CHAPTER 1

INTRODUCTION

1.1 Image Processing

Image Processing is a technique to improve the quality of raw images received from cameras placed on satellites, space probes and aircrafts or pictures taken in normal day-to-day life for various applications.

In past some years various techniques have been developed in Image Processing. Most of the techniques are developed for enhancing images obtained from unmanned spacecrafts, space probes and military reconnaissance flights. Image Processing systems are becoming popular due to easy availability of powerful personnel computers, large size memory devices, graphics software etc.

Image Processing is used in various applications such as: Remote Sensing, Medical Imaging, Non-destructive Evaluation, Forensic Studies, Textiles, Material Science, Military, Film industry, Document processing, Graphic arts and Printing Industry. There are two methods available in Image Processing [1] is shown in the Figure 1.1

*Analog Image Processing:* Refers to the alteration of image through electrical means. The most common example is the television image.

*Digital Image Processing:* Digital computers are used to process the image. The image will be converted to digital form using a scanner-digitizer and then process it. It is defined as the subjecting numerical representations of objects to a series of operations in order to obtain a desired result. It starts with one image and produces a modified version of the same. It is therefore a process that takes an image into another.
The various image processing techniques in the digital image processing are:

*Image representation:* In computing, all data is logically represented in binary. This is true of images as well as numbers and text. However, an important distinction needs to be made between how image data is displayed and how it is stored. Displaying involves bitmap representation, whereas storing as a file involves many image formats, such as jpeg and png.

*Image preprocessing:* Pre-processing methods use a small neighborhood of a pixel in an input image to get a new brightness value in the output image. Such pre-processing operations are also called filtration.

*Image enhancement:* To highlight certain image features for subsequent analysis or for image display [1]. Examples include contrast and edge enhancement, pseudo-coloring, noise filtering, sharpening, and magnifying.

*Image restoration:* To "compensate for" or "undo" defects which degrade an image. Degradation comes in many forms such as motion blur, noise, and camera misfocus.

*Image analysis:* To make quantitative measurements from an image to produce a description of it [2]. In the simplest form this task could be reading a label on a grocery item, sorting different parts on an assembly line or measuring the size and orientation of blood cells in a medical image.

*Image reconstruction:* Reconstructions that improve image quality can be translated into a reduction of radiation dose because images of acceptable quality can be reconstructed at lower dose.

*Image data compression:* Compression is a very essential tool for archiving image data, image data transfer on the network, etc. There are various techniques available for lossy and lossless compressions. One of most popular compression techniques, JPEG (Joint Photographic Experts Group) uses Discrete Cosine Transformation (DCT) based compression technique and recently
wavelet based compression techniques are used for higher compression ratios with minimal loss of data.

**Figure 1.1**: Types of Image Processing
1.2 Need of Image Compression

In recent years the development and demand of multimedia products grows increasingly fast contributing to insufficient bandwidth of network and storage of memory device. The uncompressed images can occupy a large amount of memory in RAM and in storage media and they can take more time to transfer from one device to another [3]. Therefore the theory of data compression becomes more and more significant for reducing the data redundancy to save more hardware space and transmission bandwidth. In computer science and information theory data compression or source coding is the process of encoding information using fewer bits or other information bearing units than an un-encoded representation. Compression is useful because it helps reduce the consumption of expensive resources such as hard disk space or transmission bandwidth. Then the basic flow of image compression technique is shown in the Figure 1.2. It represents the compression and decompression of an image. Initially an image is converted into bit streams then those bit streams are processed by some technique to reduce it and at last the bit streams are decoded to get the image.

![Figure 1.2: Basic Flow of Image Compression technique](image-url)
1.3 Types of Image Compression

The image compression techniques are broadly divided in following two major categories.

*Lossless image compression:* The image by encoding all the information from the original files so when the image is decompressed it will be exactly identical to the original image. Examples of lossless [4] image compression are PNG and GIF.

*Lossy image compression:* The name implies it leads to loss of some information. The compressed image is similar to the original uncompressed image but not just like the previous as in the process of compression [4] some information concerning the image has been lost. They are typically suited to images. The most common example of lossy compression is JPEG. One of the lossy compression techniques is Fractal Image Compression and it is explained in the below section.

1.4 Fractal Image Compression

In order to explain the concept of fractal image compression, imagine a special type of photocopying machine that reduces the image to be copied by half and reproduces it three times on the copy shown in Figure 1.3. The output copies obtained while enabling the feedback are shown in Figure 1.4. We can observe that all the copies seem to converge to the same final image. Since the copying machine reduces the input image any initial image placed on the copying machine will be reduced to a point as we repeatedly run the machine. In fact it is only the position and the orientation of the copies that determine what the final image looks like.

A common feature of these transformations that run in a loop back mode is that for a given initial image, each image is formed from a transformed copies of itself and hence it must have detail at every scale. That is the images are fractals.
This method of generating fractals is due to John Hutchinson and more information about the various ways of generating such fractals can be found in books by Barnsley and Peitgen, Saupe, and Jurgens [5-8].

Fractal image compression has been drawing considerable attention of the researchers in the area of image compression, since Barnsley (Fisher et al., 1991) has outlined a schema based on iterated function system (IFS) for a potentially high compression scheme. Later, Jacquin came up with an algorithm based on partitioned iterated function system [5] for encoding an image. Though the performance of this algorithm has been generally found to be inferior than other schemes such as DCT based JPEG compression scheme and wavelet compression schemes the
novelty and the simplicity of the approach have arisen a lot of interests in the scientific community.

Another feature of the fractal compression scheme is the high computational cost while encoding the image though the decompression is much simpler. It may be noted also that compared to the decompression speed of other compression schemes fractal decompression is also slower.

Several reviews of the related work are found in the literature. Interestingly most of the works are based on the same principle of the basic compression scheme as proposed by Jacquin and Jacquin [5,6]. In these algorithms the image is partitioned into range blocks and for each range block; a domain block of larger size is searched so that with some affine transformation the domain block produces a close match of the range block.

