Medical Image Compression Using Quad-tree Fractals and Segmentation

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Abstract - *In this paper, the possibility of using fractal compression on medical images is investigated. The utilized fractal method takes advantage of quad-tree partitioning and the results of fractal compression on x-ray images for different range size are presented. For making tradeoff between computational cost and compression accuracy, image segmentation is used and different range size assigned for each segments of image. The results show that applying larger range size for segments outside the region of interest reduce the computation time while the quality is still preserved.*

Keywords: Medical Image Compression, Fractal, Quad-tree, Compression ratio, NMSE

1 Introduction

It is the fact that medical images are acquired in digital format [1]. As most of these images are very large in size, storing and transferring them has been always an important issue. Although the cost of storage is falling drastically as the capacity per device increases, and the cost of transmission bandwidth is also falling; there remains a strong demand for medical image compression. Since the speed of computing is also increasing dramatically, the sophistication and complexity of compression schemes which are practical for use is increasing [2]. There are numerous ways of image compressions that can be categorized into two main groups; Lossless compression and Lossy compression.

Lossy compression provides greater compression rate, but the quality of the medical image reduces. On the other hand the lossless compression provides medical images of good quality but its compression rate is relatively low compared to the Lossy compression. In medical image we are in need of compression of the medical image at larger compression rate and also we need to preserve the quality of the medical image [3]. The redundancy and similarity among different regions of images makes compression feasible.

Fractal compression is kind of lossy compression uses the property of self-similarity of fractal objects. Exact self-similarity means that the fractal object is composed of scaled down copies of itself that are translated, stretched and rotated according to a transformation. Such a transformation is called affine transformation [4].

There are several works in image compression using fractal, each of which take advantage of different characteristics of an image or various known methods of fractal encoding. These methods are originated from the same ancestor by great number of similarities but some innovations in implementation [5][6][7][8][9].

In this work, the quad-tree partitioning fractal compression is utilized on two types of image. In the first experiment the original x-ray image is compressed by applying same range size for the entire image and in the second experiment a segmented x-ray image is compressed in a way that the range size is different in each segment. It is shown that applying different range size for different parts of one image, not only maintains its important information but also reduce the computation time. Remaining of the paper is organized as follow: section 2 gives more information about fractal compression, in section 3 the proposed algorithm is presented, the results of simulation are shown in section 4, and finally in section 5 the conclusion and future works are discussed.

2 Fractal Image Compression

Fractal encoding is a mathematical process used to encode any given image as a set of mathematical data that describes the fractal properties of the image. Fractal compression is very beneficial due to high Compression ratio, the decoding stage of the algorithm is independent of the reconstructed image and the reconstructed image is of good quality [10].

Fractal encoding relies on the fact that all objects contain information in the form of similar, repeating patterns called an attractor. Fractal encoding is largely used to convert the image into fractal codes. In the decoding it is just the reverse, in which a set of fractal codes are converted to image. The encoding process has intense computation, since large number of iterations is required to find the fractal patterns in an image.

The decoding process is much simpler as it interprets the fractal codes into the image. Fractal image compression is achieved either by using Iterated Function Systems (IFS) or by Partitioned Iterated Function Systems (PIFS).

The IFS uses contractive affine transformations which are combinations of three basic transformations; shear (enables rotation and reflection), translation (movement of a shape), and scaling/dilation (changing the size of a shape).
A single transformation may be described by

$$w_i \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} a_i & b_i \\ c_i & d_i \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} e_i \\ f_i \end{bmatrix} \qquad (1)$$

The coefficients a, d determine the dilation, the coefficients b, c determine the shear, and e, f specify the translation.

