REMOTE-SENSING IMAGE COMPRESSION BASED ON FRACTAL THEORY

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KEY WORDS: Remote Sensing Image, Fractal Compression, Iterated Function System, Classification, Self-similarity

ABSTRACT:

The high compression ratio and excellent quality of fractal image compression have restricted the applications, due to the consuming encoding time. This paper discusses an improved method of the fractal remote-sensing image compression. The method is to divide the images and searching the iterated function system between the range blocks and the domain blocks quickly through analyzing the texture characters of the images. The goal is to identify the most similar range blocks and domain blocks among the blocks with same characteristic features. The test results demonstrated the quality and the speed of the remote-sensing images coding were improved with this method.

1. INTRODUCTION

The spatial resolution of remote sensing images is of unceasing enhancement; huge amount of data will require much more storage space and transmission time. In order to solve the problem of storage space and transmission time, the remote sensing images compression becomes one of the hot topics at present.

Recently, the main image compression methods are the JPEG compression standard, the wavelet analysis compression and so on (Hongmei Tang, 2004). But the characteristics of the remote sensing images are different from the other general images; its content is mostly about natural surface, such as the water, vegetation, mountains, etc. These textures are often clear, and the content generally has the characteristic of the self-similarity. In this paper, a traditional fractal compression method applied in the remote sensing images is introduced. As the exhausted encoding time, an improved method base on the classification is discussed. It could be proved to lower the encoding time.

2. THE BASIC PRINCIPLE OF FRACTAL COMPRESSION

The most famous characteristic of Fractal is the self-similar. It means no matter how changes of the scale of geometry, a small part of any image is extremely similar with the larger part ones. From the perspective of fractal image compression, it is to the most efficiently use of the self-similarity between the parts and blocks of image. The main point is to divide an image into several parts (range blocks), which aren't overlapped; meanwhile, dividing the image into several blocks (domain blocks) that could overlap each other. Then for each range blocks R_i, finding the most similar domain block D_i to match with them. At last, establishing the relationship between the range blocks and domain blocks: the domain block may infinite approach to the range block through the affine transformation, that is $R_i \approx w_i(D_i)$. For each range blocks, finding the Iterated function w_i, range blocks are storied in the form of Iterated Function. The Iterated Function often can be expressed by only a few parameters, and according to the Collage Theorem, the iterated image (decoded image) has nothing to do with the original images. Therefore, the fractal compression can be achieved at a high compression ratio. When decoding the images, we need only iterate the Iterated Function parameters of each range blocks; the original images can be restored.

Iterated Function System (listed IFS) is the important content of fractal theory. The basic idea is to identify geometric objects as a whole and partial, having the self-similar structure in the meaning of affined change. The most important theorem of fractal image compression is the Collage Theorem (Welstead, 1999). This theorem proves that for a range block we can always find the domain block, which is closest to the range block with a low erroneous distortion. It also manifested that the decoding image is nothing to do with the original image. So only saving every Iterated function w_i, it can achieve the aim of compression (Yudong Fang, 1996).

3. THE EXPERIMENTS OF FRACTAL REMOTE SENSING IMAGE COMPRESSION

In this experiment, a 512 × 512 greyscale TM image, with 265 grey levels for each pixels has been taken for being compressed using the fractal method. The concrete compression methods involve the three steps:

Step1 Setting the size of domain blocks D_i for 16 × 16 pixels, the size of range blocks R_i for 8 × 8 pixels. The range blocks aren't overlapped each other, so the number of range blocks in the image is $\frac{512}{8} \times \frac{512}{8} = 4096$. The domain blocks could overlap, therefore the number of them in the image is (512-16+1) × (512-16+1) = 247009.

Step2 To each range block R_i, find the most similar domain block D_i and the relevant d_{ij} (i=1, 2...8, j=1, 2...8), s_i, o_i, let the domain block D_i be closest to the range block through the domain block transformation. d_{ij} is the pixel value of domain block after the rotary-reflection and stretching transformations, s_i, o_i are the factors of contrast and brightness which can make the domain block be closest to the range block. The main step is:

A. The 16 × 16 pixels grey domain blocks are made into 8 × 8 pixels grey domain blocks by averaging four pixels into one pixel.