The fractal coder algorithm has again attracted some attention as a tool in image processing applications. The fractal image compression (FIC) when applied to certain type of images and database applications, leads to relatively high compression ratios. Aerial photography and satellite imaging are applications where image self similarity is high and fractal coding can proof useful. Recently fractal coding has been applied to other fields such as image restoration, image recognition, medical image classification, watermarking and digital signature embedding. The technique has also been used in feature extraction and recognition. Applications such as handwriting recognition and face recognition are some samples. Fractal techniques that are used for image compression has recently been applied in remote recognition of high voltage discharges [7]. The decoding of fractal coded data is straightforward and fast.

Generally one image is firstly partitioned into some square blocks in FIC, and then these square blocks compose a set called the pool. According to two kinds of size, an image is partitioned into two different pools. The pool composed by the blocks with larger size is called
the domain pool, and the other pool is called the range pool. The cells in the range pool are the blocks to be encoded. The blocks in the domain pool are contracted to the same size as the range blocks, and then FIC takes the domain pool as a virtual codebook. The matching domain block for each range block needs to be searched. Exhaustive search of the matching block pairs costs too much time which is one of the major difficulties in FIC.

As the searching of domains for individual ranges takes considerable time in the encoding stage, there are various efforts to reduce the search and thus enhancing the compression speed [8]. The compression speed of fractal image compression can be increased by the followings category.

✓ By partitioning the domain blocks into several classes and given a range block and its class, the search is restricted only within the domain pool of similar class.

✓ By reducing the size of the domain pool

✓ By mapping a range block and domain blocks to a feature space and considering only the nearer neighbors of the range block in that space.

✓ By down sampling range and domain blocks and refining the search from coarse to finer resolutions.

✓ Employing genetic algorithm for searching domain blocks.

✓ Applying hybrid schemes like using DCT inner product, DFT or DCT on the domains and exploiting the cross correlation in the transformed space.

The techniques to increase the speed of the fractal image compression are as follows:

- Classification techniques
- Quad- tree technique
- Spatial correlation
• Evolutionary computation technique
• Hybrid technique

These speedup techniques are explained in the forthcoming sections.

1.4.1 Classification technique

This is one of the important techniques to improve the compression speed of the fractal image compression. The compression speed in fractal image compression is increased by using this partition method. In which the input image is divided into small non overlapping square blocks typically called as Range blocks. Then the range blocks are again divided into 4 blocks called as Domain blocks. Then each domain blocks are compared against a subset of all possible range blocks. The range block size is reduced to process the comparison [9]. Determine which larger block has the lowest difference according to some measure between it and the domain block. A gray scale transform is calculated to match intensity levels between large block and domain block precisely. In this concept many researchers produced their ideas to make a fast fractal image compression.

Parallel processing is a method in which many small tasks are used to solve one large problem, has been facilitated by two major developments the development of massively parallel processors (MPPs) and the widespread use of distributed computing. Distributed computing offers many advantages for instance by using existing hardware the cost of this computing can be significantly reduced. In addition the virtual computer resource that is created by distributed computing can grow in stages and can thus take advantage of the latest computational and network technologies. As distributed computing and MPP have gained in popularity the notion of message passing has also become increasingly common. The Parallel Virtual Machine (PVM) system uses a message passing model to allow programmers to take advantage of distributed
computing using a wide variety of computer types including MPPs. To be effective distributed computing requires high communication speeds [10].

As already mentioned by Fisher the simplest way to implement the fractal image compression with quad tree partition in parallel is to assign a piece of image to each processor element. In dealing with images consisting of more than one million pixels we applied the regional search to reduce the compression time. The fractal image compression using regional search on a PVM is parallelized and the regional search for the fractal image compression to reduce the communication cost on the distributed system PVM [11]. The regional search is to search the partitioned iterated function system from a region of the image instead of over the whole image.

Fractal coding offers many promising qualities such as high compression ratio, good image quality, and resolution independence of the decoded image. However the encoding process suffers from the long search time of the domain block pool. Much research has been done to speed it. The fractal theory and many speed up techniques such as block classification, code-book clustering, etc, are discussed in the recent book by Y. Fisher. An incremental procedure which limits the domain blocks pixels given a range block and an upper bound on their distance [12]. The domain blocks are arranged in a tree and navigate it to select a small number of candidate blocks which increases the speed of the compression.

Image compression takes advantage on the one hand of human eye limits, and on the other hand of the natural redundancy of images. Based on the fact that human eye can tolerate small errors in images several compression methods have been developed during the last two decades. FIC and WTC are the most recent techniques and they seem to be very promise [13].
High redundancy present in images a rule based technique can be used to iteratively reconstruct an image from limited image patterns [14]. This technique substantially reduces the memory requirement and speeds up the reconstruction.

The basic idea is to represent an image as the fixed points of Iterated Function system IFSs. Therefore, an input image can virtually be represented by a series of IFS codes. In this way, a compression ratio 10000:1 can be achieved. The research work to be presented based on a novel data structure called Spiral Architecture (SA) which is inspired from anatomical considerations of the primate’s vision [49]. On Spiral Architecture an image is a collection of hexagonal picture elements. In the case of human eye these elements (hexagons) would represent the relative position of the rods and cones on the retina. The property of interest was the physical proximity of the hexagonal pixels with neighboring addresses.

In fractal image compression the encoding step is computationally expensive, because every range block must be compared to all domain blocks in the codebook to find the best-matched one during the coding procedure. A fast classification algorithm using DCT coefficients is to reduce the runtime of the fractal image compression algorithm.

A novel fractal compression scheme is proposed to meet both the efficiency and the reconstructed image quality requirements. 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 proposed by Fisher in 1992. Secondly the domain blocks are sorted in each class by APCCs between these domain blocks and a preset block. Then the matching domain block for a range block can be searched from the APCC interval in which these domain blocks have the closer APCC [15]. 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 the APCC based FIC scheme.

