International Journal of Electronics and Electrical Engineering

Volume 3 | Issue 1 Article 13

July 2014

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Recommended Citation
ENJELA, SAEMA and ANANTH, A.G. (2014) "BASED ON RANGE AND DOMAIN FRACTAL IMAGE COMPRESSION OF SATELLITE IMAGERIES IMPROVED ALGORITHM FOR RESEARCH," *International Journal of Electronics and Electical Engineering*: Vol. 3 : Iss. 1 , Article 13.
DOI: 10.47893/IJEEE.2014.1130
Available at: https://www.interscience.in/ijeee/vol3/iss1/13

BASED ON RANGE AND DOMAIN FRACTAL IMAGE COMPRESSION OF SATELLITE IMAGERIES IMPROVED ALGORITHM FOR RESEARCH

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Abstract*:* Fractal coding is a novel method to compress images, which was proposed by Barnsley, and implemented by Jacquin. It offers many advantages. Fractal image coding has the advantage of higher compression ratio, but is a lossy compression scheme. The encoding procedure consists of dividing the image into range blocks and domain blocks and then it takes a range block and matches it with the domain block. The image is encoded by partitioning the domain block and using affine transformation to achieve fractal compression. The image is reconstructed using iterative functions and inverse transforms. However, the encoding time of traditional fractal compression technique is too long to achieve real-time image compression, so it cannot be widely used. Based on the theory of fractal image compression; this paper raised an improved algorithm form the aspect of image segmentation. In the present work the fractal coding techniques are applied for the compression of satellite imageries. The Peak Signal to Noise Ratio (PSNR) values are determined for images namely Satellite Rural image and Satellite Urban image. The Matlab simulation results for the reconstructed image shows that PSNR values achievable for Satellite Rural image ~33 and for Satellite urban image ~42.

Keywords: *Fractal; Fractal image; quad-tree; Encoding time; Image segmentation; Quick encoding; iterated function system (IFS); image compression*

1. INTRODUCTION

Fractal image compression is a new method to compress images. Unlike conventional method its purpose is to reduce redundancy between blocks. It was proposed by Barnsley in 1988 [1], and implemented by Jacquin [6, 7]. It is based on the theory of iterated function systems (IFS) theory developed by Hutchinson [4] and Barnsley [2]. By far there are lots of published work, such as [5, 8, 9], and the book [3]. The basic idea of the method is as follows. At first, an image is partitioned into non-overlapping blocks, which are called range blocks. Then for each range block a contractive affine transformation and a domain block are determined so that the result block generated by applying the affine transformation to the domain block is similar enough to the range block. The domain block of a transformation should be larger in area than its corresponding range block in order for the transformation to be contractive. At last, all the contractive affine transformations, which just compose contractive IFS, consist of a code of the image. When decoding, the code is iterated repeatedly on any starting image, and the result image is just the decoded image. In general the number of iterates is 6 to 8. Simulation results show that the runtime of the proposed algorithm is reduced greatly compared to the existing methods. At the same time, the new algorithm also achieved high PSNR values. Fractal coding is a novel method to compress images. It offers many advantages. In [10] proposes a new method using best polynomial approx imation to decide whether a domain block is similar enough to a given range block. Also gives a kind of domain pool. It is found that the probability distribution of 8 isometrics in the fractal code is not average. And consequently it is proposed to use only 2 or 4 isometrics to speed up compression.

The paper is organized as follows. Section 2 describes the Fractal compression technique. After this, section 3 presents the affine transform. Then section 4 gives mathematical foundation of IFS in [2]. Section 6 describes the proposed algorithm used in this paper.

2. FRACTAL COMPRESSION

There are several different ways to approach the fractal compression. One way is to use the fixed point transformation. A function f (.) is said to have a fixed point x0 if f(x0) = x0. Suppose the function f (.) to be of the form ax + b. Then, except for when a = 1, this equation always has a fixed point.

$$ax0 + b = x0 \text{ then } x0 = b/(1-a) \quad \ldots\ldots\ldots (1)$$

This means that to transmit the value of x0, using the values of ‘a’ and ‘b’ and obtain x0 at the receiver using (1). Instead of solve this equation to obtain x0, we could take a guess at what x0 using recursion

$$X0\,(n+1) = a\,x0(n) + b \quad \ldots\ldots\ldots.. (2)$$

Thus, the value of x0 is accurately specified by fixed point equation. The receiver can retrieve the value either b the solution of (1) or via the recursion (2). In this paper we partition the image into blocks R_k, called range blocks, and obtain a transformation f_k for each block. The transformations f_k are not fixed point transformations since they do not satisfy the equation $\mathbf{f_k (R_k) = R_k}$. Instead, they are a mapping from a block of pixels D_k from some other part of the image. While each individual mapping f_k is not a fixed point mapping, that can combine all these mappings to generate a fixed point mapping. The image blocks D_k are called domain blocks, and they are chosen to be larger than the range blocks. The domain blocks are obtained by sliding a K X K window over the image in steps of K/2 or K/4 pixels. The transformations f_k are composed of a geometric transformation g_k and a massif transformation m_k. The geometric transformation consists of moving the domain block to the location of the range block and adjusting the size of the domain block to match the size of the range block.