The PIFS, which is a modified version of IFS, take advantage of 2 other parameters which are contrast and brightness. These two additional features give enough power to decode grayscale images from a description of the image consisting of the fractal operator. This transformation is described by

$$w_i \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} a_i & b_i & 0 \\ c_i & d_i & 0 \\ 0 & 0 & s_i \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} + \begin{bmatrix} e_i \\ f_i \\ o_i \end{bmatrix} \quad (2)$$

In which s_i specifies the contrast, o_i the brightness, and z variable is brightness function for given domain for each pair of x, y

$$z = f(x, y) \quad (3)$$

The partitioning scheme used to demarcate the range blocks is one of the most crucial elements of the fractal compression method. The fidelity and quality of the reconstructed image, the length and the structure of the fractal code, the shape of the transformations used to map domains into ranges and their descriptions in the fractal, code compression ratio, encoding time and all other important characteristics of the compression method are somehow influenced by the choice of the partitioning method [11]. There are plenty of partitioning methods among which quad-tree partitioning is selected for this work.

2.1 Quad-tree Partitioning

Partitioning the image in tree structure is the most popular partitioning mechanism. A quad-tree partitioning is a representation of an image as a tree in which each node corresponding to a square portion of the image contains four sub-nodes corresponding to the four quadrants of the square, the root of the tree being the initial image [12][13]. Fig. 1 shows the mechanism.

The squares at the nodes are compared with domains in the domain pool **D**, which are twice the range size. The pixels in the domain are averaged in groups of four so that the domain is reduced to the size of range and the affine transformation of the pixel values is found that minimizes the root mean square (RMS) difference between the transformed domain pixel values and the range pixel values. With a tolerance factor given for the rate or the quality, this method will break up into squares, thereby creating additional ranges with corresponding transformation codes and improving the reconstructed image quality until the desired rate or quality is obtained.

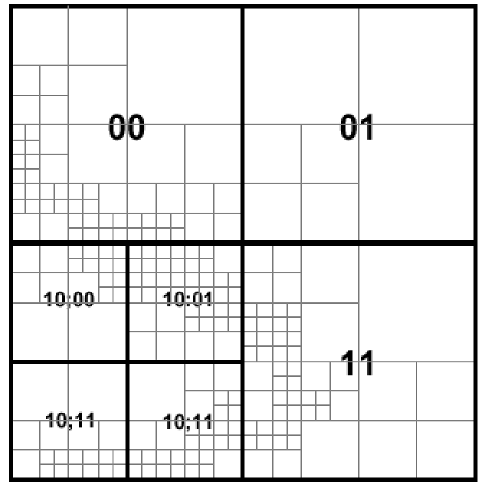

Fig. 1 Representation of Quad-tree mechanism

2.2 Decoding

Decoding process is done by iterating the set of transformations on an arbitrary initial image and the quad-tree partition is used to determine the range in the image. For each range block, the size of the domain block that maps to it, is shrunk by 2x2 pixel averaging. The pixel values of the shrunken domain block are then placed in the location in the range determined by the orientation information after scaling and offsetting. Computing all the range blocks constitutes one iteration. After several iterations, the decompressed image will be very close to the original image.

When the fractal image compression is compared to other methods used to compress different images, some of the main advantages and disadvantages can be summarized as follow:

Fractal compression advantages include; good mathematical encoding frame, resolution-free decoding, high compression ratio, and fast decompression. On the other hand, the same method suffers from slow encoding process [14].

3 Proposed Method

As it was mentioned in the previous section, fractal compression has got favourable characteristics that make it appropriate for compressing images with high compression ratio. But it should be taken in mind that for having decompressed image with acceptable degradation, the partitioning range size need to be very small. Applying small range size leads to increasing the computation time especially in encoding part which is undesirable.

In current method, the goal is using fractal compression by making less degradation on the decompressed image and reducing computation time. For doing so, the original image is partitioned into two segments, the background and the region of interest (ROI). For the background, whose information is not significant, the large range size can be used, while for the major part or the region of interest the small range size should apply to avoid loss of information.

3.1 Image Segmentation

In this stage the original image is segmented into ROI, which is considered to be the most important, and background, which is less important.