To decrease the computational cost during the domain block search some efforts have focused on reducing the comparing complexity for making encoding faster. The classification or clustering methods [16] which speed the search up by restricting the search space to a subset of the domain block pool in which features extracted from the blocks are represented. An example is Kovacs method that used the direction of the approximate first derivative and a normalized root mean square error of the fitting plane in the given block. Organize the domain blocks into a tree structure is another approach which allows for faster searching as compared to a linear search [17]. This approach can provide a reasonable speedup while maintaining the same quality of compression. Fast fractal image compression using spatial correlation is another method. DCT based classification have been used for speedup the comparison time. Some of no search methods have been proposed [18]. The "no search method" works so fast but the reconstruction image quality is not good. Another approach is to minimize the search by excluding domain blocks. Examples include Jacobs's method of skipping adjacent domain blocks, Tong's method an adaptive search algorithm based on the standard deviation (STO) difference between range and domain blocks, Monro's localizing the domain pool relative to a given range and Saupe's Lean Domain Pool method which discards a fraction of domain blocks based on variance. Instead of the expensive least squared Metric a new less expensive compared Metric algorithm based on DCT coefficients is proposed. The new Metric algorithm and new classification algorithm allows us to reduce the encoding runtime greatly. In this algorithm 20 blocks are reshaped into 10 arrays. Fast encoding is obtained without applying an isometric transformation on the reshaped 10 array.

An edge based classification scheme to speed up the fractal encoder is proposed. The classifier utilizes only two DCT coefficients the lowest horizontal and vertical coefficients. Image
blocks are classified into three classes which are smooth class diagonal/sub-diagonal edge class and horizontal/vertical edge class. During the encoding process only the blocks of the same class are required to perform the similarity measurement. Since the searching space is reduced the encoding speed is improved. The classifier is designed based on the edge properties which is also compatible to the idea of fractal coding, i.e. self-similarity. Thus the sub-optimum searches still preserve good quality. Moreover, since the scheme is simple the overhead is minor compared to the complexity of the encoder. The thresholds of the classifier are adaptively determined from the range pool of the original image so that we can equally partition the range pool into three classes. Therefore, a speedup ratio of 3 can be maintained, which is independent of the given images. The classifier is designed according to the edge properties the quality of the decoded image is preserved.

Furao and Hasegawa [19] first introduced the classic no-search fractal image encoding method and got the fastest speed of fractal image coding up to the present. It achieved high compression ratio at the expense of poor quality of the reconstructed image. In order to improve the reconstruction fidelity, a modified gray-level transform is introduced by using an adaptive plane with more transform coefficients to encode the blocks and it achieved a higher quality of the reconstructed image at higher bits per pixel (bpp). However such an adaptive plane solution is unsatisfactory one reason being that the adaptive plane only takes account of three sub-blocks of the block instead of the whole block.

As fractal image encoding algorithms can yield high-resolution reconstructed images at very high compression ratio and therefore have a great potential for improving the efficiency of image storage and image transmission. A novel fast fractal image encoding algorithm based on a special image feature is described. The algorithm yields excellent performance for the matching search carried out during encoding and speeds up the encoding remarkably in comparison with
the baseline fractal encoding method. The baseline fractal encoding algorithm requires a great deal of time to complete the best matching search between the range and domain blocks which greatly limits practical applications of the algorithm [20]. This method can reduce the search space significantly and excludes the most inappropriate domain blocks for each range block before carrying out the best matching search.

Fractal Image compression is a novel technique in the field of image compression [21]; it is based on affine contractive transforms and utilizes the existence of self-symmetry in the image. This technique has grabbed much attention in recent years because of manifold advantages very high compression ratio, high decompression speed, high bit-rate and resolution independence. Since 1990 a lot of techniques and improvements have been published in this field.

The discovery of DCT (Discrete Cosine Transform) in 1974 [22] is an important achievement for the scientific, engineering, and research communities working on image compression. Many image compression methods including the JPEG, MPEG and H.261 [23] standards are based on the DCT. The attractiveness of the DCT is twofold, (a) it is nearly optimal with high positive values of adjacent sample correlation and (b) it can be computed via the DFT (Discrete Fourier Transform) using a fast Fourier transform algorithm. However DCT has high compression ratio if and only if the original images contain highly redundant information.

Apart from DCT neural networks and genetic algorithms are being developed to explore the future of image coding [24]. A major shortcoming of neural networks lies in the long training times that they require particularly when many layers are used. The one dimensional experiments done by Goertzel, et al [25] demonstrated the potential effectiveness of genetic algorithms for solving the IFS (Iterated Function System the IFS random iteration algorithm is a method for generating fractal images) inverse problem.
In image compression and decompression, fractal theory can obtain a high compression ratio and a low loss ratio. However, it is limited by the tremendous number of computations required to determine the fractal code needed to perform image decompression. Hence neural network approaches to apply partition in fractal image compression [26]. PIFS for image compression and decompression it can obtain high quality decompressed images and that the compression ratio is as good.

The idea of the fractal image compression (FIC) is based on the assumption that the images redundancies can be efficiently exploited by means of block self-affine transformations [27]. A visual based PSO [28] with k-restriction and intuitive move for fractal image compression. The k-restriction is designed by using classification scheme based on edge-type classifier, which avoids 125 times faster with quality decay from 28.91 to 28.02 in dB.

The excellent visual quality and compression rate of fractal image coding have limited applications due to exhaustive inherent encoding time. Fast and efficient image coder that applies the speed of the wavelet transform to the image quality of the fractal compression [29]. Fast fractal encoding using Fisher’s domain classification is applied to the low pass sub band of wavelet transformed image and a modified set partitioning in hierarchical trees (SPIHT) coding, on the remaining coefficients.

Fractal coding which is a powerful means of image compression has the major short coming of being extremely sluggish. The main bottle neck in fractal coding is the search process which causes the mentioned sluggishness. The classification was devised with the intention of being hardware realizable to increase the speed of fractal image compression. A scheme was also laid out to store the classified domain and range data in order to accommodate easy hardware retrieval of the information. Another aspect of the proposed hardware was the reduction of image accesses. This reduction helped us boost the coding speed as well as reduce the power
consumption. Once a group of domain blocks are brought into the hardware they are compared with as many range blocks as possible. Furthermore, parallel operations were performed when possible. While high compression ratios were attained, the qualities of the decoded images were comparable with the software implemented fractal algorithms.

