

A New Algorithm for Fractal Coding Using Self Organizing Map

¹Bhavani, S. and ²K. Thanushkodi

¹Department of ECE, Sri Shakthi Institute of Engineering and Technology, Coimbatore, India

²Akshaya College of Engineering and Technology, Coimbatore, India

Abstract: Problem statement: In medical imaging, lossy compression schemes are generally not used due to possible loss of useful clinical information and also degradations may result in lossy compression owing to operations like enhancement. As the medical images are huge in size a good lossy compression technology is required to store them in medical archives in an economical manner. There is a need for efficient compression schemes for medical image data. **Approach:** We had addressed the possibility of using fractal image compression for compressing medical images in our work. We had proposed a novel quasi-losses fractal coding scheme, which would preserve important feature rich portions of the medical image as the domain blocks and generate the remaining part of the image from it using fractal transformations. This study addresses a machine learning based model using SOM to improve the performance and also to reduce the encoding computational complexity. **Results:** The performance of the proposed algorithm was evaluated in terms of compression ratio, PSNR and encoding computation time, with standard fractal coding for MRI image datasets of size 512×512 over various thresholds. The encoding speed of SOM based proposed algorithm was obtained as 37.17 sec which was very less compared to that achieved in standard fractal image coding algorithm of 1738 sec and also the proposed algorithm improves the PSNR by 2.23 compared to standard fractal algorithm. **Conclusion:** The results obtained prove that the proposed algorithm outperforms some of the currently existing methods thereby ensuring the possibility of using fractal based image compression algorithms for medical image compression.

Key words: Fractal image compression, patterns appeared nearly, shows blocking artifacts, maximum possible values, arithmetic mean, standard fractal image

INTRODUCTION

A fractal is a structure that is made up of similar forms and patterns that occur in many different sizes. The term fractal was first used by Benoit Mandelbrot to describe repeating patterns that he observed occurring in many different structures (Mandelbrot, 1983). These patterns appeared nearly identical in form at any size and occurred naturally in all things. These fractals could be described and mathematically modeled. The interest of applying fractals has increased in recent years. Even though Fractal scheme is promoted by Barnsley (2000) who found fractal image compression technology, it was first made available to public by Jacobs and Boss (1989) who used regular partitioning of segments and classification of curve of random fractal curve (Jacobs *et al.*, 1992) were the first to introduce the concept of iterated function systems based fractal image compression (Barnsley, 1996). Fractal image coding is described based on theory of Iterated contractive image transformations (Jacquin, 1992). A new approach to image compression using iterated transform is presented (Hutchinson, 1981) which have

found the basics from the theory of IFS developed by (Hutchinson, 1981; Barnsley and Jacquin, 1988). The problem of finding a suitable IFS code is solved by use of a library of IFS codes and complex moments and by using simulated annealing method for solving nonlinear equations in presented in (Ali and Clarkson, 1991). Fractal image compression signal to noise ratio is found to be moderately better for smaller images for a given degree of compression as indicated.

Self-similarity or scaling is one of the main properties of fractal geometry. One of the measures of image quality is artifacts. Fractal shows blocking artifacts at higher compression ratio but at low ratio it tends to be localized. Speed up methods in fractal image coding based on feature vector and classification approaches and complexity in fractal image decoding is detailed in (Polvere and Nappi, 2000). Further speeding up fractal image compression by using a new adapted method based on computing the highest value of the pixel of the image to reduce the computational complexity in the encoder stage is addressed. A fast and efficient hybrid scheme (Hassaballah *et al.*, 2005) using

Corresponding Author: Bhavani, S., Department of ECE, Sri Shakthi Institute of Engineering and Technology, Coimbatore, India

a wavelet transform improves the image quality in fractal image compression, whereas hybrid coding based on partial mapping where only part of the image is encoded using fractal technique and the remaining part is modeled using other algorithms demonstrates the compatibility of fractal image coding algorithm with other methods (Wang *et al.*, 2000). A faster fractal image compression using quad tree recomposition is addressed in (Jackson *et al.*, 1997). The complexity in fractal image decoding is detailed in (Saupe and Hamzaoui, 1994). In survey on coding algorithms in medical image compression addressed in (Bhavani and Thanushkodi, 2010), it is found that fractal image compression exploits self-similarity among image elements and hence reproduces image elements with high compression rate. Lengthy encoding process is another drawback of fractal compression as it leads to increase in computational encoding complexity. This study addresses to above mentioned issues of fractal image compression.