For this work k-means clustering is applied and the original image can be segmented into k clusters in which k is selectable by user. Depending on how accurate the output image needs to be, various cluster numbers can be assigned. The result of the implementation is shown in the following section.

3.2 Image Compression

The second stage is compressing image by taking advantage of fractal method. Here, quad-tree partitioning is applied and the domain size is considered two times the range size. In each part by rotating, flipping, and transposing the selected range we try to find the best similar part and find the parameters of affine transformation. After sweeping the whole image, the table of coefficients is produced and ready for the decompression algorithm. Despite the encoding which is complicated and time consuming, the decoding algorithm is straight forward and relatively fast.

4 Experimantal Result

In this section, the implementation of the method is presented. The required codes are written in Matlab, by taking advantage of some pre-defined functions in image processing tool box.

This experiment consists of two parts, in the first part only the fractal compression is used and the results of different range size are presented. In the second part, which has two stages, firstly the image is segmented and then the fractal compression is applied.

4.1 Results of Fractal Compression

The following are the results of applying fractal image compression using quad-tree partitioning and different range size. As it is clear selecting smaller range size will produce better decompressed image with less noticeable artefacts which is more desirable. But at the same time making range size smaller needs more computation and the code will be very slow to produce the final coefficient results of the encoding part. To enhance this condition the second experiment is done.

Fig. 2 shows the results with 3 different range sizes for two sample x-ray images. To have a better sense of the resulting decompressed image quality, for each range size the Normalized Mean Square Error (NMSE) is also calculated. Moreover, the compression ratio needs to be calculated, the result of these calculations is shown in Table I. These results show that applying smaller range size leads to high quality decompressed image but low compression ratio.