Fractal image coding method is a novel compression method, in which the local self-similarity of the image is used to eliminate cross-scale redundancy existing in image data. It receives wide academic attention with its innovative idea, high compression ratio, high decoding speed, independent resolution etc. however, for the encoding time and quality of decoding needs to be improved, there have been many new methods in fractal coding [30]. The improved methods focus on reducing coding time, combining DCT or wavelet method and block-based division.

By exploiting redundancy in an image, fractal compression can achieve a high compression ratio and a good image quality in a lossy compression format. However, the primary disadvantage of fractal encoding is its high computational demands resulting in unacceptably long compression times [31, 32]. Improve the encoding time; a Search Number Adaptive Control (SNAC) is applied to limit the number of domain block searched [33].

An edge property-based neighborhood region search method is proposed to speed up the fractal encoder. The method executes the optimal search process in the frequency domain. A coordinate system is constructed from two discrete cosine transformation (DCT) coefficients of image blocks: The lowest vertical coefficient and the lowest horizontal coefficient. The reason for executing the optimal search process in the frequency domain is that by mapping all the range and domain blocks into the coordinate system those blocks with similar edge shapes will concentrate together. Hence the range block is limited to the region surrounding itself to find the best domain block. Moreover for traditional fractal image encoding methods the range block
must be matched with all the 8 transformed ones of the domain block to find the fractal code. But for the proposed method, by considering the edge property of block, the similarity match for each range block is done only with 4 transformed ones of the domain blocks.

A fast no-search fractal image coding algorithm based on a modified gray-level transform, which make use of more transform parameters to encode the blocks to decrease the matching error and enhance the possibility of successful domain-range matching. Such a method can reduce the matching blocks and speed up the encoding process with the quality of the reconstructed images improved. This research supplies a support for the use of fractal image compression in real-time products.

Artificial Neural Network is widely used on many research fields because of its high speed for execution and low cost for hardware implementation. ANN is using in fractal image compression because most of the well-known methodology in fractal transformation are rather computational intensive [34]. The artificial neural network is used in the fractal image compression to increase the processing speed.

A new method to reduce the encoding time based on computing the gray level difference of domain and range blocks [35]. A comparison for best match is performed between the domain and range blocks only if the range block gray level difference is less than the domain block gray level difference. This reduces the number of comparisons, and thereby the encoding time considerably, while obtaining good fidelity and compression ratio for the decoded image.

Fractal image encoding is attractive due to its potential high compression ratio, fast decompression and multi-resolution properties [36]. Reduce the encoding time based on computing the gray level difference and normal variance of domain and range blocks.
1.4.2 Quad-tree technique

Data compression has become an important issue in relation to storage and transmission. This issue is especially true for databases consisting of a large number of detailed computer images. Many methods have been proposed in recent years for achieving high compression ratios for compressed image storage. A very promising compression technique in terms of compression ratios is fractal image compression [37]. Fractal image compression exploits natural affine redundancy present in typical images to achieve a high compression ratio in a lossy compression format. Fractal based compression algorithms however have high computational demands. To obtain faster compression a sequential fractal image compression algorithm may be translated into a parallel algorithm. This translation takes advantage of the inherently parallel nature from a data domain viewpoint of the fractal transform process.

The concept of the local iterated function system made breakthrough progress in implementing an algorithm of fractal image coding based on automatic block. The main idea of this method is that it makes use of the fixed point which is decided by the transformation to approximate to the coded image. However, the coding speed of existing fractal image compression algorithms based on block has no qualitative improvement. A fractal image compression coding scheme based on wavelet transform with diamond search is to offer fast positioning [38]. This method has benefits in reducing the search time and enhancing the coding speed.

The resulting images are strikingly good even at very high compression rates and the technique additionally shows promise for simultaneous rectification of the image. Although fractal image decompression is a relatively inexpensive operation widespread use of the technology is limited by the computational complexity of the fractal compression itself. This complexity results from a search for contractive regions of self-similarity within the image.
Conceptually the problem is that of irregular parallelism. The search can begin in a highly parallel fashion but must become increasingly dependent as the process converges. Macro parallelism techniques based upon loosely communicating computers each assigned its region of the search space [39]. As the search progresses each computer periodically broadcast its search status and all cooperatively read just to speed the process.

The combination of fractal coding with a codebook to create a still image coder with the capability of parallelization is presented [40]. The image is divided into equally sized regions which can be processed in parallel leading to high encoding speed. For each image block the search for the best approximation is performed only inside its corresponding region, instead of the whole image as in traditional fractal coding schemes. To compensate for possible quality degradation, the search is extended to a codebook. In this way a significant decrease of the computational effort is achieved while the image quality is increased in terms of SNR.

For many multimedia applications including VOD and image database, Fractal image compression algorithm has excellent characteristics in terms of high compression ratio and fast decompression speed but has been widely studied only in regard to software. Low power quad tree fractal image decoder [41] which can decode 256x256, 8 bits gray-scale images in real-time.

Based on the features of locality and uniformity on SA in various methods was investigated for lossless and lossy image compression and concluded that SA based image compression would improve the performance of image compression.

A more flexible FIC method on spiral architecture was proposed to enhance the compression speed. In order to have a clearer comparison with the Fisher’s FIC method based on square structure the size of domain blocks was set to be 4 times of the size of range blocks.
Image compression is an important step for distributed and network based pattern recognition. For real time object recognition or reconstruction image compression can greatly reduce the image size and hence increase the processing speed and enhance performance. Fractal image compression is a relatively recent image compression method. Its basic idea is to represent images as a fixed point of a contractive Iterated Function System (IFS) [42]. Spiral Architecture (SA) is a novel image structure on which images are displayed as a collection of hexagonal pixels. The efficiency and accuracy of image processing on SA have been demonstrated in many recently published papers. We have shown the existence of contractive IFS’s through the construction of a Complete Metric Space on SA. The selection of range and domain blocks for fractal image compression is highly related to the uniform image separation specific to SA.

In order to speed up the encoding process for fractal image compression the range blocks are obtained by partitioning the image using adaptive quad trees [43]. Then the high order spectrum based on nonparametric double spectrum estimation to constitute the eigenvector for the image block which size is larger than 4 X 4. The lower dimension kd-tree structure is to be created while orthogonal projecting these eigenvectors of high order spectrum for the image block. The fractal code is quickly obtained by using nearest neighbor searching algorithm and quantizing the transform parameters.