B. Choose the eight different basic rotary-reflection and stretching transformation methods for every 8 × 8 grey domain blocks: reflection by mid-vertical axis, reflection by mid-horizontal axis, reflection by first diagonal and second diagonal, rotation by $0°, 90°, 180°, 270°$. For each 8 × 8 pixel grey domain blocks, it could obtain eight grey blocks through the transformation. For the 247009 different domain blocks, we get 247009×8 different domain blocks through the eight basic transformations.

C. For each domain blocks, supposing that the pixel value of domain block is d_{ij} $(i = 1, 2, \cdots 8;\ j = 1, 2, \cdots 8)$ after the eight transformations. r_{ij} (i=1, 2...8, j=1, 2...8) is the pixel value of range block. The S (contrast) could be obtained from:

$$s = \frac{64\sum_{i=1}^{8}\sum_{j=1}^{8} d_{ij}r_{ij} - \sum_{i=1}^{8}\sum_{j=1}^{8} d_{ij}\sum_{i=1}^{8}\sum_{j=1}^{8} r_{ij}}{64\sum_{i=1}^{8}\sum_{j=1}^{8} d_{ij}^2 - (\sum_{i=1}^{8}\sum_{j=1}^{8} d_{ij})^2} \tag{1}$$

And O (brightness) could be obtained from:

$$o = \frac{\sum_{i=1}^{8}\sum_{j=1}^{8} r_{ij} - s \cdot \sum_{i=1}^{8}\sum_{j=1}^{8} d_{ij}}{64} \tag{2}$$

It could minimize the Root Mean Square (RMS), the less the RMS is, the closer the domain block and range block are.

For the range block and transformed domain block, the definition of RMS is:

$$rms = \sqrt{\sum_{i=1}^{8}\sum_{j=1}^{8} (s \cdot d_{ij} + o - r_{ij})^2} \tag{3}$$

So the RMS is:

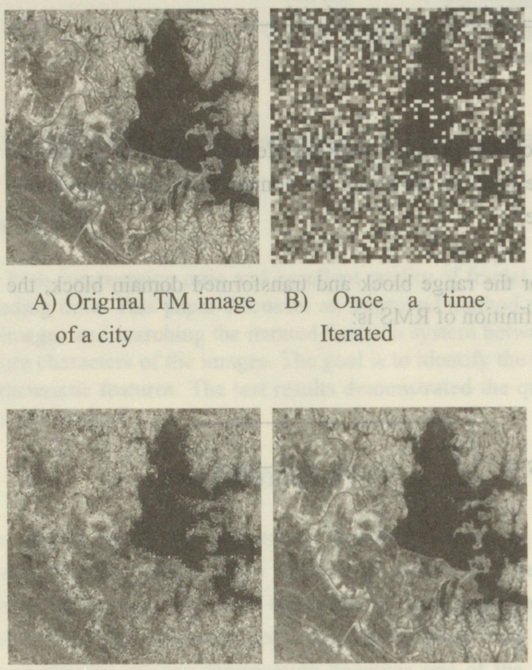
$$rms = \frac{1}{8}\sqrt{\left[\sum_{i=1}^{8}\sum_{j=1}^{8} r_{ij}^2 + s\left(s\sum_{i=1}^{8}\sum_{j=1}^{8} d_{ij}^2 - 2\sum_{i=1}^{8}\sum_{j=1}^{8} d_{ij}r_{ij} + 2o\sum_{i=1}^{8}\sum_{j=1}^{8} r_{ij}\right) + o\left(64o - 2\sum_{i=1}^{8}\sum_{j=1}^{8} d_{ij}\right)\right]} \tag{4}$$

For each range blocks R_i, calculate the 247009×8 transformed domain block and find the S (brightness), O (contrast), rms. From above results, recording the S, O that make the RMS be most minimum and the position of domain block, the ways of the domain block's transformation. So, the encoding for one range block has been finished, that means it has gotten the W_i.