MATERIALS AND METHODS

Standard fractal compression: A two dimensional image is represented mathematically as $z = f(x, y)$ where $f(x, y)$ represents the gray level with 0 being black and 1 being white at the point (x,y) in an image. I denote the close Interval $[0 1]$. On applying transformation ‘W’, on to the image ‘f’, we get a transformed Image $W(f)$. W always moves points closer together as it is contractive. Affine transformations are combinations of rotations, scaling and translations of the coordinate axes in n-dimensional space which always map squares to parallelograms. The general form of affine transformation is given by Eq. 1:

$$W = \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} e \\ f \end{bmatrix} = \begin{bmatrix} ax+by+e \\ cx+dy+f \end{bmatrix} \tag{1}$$

If the translations (e and f), scaling factors(r and s) and rotations (θ and ϕ) are known in advance, then the coefficients may be calculated. The transformation found suitable for encoding gray scale images thought of as a three dimensional image with coordinates as x and y and intensity as z is given in Eq. 2: where s_i controls the contrast and o_i controls the brightness of transformation:

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

Encoding and decoding of images: According to contractive mapping fixed theorem which states that if the transformation is contractive then, when applied repeatedly starting with any initial point, we converge to a unique fixed point. If X is a complex metric space and $W: X \rightarrow X$ is contractive then W has a unique fixed point IWI. In simple, collection of transformation defines an image. The encoding process partitions the image ‘f’ into pieces to which we apply transform w_i to get back the original image (Barnsley, 2000). A portion of the original image we denote by D_i and apply w_i on D_i The partitioned domain of the original image is represented by v_i where $v_i (D_i) = R_i$ (Range blocks). Hence $UR_i = I^2$ with $R_i \cap R_j$ when $i \neq j$. If ‘f’ is the image and W is the transformation then the transformed image is given by $f = W(f) = w_1(f) \cup w_2(f) \cup w_3(f) \dots \dots \cup w_n(f)$. The map W is defined as union of $w_i(f)$, where $w_i = D_i \times I$ and we get transformed domain. The transformed domain is compared with the range block and if it matches, it is copied as Range. We find D_i and maps w_i such that when we apply w_i to a part of the image over D_i , some portions are found to be lost in R_i . The problem lies in finding pieces of R_i (corresponding to D_i) in encoding process. One of the most notable features of fractal image compression is that the decoding process is simple. The decoder proceeds its work in the same way as in the case of the traditional encoder (i.e., fixed block size encoding).The decoder consumes less time for computation compared to that of an encoder. The decoding time generally depends on the number of Iterations and here it takes only few iterations ranging from 4-8 to reach the fixed point.

Proposed fractal image compression: w_i is determined uniquely for a chosen metric. Jacquin (1992) root mean square error was chosen as the metric. In standard fractal image compression proposed it uses distance as metric, whereas in (Iano *et al.*, 2006) it uses entropy as the metric. In our proposed method we have chosen variance as our metric since variance is independent of change of origin but not scale. Standard deviation denoted by σ is the positive square root of arithmetic mean of squares of deviations of the given values from their arithmetic mean. The purpose of squaring deviations overcomes the drawback of ignoring the signs in mean deviation.

Proposed domain-range block separation algorithm: In our proposed algorithm the domain and the range blocks are separated based on variance computed of each blocks in the block set. The feature rich blocks are selected as domain blocks and preserved along with transformation coefficients. Image ‘f’ is partitioned into image B comprising blocks b_1, b_2, \dots, b_n using quad tree

decomposition method. Initially Range and domain block sets are null sets. Using the quad tree decomposition method as proposed the image is partitioned into large range blocks initially. The best transformation of each block is then found. If the transformation is discarded using the metric, the range block is divided into 4 quadratic sub blocks and again best transformation is searched for each sub block. This continues until all the blocks are covered. If the subdivision is not done in equal proportions the tree resulting from it may lose the property of symmetry. The minimum and maximum possible values of σ_i are restricted corresponding to s_i . Once the choice of R and D has been made, choosing a set $\{R_i\} \in R$ and the corresponding set $\{D_i\} \in D$, for encoding should yield good compression and high picture quality. The encoding time depends on the time taken in finding the domains D_i .