By sending the average of the original image, which has a small effect on compression ratio, a faster decompression than the time arbitrary initial image is used [44].

The idea of the fractal image compression (FIC) is based on the assumption that the image redundancies can be efficiently exploited by means of block self-affine transformations. The fractal transform for image compression was introduced by Barnsley and Demko. The first practical fractal image compression scheme was introduced by Jacquin and Jacobs et al. [45], which utilized block based transformations and an exhaustive search strategy. Their approach
was an improved version of the system patented by Barnsley [46]. The computational complexity can be reduced by partitioning and classifying the image sub blocks [47] or limiting the search space.

In Fisher’s classification method a given image block was divided into four quadrants. For each quadrant the average and the variance were computed. According to certain combination of these values 72 classes were constructed. This method reduced the searching space efficiently. However, it required large amount of computations and moreover the arrangement of these 72 classes was complicated.

In Wang et al. [47] four types of range blocks were defined based on the edge of the decoded image. They used a hybrid type of coding mechanism to achieve higher compression ratio while maintaining reasonable image quality. However they did not provide any guideline of threshold determination thus the speedup ratio varied unstably from about 1.6 to 5. In Lee et al., the search of domain blocks is limited by using the variance of the block. Although they provide a 1–10 times of speedup, the speedup ratio is image dependent. A single kick out condition is proposed to speed up the encoder. However they need to combine the DCT inner product algorithm proposed in [48] to retain a speedup ratio of 4. With the aim of enhancing gray-level transform, an improved gray-level transform based on a fitting plane to implement a no-search fractal image compression. The results show that on one hand in comparison with our previous scheme this improved method can speed up the encoding time reduce the bpp and improve the quality of the reconstructed images. A better gray level transform based on a fitting plane to minimize the matching error in the fractal image compression [48]. Fewer bits are used to store the encoding coefficients. Thus, such an improved scheme can reduce the encoding blocks and decrease the bpp with the quality of the reconstructed images improved.
Digital watermarking is known as a process of embedding some information within a digital media such that the embedded data becomes its part. This technique serves a number of purposes such as copyright protection, data authentication, data indexing and so forth. Digital watermarking is typically classified into two categories: robust and fragile. These different types have been designed for different applications.

Robust watermarking scheme is used for identification purpose. In this case the embedded signature should be robust against various attacks and can be retrieved for copyright protection or ownership verification [49]. In fragile watermarking the embedded signature will be destroyed if the content of data is maliciously altered. This technique can be used to detect any unauthorized alterations, modifications or changes in an image.

Moreover, since most multimedia data are distributed in compressed format some semi-fragile watermarking methods have been presented that can survive lossy compression in order to distinguish compression noise from intentional.

Fractal coding is a famous coding that has been used in image processing since 1990. This coding is proper for watermarking because it makes it possible to insert watermark into an image with little changes in the host image. A multi-purpose fractal based watermarking method with a local search region is presented to provide a reliable verification and data integrity authentication [49]. This method utilizes Fuzzy C-Mean clustering (FCM) in order to specify the watermark bits. The proposed method is fragile and robust to manipulations simultaneously. To overcome high computational complexity of fractal coding a new simple coding is also presented to increase watermarking speed. It also improves the watermarking robustness.

A novel fractal video coding method with region based functionality is used to reduce the encoding time and improve the encoding quality [50]. The conventional CPM/NCIM method is improved and a new hexagon motion estimation technology is applied to further raise the
compression efficiency as the encoding time is essentially spent on the search for the best matching block in a large domain pool. FFT based block matching technique [51] which has less reconstruction loss and significantly increases the speed of the encoding process of fractal image compression.

### 1.4.3 Spatial Correlation Technique

The spatial correlation on the range and domain blocks many fast FIC schemes were proposed by searching the matching domain block from the adjacent domain block of the current range block or from the adjacent domain blocks of the domain block which is the matching block for the adjacent range block of the current range block. Classification was also applied in some fast FIC schemes to classify the domain blocks into some different classes then the matching block for a range block can be searched from several classes closely associated with the range block. Fisher’s fast FIC scheme proposed in 1992 is a typical classification scheme. Some other strategies such as synthesis with other technologies and sorting with some features were applied to speed up encoding in FIC.

The emergence of the fractal concept provides us a dialectic way of thinking to learn about things of the relationship between the part and the whole also provides a simple and powerful geometric language to describe the complexity of natural and social phenomenon. Wavelet is an important breakthrough in tools and methods has been successfully applied to multiple branches and signal processing [52]. With the function of amplification and shift wavelet became effective tool for local singularity analysis. Therefore wavelet is powerful tool to reveal fractal local scaling properties. Image contains obvious fractal features using appropriate means of wavelet transform and fractal processing approach you can achieve better results.

Principle and defects of embedded zero-tree wavelet coding are analyzed. Based on this anew image compression algorithm based on fractal wavelet is proposed. For wavelet transferred
image there is great relevance between sub bands with the same direction but different resolutions [53]. This algorithm adopts diverse error thresholds as well as searching steps when fractal searching is made. Great searching steps along with small error thresholds apply to high frequency sub-bands while the contrary is suitable for low ones. The compression rate is largely increased by this algorithm and the speed of encoding without reducing SNR and quality of decoded images. Reduce the encoding time based on computing the gray level difference and normal variance of domain and range blocks [54].

The self-similarity property of images is the essence of fractal image compression methods and there are great similarities among the sublevel bands with the same orientation when the wavelet transform is finished. Therefore, many investigators have utilized the similarity property of sublevel blocks for wavelet fractal image coding. Davis employed a wavelet tree based fractal coding method which combined wavelet transform and a zero tree structure proposed by Shapiro. This algorithm is a classical fractal coding algorithm. However, the traditional wavelet tree based fractal coding algorithm does lose sight of the property that the energy would be highly contained in low frequency sublevel bands when the wavelet transform is applied to an image and it also fails to consider the self-similarity property of fractal images [54]. So the adaptive wavelet fractal compression algorithm with a four-fork tree is used to speed up the compression.

