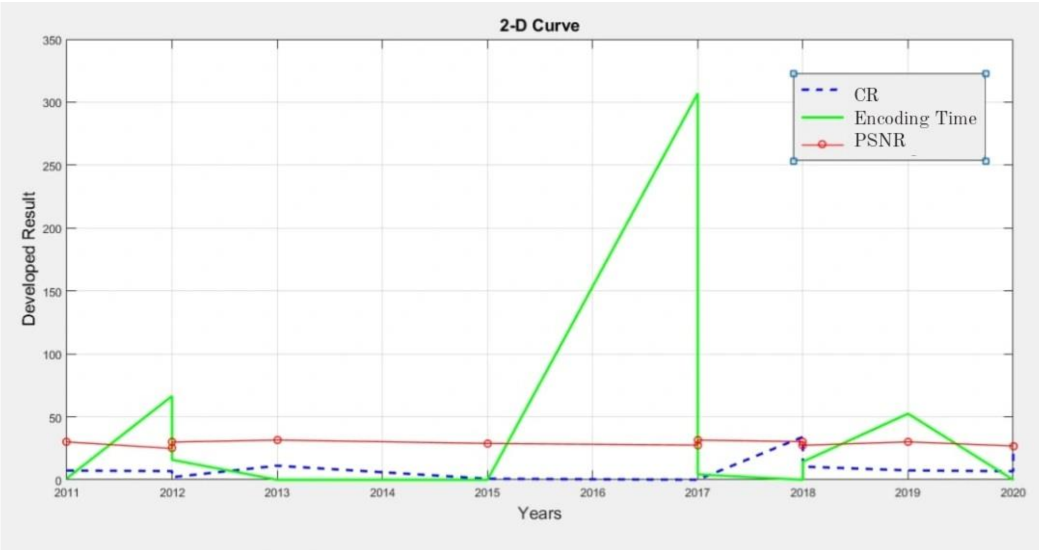

FIG. 3. LITERATURE REVIEW RESULT CURVE FOR IMAGE COMPRESS.

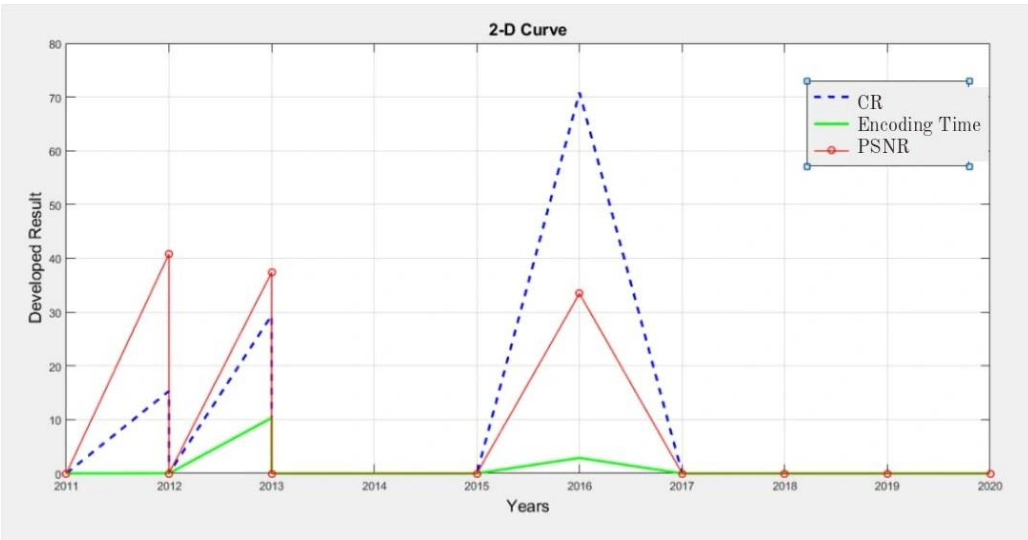

FIG. 4. LITERATURE REVIEW RESULT CURVE FOR VIDEO COMPRESS.

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V. CONCLUSIONS

The study of papers demonstrates various approaches of designing the fractal video and image compression. It found that the fractal compression is designed using multi techniques and with each one we found different results. In general, the main challenges of fractal compression systems are compression ratio (CR), peak signal to noise ratio (PSNR) and Encoding time. From the Table I that contains the summary of some previous work, where high compression ratio (CR) with reasonable Encoding time of image compression was achieved in [21] when they used Featuring Deep Data Pipelining Strategy on Lena image (1024×1024) with block size (8×8) , but the quality of image was very poor as compared with others, while high compression ratio(CR) of video compression was achieved by using "Fast Quadtree using normalized cross correlation Method using FFT " in [18] for 'Foreman' video with frame size(352×288) and block size(4×4) but this technique required high Encoding time .

The proposal research is concerned more with accelerating compression processing based on fractals, so from the Table I we can notice that the best technique that gives high speed up compression with Less encoding time by using "DCT with Quadtree Partitioning" in [17] which applied on Lena image with Image size(256× 256) and Block size(8×8). As for video compression the highest speed achieve in [12] Which reduced the encoding time and increased the quality of video sequence that applied on 'mother–daughter' video with frame size(352×288) and block size(8×8) by using "Fractal video sequences compression coding with region-based on functionality" technique.

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