$\check{R}_k = f_k (D_k) = m_k (g_k (D_k))$ ..... (3)

$\check{R}_k$ instead of R_k in (3) because it is not possible to find an exact functional between domain and range blocks, since some loss of information. This loss is measured in terms of mean squared error. In order to reduce the computations, restrict the number of domain blocks to search. However, in order to get the best possible approximation, the pool of domain blocks to be as large as possible. The elements of the domain pool are then divided in to shade blocks, edge blocks, and midrange blocks. The shade blocks are those in which the variance of pixel values within the block is small. The edge block, contains those blocks that have a sharp change of intensity values. The midrange blocks are those that fit into not too smooth but with no well defined edges. The encoding procedure proceeds as a range block is classified into one of the three categories described above. If it is a shade block, send the average value of the block. If it is a midrange block, the massic transformation is of the form ($\alpha_k t_{ij} + \Delta_k$) where $T_k = g_k (D_k)$, and t_{ij} as the ijth pixel in T_k i, j = 0, 1, …..M-1, α_k is selected from a small set of values. Thus the possible values of α and the midrange domain blocks in the domain pool in order to find the (α_k, D_k) pair that will minimize d (R_k, $\alpha_k T_k$). The value of Δ_k is then selected as the difference of the average values of R_k, $\alpha_k T_k$. If the range block R_k is classified as an edge block. The block is first divided into a bright and a dark region. The dynamic range of the block rd (R_k) is the computed as the difference of the average values of the light and dark regions. For a given domain block, then used to compute the value of α_k by

$A_k=\min\{(rd(R_k))/(rd(T_k)),\alpha_{max}\}$ …(4)

In (4) where α_{max} is an upper bound on the scaling factor.

The work carried out in the paper is based on range and domain technique. Taking different images such as satellite Rural and satellite urban images the PSNR is calculated for the reconstructed image.

3. AFFINE TRANSFORMATION

An affine transformation w: $R_n \rightarrow R_n$ can always be written as w = Ax + b, where A € R_n x n is an n x n matrix and b € R_n is an offset vector. Such transformation will be contractive exactly when its linear part is contractive, and this depends on the metric used to measure distances. As, linear transformation can scale with, stretch with A_t, skew with Au, and rotate with A_θ.

4. MATHEMATICAL FOUNDATION OF IFS

Let (M, d) is a complete metric space. A transformation ω: M→ M is contractive if there exists a constant S [0, 1), such that

D (ω (μ), ω (ν)) ≤s d (μ, ν), \-/ μ, ν Є M,

s is called contractility factor. An iterated function system (IFS) consists of a complete metric space (M, d) and a set of contractive transformations $\_i$, i=1, 2… N, where contractility factor of $\_i$ is s_i. We define : M → M as (ν) = (i=1→N) i (ν), \-/ ν Є M

It can be proved that is a contractive transformation, and its contractility factor is s=max {s_i, i=I, 2... N} [2]. According Banach's fixed point theorem, has a unique fixed point μ Є M, such that (μ= μ).

The IFS model generates a geometrical shape with an iterative process. An IFS based modelling system is defined by a triple (x, d, s) where (x d) is a complete metric space, x is called iterative space. S is a semi group acting on points of x such that p → Tp where T is a contractive operator, s is called iterative semi group. An IFS I is a finite subset of s: I = {T0, T1, TN-1} with operators Ti € s

5. FRACTAL IMAGE COMPRESSION ALGORITHM

Fractal image compression coding method is a way to change the size of range block Ri and the domain block Di in order to achieve the purpose of getting a reasonable choice of affine transform coefficients and reduce the searching and encoding time.

Concrete steps:

1. Segment the original image I into range block size $2^{rmax} \times 2^{rmax}$, do not overlap each, as the initial range block.
2. Taken domain block D_i 2 times the size of the range block R_i in the original image I, doing averaging 8z affine transformations D_i to domain block D^t_i to domain block $D_{i.}$
3. Calculate the root of mean square of range block R and each corresponding transformed domain

block D^t_i, as the matching error d between the two blocks.

4. If a full search completed, and did not meet the conditions d segment the original block R_i into four equal, repeat (2) to (4) operations.
5. Record the current fractal coding information to the Fractal gallery, complete a fractal encoding.

Using this method to divide range block and the domain block, comparing with the traditional method of fractal coding, the number of the domain block reduced.