The baseline fractal coding (BFC) algorithm adopts an exhaustive search scheme which leads to optimal results but the approach is very time consuming. A new fast fractal encoding methods have been proposed to improve the fractal image encoding [55]. In each case the approach is taken to reduce the number of domain blocks to be matched by the use of such methods as classification, local variances, features, and adaptive search. The method can greatly reduce the computation cost as compared to the baseline fractal coding method. By reducing the
size of the search window during the domain-range matching, the fractal image compression get speed up.

The domain pool design is one of the dominant issues which affect the coding performance of fractal image compression. The LBG algorithm and propose a block-averaging method to design the efficient domain pools based on a proposed iteration-free fractal image codec [56]. The redundancies between the generated domain blocks are reduced by the proposed methods. Therefore, we can obtain the domain pools that are more efficient than those in the conventional fractal coding schemes and thus the coding performance is improved. On the other hand, the iteration process in the conventional fractal coding scheme not only requires a large size of memory and a high computation complexity but also prolongs the decoding process. The proposed iteration-free fractal codec can overcome the problems above. In computer simulation, both the LBG-based and block-averaging methods for the domain pool design in the proposed iteration-free scheme achieve excellent performances.

The trade-off between the speed of still image compression algorithm and the reconstructed image quality measured in PSNR. The embedded zero-tree wavelet (EZW) coding algorithm was proved to be a robust still image compression method which produces a fully embedded bit stream [57]. It generates high quality gray-scale images in very low bit-rates.

A new fractal face recognition methodology called FAST [58]. It is based on range domain relations: the best approximating domain is used as a spatial characterization for the corresponding range. Such characteristics produce a feature vector. FAST is more robust to expression variation and presence/ absence of transparent glasses than it is to pose illumination changes. A possible approach might consist in extracting domain information only from the areas in the proximity of the corresponding range to make FAST strategy more robust to local occlusion.
Fractal image coding has been used in many image processing applications such as feature extractions, image watermarking, image signatures, image retrievals and texture segmentation. It has the advantage of very fast decompression as well as the promise of potentially very high compression ratios. Another advantage of fractal image compression is its multi-resolution property, an image can be decoded at higher or lower resolutions than the original, and it is possible to ‘‘zoom-in’’ on sections of the image. These advantages make fractal-image coding a very attractive method for applications in multimedia for example; Microsoft adopted it for compressing thousands of images in its Encarta multimedia encyclopedia. Thus, this research supplied a strong support for the fractal image compression using for real time products.

The major short coming of the fractal encoding lies in the fact that it is inherently time intensive. Increase the compression speed of fractal image compression by randomized approach. Image characterization, both in terms of qualitative and quantitative terms, in different categories has been proposed.

The fractal image encoding method has received much attention for its many advantages over other methods, such as high decoding quality at high compression ratios. However, because every range block must be compared to all domain blocks in the codebook to find the best-matched one during the coding procedure, baseline fractal coding (BFC) is quite time consuming. To speed up fractal coding, a new fast fractal encoding algorithm is proposed. This algorithm aims at reducing the size of the search window during the domain-range matching process to minimize the computational cost [59]. A new theorem presented in this paper shows that a special feature of the image can be used to do this work. Based on this theorem, the most inappropriate domain blocks, whose features are not similar to that of the given range block, are excluded before matching. Thus, the best-matched block can be captured much more quickly than in the
BFC approach. The experimental results show that the runtime of the proposed method is reduced grey compared to the BFC method. At the same time, the new algorithm also achieves high reconstructed image quality. In addition, the method can be incorporated with other fast algorithms to achieve better performance. Therefore, the proposed algorithm has a much better application potential than BFC.

1.4.4 Evolutionary Computation Technique

Fractal images compression has benefit of higher rate of compression that is usually better than JPEG, but the most important problem of fractal images compressing is the long time spent on searching conversion replacement and it is because of the time consumed for searching the best replacement block for the original image. Therefore by finding a solution for reducing the time spent on finding the replacement block of original image of course it will be a proper method. Because of this the combination of human knowledge and searching by genetic algorithms with Schema theory is used, genetic algorithm is a global search method that imitate the natural genetic process and can solve many complicated cases that have uneven search space as most natural images have this features therefore using GA for this purpose can be useful.

The main motivation for using schema genetic algorithm is that according to natural properties a chromosome with high fitness can be a good candidate for replacing, so that each block is showed by a chromosome and the best chance for finding the best replacement block is in adjacent blocks, it is covered by Crossover and mutation mechanism that is accompanying Schema theory, this result in keeping population diversity in this mechanism.

Fractal image compression is a relative new topic in image processing area. The idea of storing image blocks as a set of transformations is very appealing. However, the speed of encoding process is always a major obstacle in this scheme [60]. The domain pool used in the
encoding process is significantly reduced by the aid of fuzzy classifier adapted fractal image compression scheme.

The genetic algorithm with schema theory was developed for fractal image compression process. The main objective of this FIC method is to reduce the time spent on finding the replacement block of original image. Therefore they use the combination of human knowledge and searching by genetic algorithms with Schema theory. The main motivation for using schema genetic algorithm is that the best chance for finding the best replacement block is in adjacent blocks.

The research reported in [61] used the properties of uniform image partitioning based on Spiral Architecture. On Spiral Architecture an image can be partitioned into a few sub-images [62] each of which is a scaled down near copy of the original image. Namely each sub-image holds all the representative intensity information contained in the original. The similar pixel intensity was found between the corresponding points in the different sub-images. Then one sub-image was chosen as the reference image and the intensity difference between the reference image and other sub-images was computed. After that the information of the original image was coded by recording only the reference sub-image and the intensity difference information.

A schema genetic algorithm is proposed for fractal image compression. The evolution is performed on each range block independently in which a chromosome represents an affine transformation corresponding to a range block. Schema theorem is utilized to design the genetic operators in GA so as to find a suitable domain block and speed up the encoder. The fitness is the degree of how a domain block is matched to the given range block.