Algorithm: Let B as a set of all the blocks in the image after quad tree decomposition, R be the set of Range blocks and D be the set of Domain blocks which should be separated from the set B.

Where:

$B = \{b_1, b_2, b_3, \dots, b_n\}$,
 Let $R = \{ \}$ and
 $D = \{ \}$

For each block in B

```

Do
{
If ( $S_{bi} > d_{min}$ )
{
 $R \leftarrow R \cup b_i$ 
}
Else if ( $\sigma_{b_i}^2 > \sigma_{max}^2 \times \tau$  and  $\sigma_{b_i}^2 \geq \sigma_{max}^2$ )
{
 $D \leftarrow D \cup b_i$ 
}
Else
{
 $R \leftarrow R \cup b_i$ 
}
}
    
```

Where:

S_{bi} = The size of the block b_i
 d_{min} = The minimum Domain Block Size
 $\sigma_{b_i}^2$ = The variance of the block b_i in the set B
 σ_{max}^2 = The maximum variance of the $d_{min} \times d_{min}$ blocks of the image
 τ = The threshold value which normally lies between 0 and 1 decides the size of the domain pool as well as the features of the blocks in the domain pool

If τ is the threshold value which normally is 0 then all the blocks of size $d_{min} \times d_{min}$ will be selected as domain blocks. If τ is 1 then all the blocks of size $d_{min} \times d_{min}$ having highest variance only will be selected as domain blocks. Hence it is clear that the compression quality as well as compression time is decided by the value of threshold ' τ '.

Proposed fractal coding algorithm-I: The following steps outline the compression process of the proposed compression algorithm:

- Read the Input image I
- Decompose the image I into a number of non overlapping blocks of various sizes using quad tree decomposition
- Separate all the feature-rich $d \times d$ sized blocks from the decomposed image based on previously mentioned domain-range block separation algorithm and Mark them as Domain Blocks and assume the remaining as Range Block
- For each Range Block, find the best matching domain block and record the coefficients of the transformation.
- Compress the Domain blocks using any lossless compression and save them as seed along with the coefficients of the transformation

SOM based fractal coding algorithm-II: In the proposed algorithm-II, we are using a self-organizing neural network based ML technique to group the domain blocks and range blocks for reducing the search space to improve the speed of encoding of the algorithm. The following steps outline the compression process of the proposed compression algorithm II. The first three steps are same as previous. In addition to the previous method, a learning algorithm is used to speed up the encoding process. With Mat lab's neural network toolbox we can create and use a SOM (neural network) in simple and easy way.

Compression:

- Read the Input image I
- Decompose the image I into a number of non overlapping blocks of various sizes using quad tree decomposition
- Separate all the feature-rich $d \times d$ sized blocks from the decomposed image based on previously mentioned domain-range block separation algorithm and Mark them as Domain Blocks and assume the remaining as Range Block
- Organize two sets of n Groups from the Domain Blocks as well as the Range blocks, based on the features of the blocks using a supervised classification technique

- For each Range Block, find its group label and find the best matching domain block from the corresponding Domain block the transformation
- De-compression

The following steps outline the decompression process. The decompression can be done by using the fractal IFS code as follows:

- Load the saved coefficients and the Seed Blocks
- Create memory buffers for the range screens
- Recreate the feature-rich areas of the range screen directly from the seed blocks (lossless-part)
- Apply the transformation using the seed blocks and recreate the remaining portion of the range screen (lossy-part)
- Reconstruct the rough blocks as well as smooth blocks as it is from IFS code since they are stored without any compression
- Reconstruct all the remaining blocks from the stored seed blocks with the help of IFS code