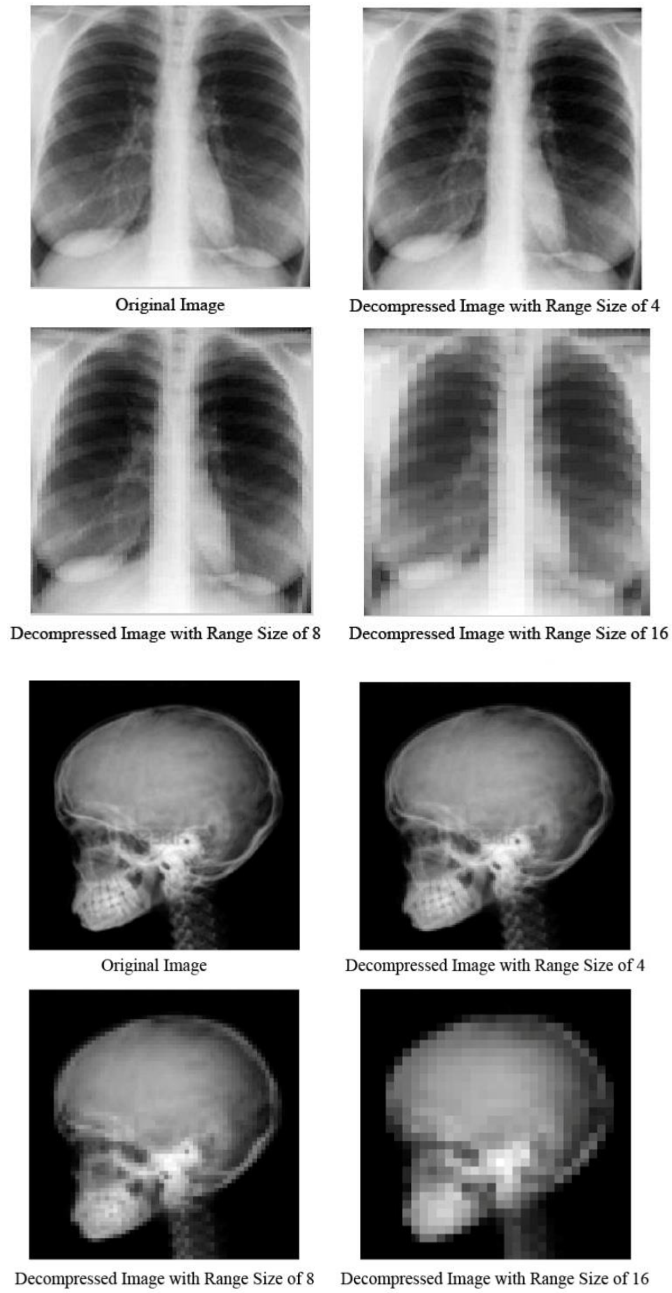

Fig. 2 Results of applying just Fractal Compression with different Range Size for two sample x-ray images

TABLE I
NORMALIZED MEAN SQUARE ERROR AND COMPRESSION RATIO FOR EACH RANGE SIZE AND TWO SAMPLE X-RAY IMAGE

Range Size	4	8	16
NMSE (chest x-ray)	1.53e-3%	5.56e-2%	3.9%
NMSE (head x-ray)	2.4e-3%	5.44e-2%	3.4%
Compression Ratio (chest x-ray)	3.2	12.8	51.2
Compression Ratio (head x-ray)	3.4	12.6	50.9