Based on the characteristics of natural images a chromosome with high fitness is a good candidate for the best match. In such a case we will have a higher probability to find better match in the near neighborhood of the corresponding domain block. Hence the searching region will be
confined to a small neighborhood of this domain block through the genetic operators which is designed according to the fitness. On the other hand a chromosome with low fitness is not a good candidate and so are the near neighbors. The fractal image compression based schema genetic algorithm method. In which the genetic operators are adapted according to the schema theorem in the evolutionary process performed on the range blocks. Such a method can speed up the encoder and also preserve the image quality.

1.4.5 Hybrid Technique

In order to make the speedup fractal image compression the hybrid method is followed to get best performance. Instead of using a single technique for improving the speed in this kind combination of two or more techniques is used. Thus the overall performance will increase rapidly.

A fractal image compression method based on spatial correlation and hybrid genetic algorithm performed in two stages to reduce the coding time [63]. The first stage exploits local optima by making use of the spatial correlation between neighboring blocks. If the local optima are not satisfied, the second stage of the algorithm is carried out in order to explore further similarities from the whole image.

A genetic algorithm with hybrid select mechanism is to speed up the encoding speed of a fractal image [64]. First, all the image blocks are classified into three classes: S type, H type, and D type according to their DCT coefficients. Then, during the GA evolution, the population at every generation is separated into two clans: a superior clan and an inferior clan according to whether the type of chromosome is the same as that of the range block to be encoded or not. The hybrid select mechanism proposed by us is used to select appropriate parents from the two clans in order to reduce the amount of MSE computations while maintaining the retrieved image quality.
While extensive research has been done on fractal image compression, fractal encoders are generally not competitive with state-of-the-art image coders. Likewise, significant bits can be saved if we modify some coding schemes in EZW coders. A hybrid fractal zero tree wavelet image coding algorithms [65] that couples EZW and fractal image coding to reduces the bit rate required to achieve a given level of perceptual image quality. It also keeps desirable properties from both types of coders, including progressive transmission, the zero tree structure, and range-domain block decoding.

Fractal image encoding has generated much interest due to its promise of high compression ratio at good decompression quality. Although it suffers from long encoding times, it has the advantage of very fast decompression. These properties made it a very attractive method for applications in multimedia: e.g. it was adopted by Microsoft for compressing thousands of images in its Encarta multimedia encyclopedia [66]. Moreover, fractal encoding is much more than just another compression method since the encoding is capturing the self-similarity of the image and such fractal structures can be further exploited for value-added image processing.

Thus fractal encoding has been widely used in, e.g. special image archive applications ranging from MR, ECG, to space images, feature extractions, image watermarking, image retrievals, texture segmentation and many other image processing applications. The alternative affine transform parameterization leads to faster convergence of fractal decoding that is robust to the initial image used in the decoding [67]. The quality of compressed image is improved by using the progressive transmission structure in the fractal image coding [68].

The ever widening adoption of information technology and improvements to the resolutions of image output devices have made it necessary for image compression algorithms to be able to preserve image details at high compression ratios. The current still image compression
standard JPEG, cannot meet this demand. Dividing images into blocks which are compressed separately, JPEG can only remove redundancies within each individual block, all the redundancies rest between blocks remain. And because its Compression relics on eliminating high frequency components of each image block, as the compression ratio gets high, JPEG has to sacrifice more and more high frequency components of each block to compensate for the redundancy remain between blocks. The more high frequency components it throws away the more image details it loses. As a result, the quality of the decoded image drops quickly as the compression ratio rises for JPEG. A novel DCT and FTC hybrid image compression algorithm [69], which dramatically improves the speed of FTC coding and JPEG’s ability of preserving image details at high compression ratios. The overall subjective quality of the whole PEG decoded image is also heightened.

A fast novel algorithm for high compression of grey scale images is based on fractal coding and multi resolution analysis concepts [70]. It achieves good image compression quality at very high compression ratios.

1.5 Video Compression by Fractal Scheme

Capturing video is easier than the capture of image and because of the availability of technology the video is captured instead of image in various applications like satellite, military and the commercial usage. The videos are mostly captured by using sensors or video camera. Because of these reason huge video files have to transfer through internet and also stored in a memory. It leads to slow down the data transfer speed and needs vast memory. In this sense the researchers invented many ideas to compress the video files. Even though they face some problems i.e. the compression takes more time because of the slow compression. In order to over such drawback and to improve the compression speed the fractal compression technique is start to use in the movable image i.e. video.
Amongst all new video compression methods fractal video compression seems to be a favorable method amongst many researchers [71-73]. It is because the method achieves a high compression ratio and needs only a simple decompression algorithm for decompression. Fractal image compression [74] is based on the iterated function system in fractal theory. There are some procedures in fractal video compression which can be implemented in parallel, such as: construction of the set of codebook cubes, matching search for each range cube, and decompression and display. Since the major computational complexity comes from the matching search procedure for each of the range cubes [75], this complexity can overcome by the parallel matching search procedure and implements it in two distributed computing environments.

Novel coding approach in scan line fractal coding family to speed up both encoding and decoding times i.e., mutual scan line fractal coding (MSFC) [76]. In this method two significant techniques for preserving the high vertical frequencies of the field sequential stereo images and for speeding up the encoding and decoding times are designed. These techniques are scan line approach and mutual domain pool design. In case of range and domain block partitions the scan-line partition technique is used to generate a set of non-overlapping blocks for ranges and overlapping blocks for domains respectively. This approach makes the high vertical frequencies intact. For the domain pool design the mutual domain pools based on equivalent properly of two complete metric spaces are designed for speeding up the encoding and decoding times. This approach is effective in the case of coding the stereo image pair in field-sequential format.

The demand for higher transmission speed and lower storage is increasing as well. This leads to the necessity for video compression. Image encoding is framed upon the fractal coding method [77]. It is based on the assumption that image redundancy can be efficiently explored through self-block transformability. It has shown good results in producing resolution independent, high-fidelity images. The decoding process, which has low complexity, also
suggests use in real time applications. The high encoding time has unfortunately produced discouraging results. In this paper, a new approach is depicted where a comparison of range blocks with the domain pool is implemented using a parallel approach.