RESULTS

We have implemented the proposed algorithm-I and II using Matlab for various metrics. The performance is evaluated with respect to PSNR, compression time and compression ratio for various thresholds. We have used MRI Image samples of size 512×512 for our analysis. From the results obtained it is observed that the average value of PSNR obtained for 4 sample MRI image datasets for a threshold of $\tau = 10^{-3}$ is found to be 31.642 as compared to 26.9 for $\tau = 10^{-6}$. This shows that as threshold decreases PSNR increases. Similarly it is found that as threshold decreases compression ratio is very much higher and also the encoding time is reduced considerably to 23.96 sec as observed from the Fig. 1 which gives the plot of the performance of the proposed algorithm-I for various thresholds. To further decrease the encoding time SOM based fractal coding has been implemented and encoding is achieved at very less time of 37.17 sec as against the 1738 sec of standard fractal coding as shown in Fig. 4. We have tested the performance of the above mentioned three algorithms with the Medical image (512×512). (Sample MRI Image 4) and the comparison of the standard fractal coding, proposed algorithm I (Improved fractal coding) and proposed algorithm-II (SOM based fractal image coding) is done. From the comparison, it is found that compression time has reduced drastically with improvement in PSNR and compression ratio in proposed algorithm-II. Figure 2 shows the PSNR chart for all three algorithms. Figure 3 and Fig. 4 illustrate the charts plotted for compression time and compression ratio for all the three algorithms.

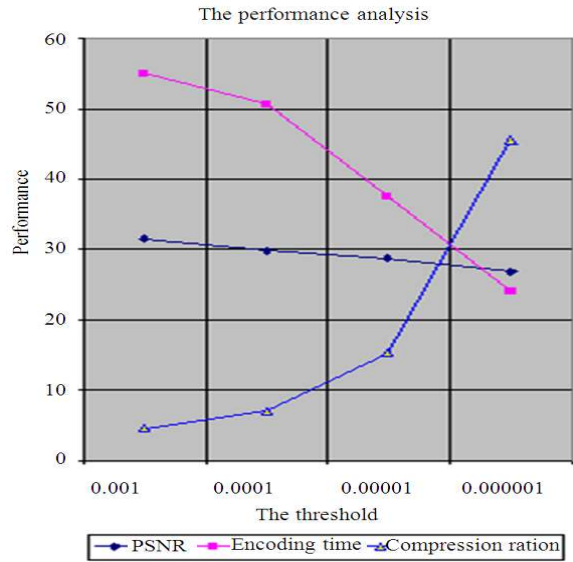


Fig. 1: Performance Analysis of proposed algorithm-I for 4 sample MR Images at different thresholds

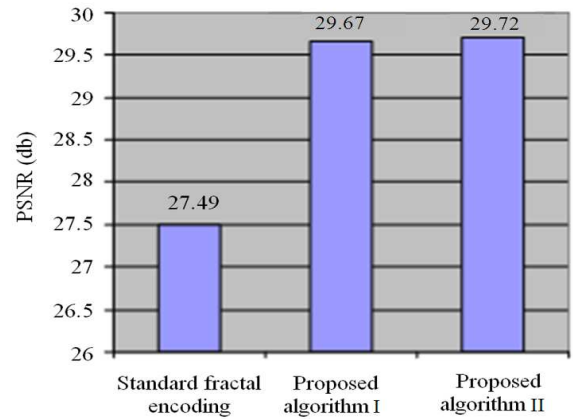


Fig. 2: PSNR comparison chart

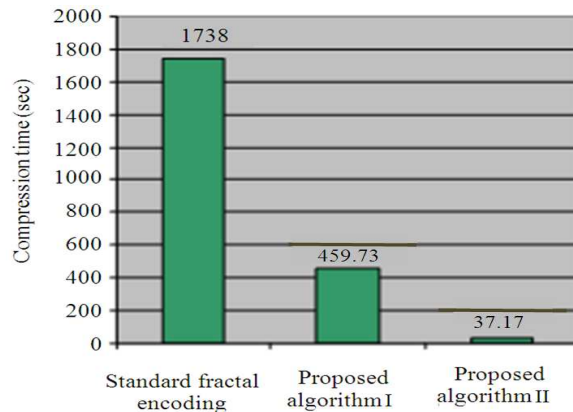


Fig. 3: Compression time compression chart

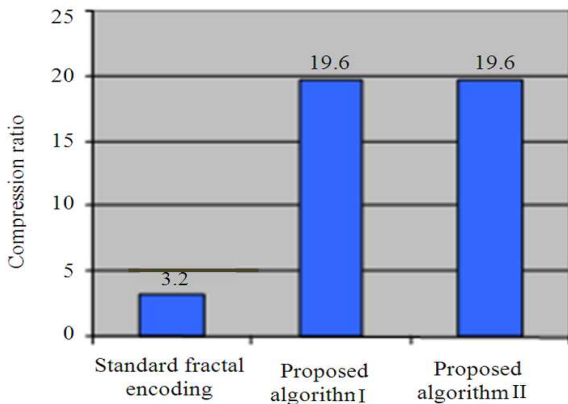


Fig. 4: Compression ratio comparison chart

DISCUSSION

If the results are carefully analyzed it is found that the proposed algorithms I and II has not only improved the performance but also has considerably reduced the encoding time. Hence the images compressed with the proposed fractal compression methods shows promising ways for applying them for medical image compression applications.