D. For each range blocks R_i, recording the corresponding W_i and saving them in the database.

Step3 When decoding, set f_0 to be a white image, first supposing the $W = \bigcup_{i=1}^{4096} w_i$, where W_i is the Iterated function, then iterating the Iterated Function parameters of each range blocks $W(f_0), W(W(f_0)), \cdots$, about seven or eight times, it can restore the original images. (Wenqu Zeng, 2002; Wee Meng Woon 2000)

The Figure 1 shows the decoding process of iterating IFS with 1, 3, 7 times.



A) Original TM image of a city B) Once a time Iterated

C) Three times Iterated D) Seven times Iterated

Figure 1. Remote sensing image compression using fractal theory

The result of the image compression is presented in the Table 1. The average of RMS for the 4096 range blocks to their closest domain blocks is 19.17; the compression ratio is 4.02:1, the Peak Signal-to-Noise Ratio of seven times iterated decoding image to the original image is 21.5891. The biggest problem is the exhausted encoding time—about 27min.

How to improve the fractal encoding speed is the main point that many scholars considered. The time-consuming of fractal compression mainly manifested in finding the most similar domain blocks to the range blocks. As the domain blocks could overlap each other, it brings a lot of computation. At present, the main solution is to reduce the search area and assure the most similar domain blocks in this area. Some of the improved ways has been described in [Shuguang W, 2004].

For some improved methods based on the classification, considering to the characteristics of remote sensing image, it could classify the image with the types of features. To different types of range blocks, we only search the most similar domain blocks in the same types of area. It can reduce the searching time and area. As the features with the same types often have the characteristics of self-similar, it can quickly and accurately obtain the most similar blocks.

On the base of above methods, first, the author makes the pre-processing of the original image: the image is classified into three types according to the pixel value. One is the water area, another is mountain and the other is residential area. The Fuzzy C-Means (FCM) clustering algorithm is taken to classify the image. Compared with crisp or hard segmentation methods, FCM is able to retain more information from the original image. (Yunsong Li, 2007). The Figure 2 shows the result of the classification using the FCM.

Figure 2. Result of the classification using FCM clustering algorithm

After classification, setting:

$$\text{The attribution value of each pixel} \begin{cases} 0 & \text{If it belongs to water} \\ 1 & \text{If it belongs to mountain} \\ 2 & \text{If it belongs to residential area} \end{cases}$$

Second, for each range blocks, the average of attribution values of 64 pixels is calculated, and the average of attribution values of 256 pixels in every domain blocks is also computed. To every range blocks, we find the closest domain blocks through the nearest average of attribution values.

Third, after finding the closest domain blocks for each range blocks, we also choose the eight different basic rotary-reflection and stretching transformations for the closest domain blocks, then calculating the minimum RSM between them. That is easy to obtain the Iterated function w_i for each range blocks.

The TM image is compressed by using the improved method; the result is showed in Table 1.

Table 1. Comparison of the two methods

METHOD	AVG RMS	PSNR	ENCODEING TIME(min)
Traditional method	19.17	21.5891	27

Improved method	22.35	20.6472	18

AVG RMS - Average of the RMS for the 4096 range blocks to their closest domain blocks

PSNR - Peak Signal-to-Noise Ratio of seven times iterated decoding image to the original image

4. DISCUSSION

Using the traditional method, the result shows that the decoding image is very similar to the original image. Though the quality of decoding image in the improved method is a bit lower, the consumed encoding time has descended to about 18min. To different types of range blocks, we only search the most similar domain blocks in the same types of area. It can reduce the searching time and area. The experiment demonstrates the speed of the remote-sensing images encoding is improved.

The image can also be classified into four or more types according to the features, and the quality of decoding image will be improved. However it's more complex when finding the closest domain blocks for the range blocks. Meanwhile the consuming-time will be enhanced. How to balance the quality of decoding image and the consuming-time of encoding is still a problem.

5. CONCLUSION

In this paper, a traditional fractal compression algorithm is described and successfully applied on remote sensing image compression. As the exhausted consuming time, an improvement of the fractal compression by pre-classifying the image has been introduced and has a better result in the speed of encoding time.

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ACKNOWLEDGEMENT

Supported by the Project-sponsored by SRF for ROCS, SEM.