**1.6 Hardware Implementation of Fractal Image Compression**

The speed of the fractal image compression is also increased in hardware level i.e. by using VLSI design. Since the fractal image compression has a major drawback in that the processing of image encoding is very computationally intensive. In particular the optimal sub image search step requires a vast amount of time. It takes several minutes to encode a 512 x 512 pixel image even if a conventional personal computer operating at 1 GHz is used to process a fractal image compression.

Several methods have been proposed to overcome this problem. They employ VLSIs for high-speed fractal image coding [78]. However, these methods still suffer from the problem of the architectures’ circuit size being much large for practical use. Furthermore the feasibility of the VLSI has not been considered in the previous works.

Also the idea that the domain block information obtained in the coding of a previous frame is used for coding of the following frame was proposed however there are no detail study for efficient implementation of VLSIs.

An efficient architecture for fractal image coding processors it makes use of parallel searching for similar domain blocks by grouping range blocks by identical classes. Furthermore to encode moving picture at high speed the idea which is utilizing the domain block information obtained in the coding of a previous frame to code the following frame is implemented the designed VLSI. According to this architecture a smaller fractal image coding VLSI can be
realized. The architecture is capable of high speed, real time encoding not only for still images but also for full motion pictures using a circuit size comparable to that of JPEG systems.

The high compression ratio of fractal encoding is based on the increasing of the computation complexity. In order to meet the application requirements of real-time sharing and transmission, it is becoming an important research area to advance the encoding speed by developing the parallelization algorithm based on multi-core programming [79]. The OpenMP program model is applied to parallelize Jacquin fractal coding algorithm.

They employ VLSIs for high-speed fractal image coding. However, these methods still suffer from the problem of the architectures circuit size being much large for practical use. Furthermore the feasibility of the VLSI has not been considered in the previous works.

Also, the idea that the domain block information obtained in the coding of a previous frame is used for coding of the following frame was proposed however there are no detail study for efficient implementation of VLSIs. This paper proposes an efficient architecture for fractal image coding processors and describes experimental results of designed VLSI. This processor makes use of parallel searching for similar domain blocks by grouping range blocks by identical classes. Furthermore to encode moving picture at high speed, the idea which is utilizing the domain block information obtained in the coding of a previous frame to code the following frame is implemented the designed VLSI. According to this architecture a smaller fractal image coding VLSI can be realized. The architecture is capable of high-speed, real-time encoding not only for still images but also for full-motion pictures using a circuit size comparable to that of JPEG systems.

Fractal image compression scheme for moving picture at high speed is achieved by using VLSI architecture. It uses parallel searching for similar domain blocks by grouping range blocks by identical classes.
The main problem of the fractal technique is a long encoding time as opposed to a short decoding time, due to the large amount of comparisons between domain and range blocks. Moreover, during image compression the encoding time depends on the compression ratio we want to achieve, during decompression the decoding time is not affected by this value. For this reasons the fractal image compression is widely used in image storage characterized by a quick access e.g. multimedia encyclopedia or image databases.

Fractal image compression [80] using ASIC to speed up the compression process and substantially improving the performance of the encoding phase. The ASIC is designed to be hosted on a PC platform by means of an interface board connected to the PCI bus. The speedup with respect to a software implementation running on a 100 MHz Pentium platform is 300. The circuit has been automatically synthesized from VHDL on a 0.7~~ CMOS standard cell technology.

Fractal image compression has been interested due to highly possible compression ratio and selectable quality variation [81]. Fractal image compression using Fisher’s and Hurtgen’s methods on DSP TMS320C5515 Stick kit is presented to make faster. Some other techniques also used for increase the speed of the fractal image compression as per the researcher’s idea. Aiming to reduce of the time on the encoding phase of fractal image compression method it is possible to design this phase as a parallel program to take advantage of multiple cores present on common machine architectures [82]. Multi-core processors are widely used across many application domains. It is important to emphasize the improvement in performance gained by the use of a multi core processor depends on the employed software algorithms, as well as their implementation.

By analyzing the sequential version of Fisher fractal coding algorithm, parallelization of Fisher algorithm is researched and implemented based on OpenMP parallel programming model.
Parallel algorithm for fractal coding is feasible and improvement in the encoding speed is extremely obvious [83].

Artificial Neural Network is widely used on many research fields because of its high speed for execution and low cost for hardware implementation. ANN is using in fractal image compression because most of the well-known methodology in fractal transformation are rather computational intensive. The artificial neural network is used in the fractal image compression to increase the processing speed.

The overall concentration of our work is to enhance the speed of the fractal image compression. From our proposed techniques we tried to increase the compression speed of the fractal image compression. The elaborated explanation of our work is explained in the forthcoming sections.

1.7 Contribution of this Research Work

The major contribution of this Research work is to overcome the drawback of fractal image compression which is the increased encoding time, this work implemented several techniques to increase the speed of fractal image compression like, the speed up technique using genetic algorithm, accelerating fractal image compression by adaptive domain pool scheme, Huffman Coding, fast fractal image compression using statistical self similarities mechanism, fast search strategy using optimization for fractal image compression. The various speed up techniques are contrasted in accordance with certain efficiency metrics like compression ratio, speedup and peak signal to noise ratio. The test outcome on standard images indicates a significant reduction in computational load and thereby achieving a higher speed up of the encoding process.
1.8 Organization of the Thesis

The focus of the thesis is to study various approaches for enhancing the compression speed of fractal image compression, while maintaining a higher compression ratio and acceptable peak signal to noise ratio values.

Chapter 2 deals with the review of the various methods available in the literature using various approaches like genetic algorithm, DCT, DWT, statistical self similarity and particle swarm optimization (PSO).

Chapter 3 focuses on the various time complexity reduction methods like genetic algorithm, Huffman coding and adaptive domain pool scheme.

Chapter 4 deals with fast fractal image compression using statistical self similarity mechanism where a new mechanism is proposed.

Chapter 5 deals with fast fractal image compression using wavelet and PSO transformation methods, where the PSO method is compared with DCT and DWT.

Chapter 6 deals with fast search strategies using optimization for fractal image compression, where the modified PSO algorithm is proposed, and its performance is compared with all the earlier methods discussed.

In chapter 7 the summary of the work is presented with contributions of the research work and directions for the future research are highlighted.