CONCLUSION

This study addresses to an improved SOM based fractal compression technique which is used to test the possibility of the fractal compression to medical imaging. The two newly proposed methods competes the standard fractal image compression algorithms. Since the proposed algorithm is regenerating feature rich portions of the images without any loss of information at that region, the perceptual quality of the image is found to be very good than that of the standard fractal image compression algorithm. SOM based model is used for improving the performance of the fractal coding scheme and also to reduce the encoding time. The results obtained for the proposed algorithm shows the improvement in encoding speed, outperforming some of the currently existing methods thereby ensuring the suitability of using fractal based image compression algorithms for medical image compression. Hybrid fractal coding is not addressed in our work. Our future work will be based on hybrid coding which allows for region of interest coding.

REFERENCES

Ali, M. and G.T. Clarkson, 1991. Fractal image compression. Proceedings of 1st Seminar on Information Technology and its Applications Mark Field Conference Centre, (ITAMFCC' 91), Leicester, UK., pp: 1-12.

Barnsley, M.F. and A.E. Jacquin, 1988. Application of recurrent IFS to images. *PIE Visual Commun. Image Process.*, 1001: 122-131.

Barnsley, M.F., 1996. Fractal image compression. *Notices of the AMS.*

Barnsley, M.F., 2000. *Fractals Everywhere*. 2nd Edn., Morgan Kaufmann, San Diego, ISBN-10: 0120790696, pp: 534.

Bhavani, S. and K.Thanushkodi, 2010. A survey on coding algorithms in medical image compression. *Int. J. Comput. Sci. Eng.*, 02: 1429-1434.

Hassaballah, M., M.M. Makky and Y.B. Mahdy, 2005. A fast fractal image compression method based entropy. *Elect. Lett. Comput. Vision Image Anal.*, 5: 30-40.

Hutchinson, J.E., 1981. Fractals and self-similarity. *Indiana Univ. Math. J.*, 30: 713-747.

Iano, Y., F.S. da Silva and A.L.M. Cruz, 2006. A fast and efficient hybrid fractal-wavelet image coder. *IEEE Trans. Image Process.*, 15: 98-105. DOI: 10.1109/TIP.2005.860317

Jackson, D.J., W. Mahmoud, W.A. Stapleton and P.T. Gaughan, 1997. Faster fractal image compression using quadtree recomposition. *Image Vision Comput.*, 15: 759-767. DOI: 10.1016/S0262-8856(97)00020-6

Jacobs, E.W. and R.D. Boss, 1989. Fractal based image Compression. NOSC Technical Report, 1315, Naval Ocean Systems Centre, San Diego, CA.

Jacobs, E.W., Y. Fisher and R.D. Boss, 1992. Image compression: A study of the iterated transform method. *Signal Process.*, 29: 251-263. DOI: 10.1016/0165-1684(92)90085-B

Jacquin, A.E., 1992. Image coding based on a fractal theory of iterated contractive image transformations. *IEEE Trans. Image Process.*, 1: 18-30. DOI: 10.1109/83.128028

Mandelbrot, B.B., 1983. *The Fractal Geometry of Nature*. 1st Edn., Freeman, New York, ISBN-10: 0716711869, pp: 468.

Polvere, M. and M. Nappi, 2000. Speed-up in fractal image coding: Comparison of methods. *IEEE Tran. Image Process.*, 9:1002-1009. DOI: 10.1109/83.846243

Saupe, D. and R. Hamzaoui, 1994. Complexity reduction methods for fractal image compression. Proceedings of the IMA Conference on Image Processing, Mathematical Methods and Applications (IPMMA' 94), The Pennsylvania State University.

Wang, Z., D. Zhang and Y. Yu, 2000. Hybrid image coding based on partial fractal mapping. *Signal Process.: Image Commun.*, 15: 767-779. DOI: 10.1016/S0923-5965(99)00018-1