6. THE PROPOSED ALGORITHM

The algorithm steps are as follows.

1. The side of the maximum range block is (2^{rmax}) and the side of the minimal range block is (2^{rmin}), initialize the size of the range block is ($2^{rmax} \times 2^{rmax}$) and minimal size of could-be-compressed range block is ($2^{rmin} \times 2^{rmin}$).
2. Search the entire space; get the range block R_i and the best-matching domain block D_i , stored the fractal codes information {(D_{xi}, D_{yi}), s_i , o_i , U_i }, that is, location of the domain block in the image space, contrast factor, brightness and type of affine transformation.
3. Find the next best-matching domain block D_i of the range block R_i: the location of the domain block D_i centred at the previous domain block (D_{xi},D_{yi}), search in the area size of H ×W .
4. Calculate the RMS d of the range block R_i and the matched domain block D_i as their matching error. If d< **ε**, stored the fractal codes information and skip to step 8. If d > ε, expand search area in step T, that is, H = H + T, W =W + T, continue searching for the best matching domain block $D_{i.}$
5. If the matching error between the range block and the domain block is still greater than the tolerable error, continue to expand the search area of the domain block, with condition that the region cannot be greater than the original image.
6. When the search area is greater than or equal to the size of the original image, it indicate the totally search region cannot meets the condition of less than the tolerable error. The range block is divided into four equal blocks, and operate step 4 for each block. Stop till the side length is less than or equal to 2^{rmin} record the smallest difference error in the whole process.
7. The current range block cannot be segment, it indicates the matching domain blocks searched cannot meet the requirements yet, record current fractal codes information.
8. Determine whether the match searching is complete or not, if it is, the decoding operation can be completed, otherwise continue to do step 3.

When the range block locates in the complex image areas, it will be divided into more pieces. If the range block locates in the smooth image region, it is no need for division.

7. RESULTS AND DISCUSSIONS

The algorithm realized in Matlab to code and to decode the satellite image of Urban of size 1377 X 955, rural image of size 995 X 57.The compression ratios and the PSNR values obtained for the reconstructed Satellite Rural Image and Satellite Urban Image is listed in Table 1. The original image and the reconstructed image after fractal encoding-decoding is shown in Figure 1 and 2.

Table I. The Experimental Data

Image type	Psnr		Compression ratio	
	GA	IA	GA	IA
Urban	21.93	+42.808	3.2	5.9
Rural	18.01	+33.233	3.2	5.5

GA= given algorithm; IA= improved algorithm

Original **reconstructed**

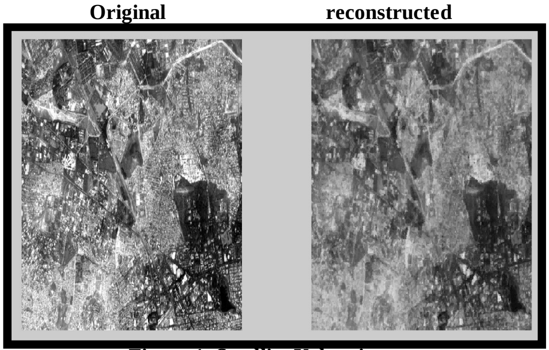

Figure 1. Satellite Urban image

Original **reconstructed**

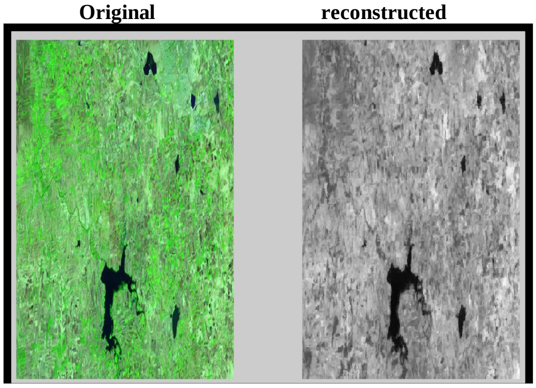

Figure 2. Satellite Rural image

It is clearly seen from the Table 1 that for Satellite Rural Image and Satellite Urban image the compression ratio are ~5.5 and ~5.9. The PSNR values achievable for Satellite Rural image is ~33.233 and for the urban image is ~42.808. The Urban image shows the highest PSNR values compared to rural image. Further it can be seen from the Figures that the reconstructed urban image has a better quality of the reconstructed image compared to that of rural image.

These results suggest that the urban images contain more fractal information compared to that of rural image. The fractal coding techniques are better suited for the compression of satellite urban images.

8. ACKNOWLEDGEMENTS

I thank my guide Dr.A.G.Ananth, HOD the Staff and Department of Telecommunication Engineering, RV College of Engineering, Bangalore for providing me an opportunity and resource to carry out the work.

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