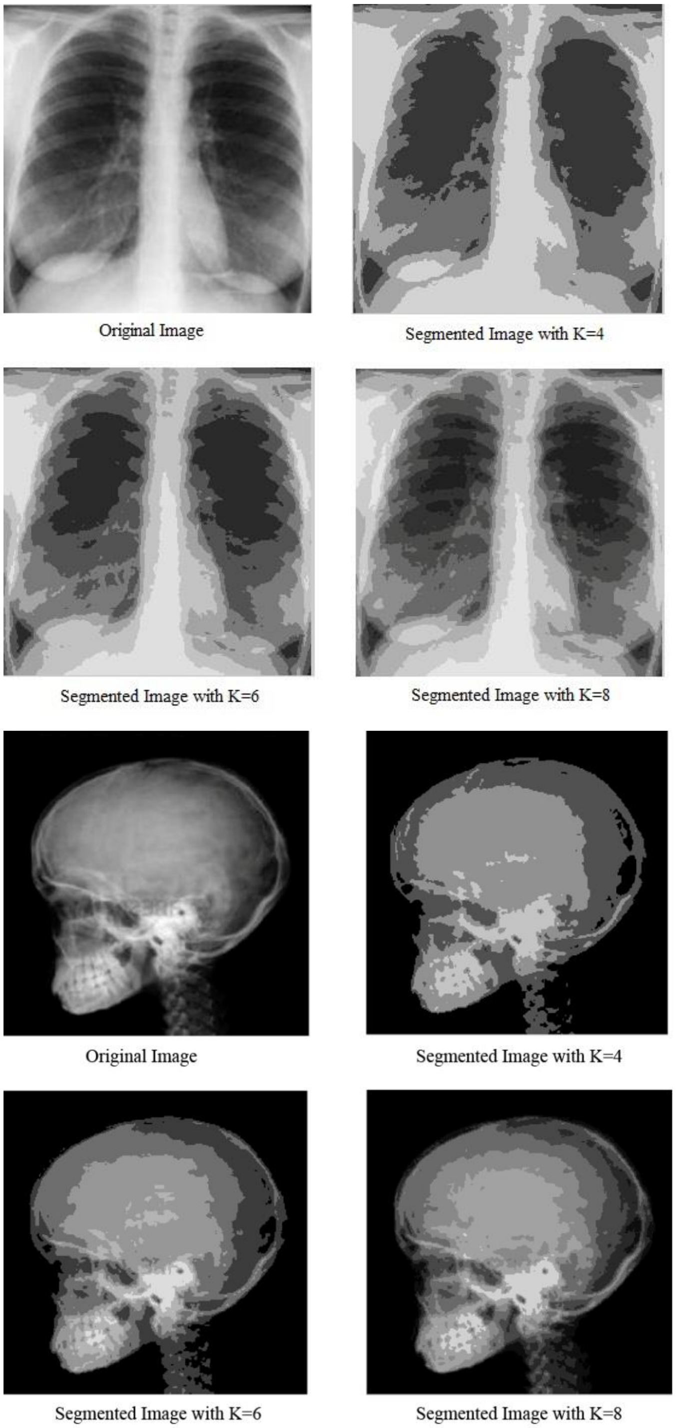

Fig. 3 Result of Segmentation with different clustering level for two sample x-ray image

4.2 Results of combining Segmentation and Fractals

In this experiment, the original image is firstly segmented to different clusters. Then for unimportant clusters (like background) large range size is applied and for the rest, which are assumed as ROI small range size is used. Fig. 3 shows the result image of the segmentation with different numbers of clusters and two sample x-ray images. Fig. 4 shows the final result of combining segmentation and compression for the two sample images. This result are for 6 level clustering and applying range size 8 for background cluster and 4 for ROI clusters. Needless to say that, there is a tradeoff between number of clusters, range size, quality of final decompressed image, and elapsed time for running the code. Based on the application, each of these parameters can be changed to achieve the best result. The calculated NMSE and compression ratio for sample experiment are presented in Table II.

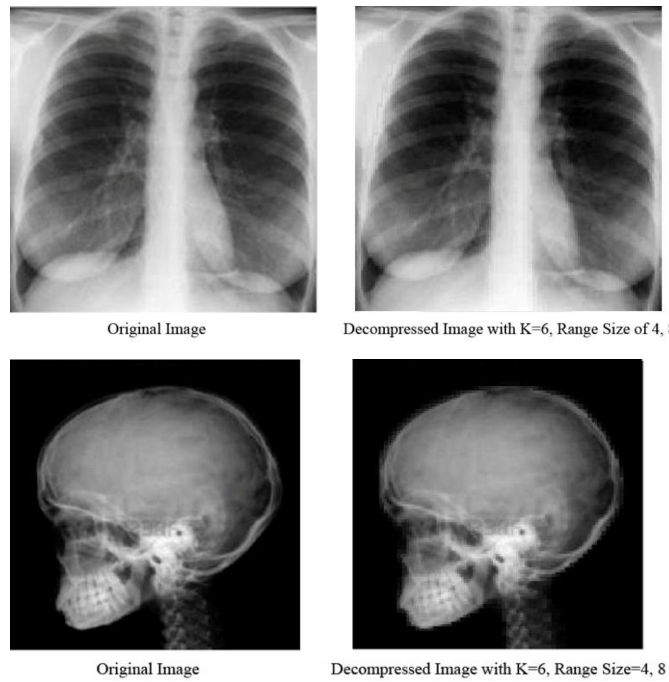

Fig. 4 Result of Combining Segmentation and Fractal Compression for two sample x-ray image

TABLE II
NORMALIZED MEAN SQUARE ERROR AND COMPRESSION RATIO FOR TWO SAMPLE X-RAY IMAGE BY APPLYING SEGMENTATION

x-ray sample	chest x-ray	head x-ray
NMSE	8.6e-3%	1.03e-2%
Compression Ratio	5.3	5.9

5 Conclusion

In this work, we try to compress medical x-ray image effectively by taking advantage of combining segmentation and Fractal compression. The results show that, when different range sizes are applied for different clusters, which are the output of segmentation, not only the computation time can be reduced, but the information of critical points in the image will preserve as well.

There are still some ways to improve the result of proposed method such as reducing blocky output in decompressed image. The exploited partitioning scheme is very likely the reason for this problem, it is believed that introducing a quad-map partitioning with overlapping ranges would be a better solution [15]. We can also apply other distributions to exploit self-similarity characteristic of images [16].

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