AN IMPROVED METHOD OF REMOTE SENSING IMAGE COMPRESSION BASED ON FRACTAL AND WAVELET DOMAIN

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ABSTRACT:

One of the efficient solutions for data transmission and storage of huge remote sensing images is the high-fidelity and rapid compression. The hybrid algorithms based on fractal coding and wavelet transformation have already been developed and are becoming very popular at present. In this paper, an improved method of remote sensing image compression based on fractal coding and wavelet domain is proposed. Firstly, the method uses the wavelet-transformation to create the similarity between sub-bands of an image, and the fractal algorithm is exploited to code for adjacent high-frequency bands with similarity character, it is must be mentioned that some improvement has been used to speed up searching for similarity blocks during the step. Consequently, fractal iterative decoding and wavelet inverse transform are applied to reconstruct the image. From the above, it can be concluded the method proposed in this paper not only makes full use of the characteristic of wavelet multi-resolution, but also considers the self-similarity among objects. Finally, some experiments have been given, and the results demonstrates that the method can do well in the remote sensing image compression, less losing of the image information and more recovering of image quality. Moreover, ensuring the signal-noise ratio of the image, it can better increase the image coding efficiency

1. INTRODUCTION

With the updating and developing of remote sensing sensors and equipments, the resolution of remote sensing images is high increasing. However, it also brings tremendous numbers of data and high-dimensional data [1]. The fractal image compression technology which is a modern image coding method has been attracting much attention [2]. It not only considers the interrelation between local data, and also between global data and local data. So fractal image compression is suitable for images with self-similar or self-affine. There are a lot of self-similar or the self-affine image in natural world, fractal image compression is used in many fields. In recent years, wavelet transform coding method used in image compression has been achieved better results [3]. Generally speaking, the compression algorithm based on wavelet transform has slight higher compression ratio, but the details of the image must lost. So when the quality of image reconstruction goes up, the compression ratio should reduce. Remote sensing image has complex features and valuable information, the loss of information requires tight restrictions [4]. This paper fully exploited mathematical microscope of wavelet and the fractal self-similar characteristic; the problems [5] brought by every single method can be resolved.

2. METHODOLOGY

2.1 Multi-resolution Analysis of Wavelet

Since the concept of multi-resolution analysis was put forward by Mallat in1988, wavelet transform has always been a precedent in image processing fields. The thought of multi-resolution analysis is to decompose the signal into two components including low-frequency and high-frequency by ideal filter. It preserves the high-frequency component; each of the low-frequency components keeps on decomposing. That is so called signal multi-resolution analysis. Take the original signal $f(t)$ for example, the frequency space is V_0. Low-frequency space V_1 and high-frequency space W_1 is created after one level decomposing. Then V_1 is decomposed into V_2 and W_2 after the second decomposition … The purpose of these decompositions are to structure an orthogonal wavelet which highly approach to space $L^2(R)$ in the frequency. Suppose that the resolution of signal 2^j is similar to A_{2^j}, it can be considered as all the possible signal of 2^j resolution in the space $\{V_{2^j}\}$ .The properties of multi-resolution analysis can been seen as following [6]:

(1) The similarity of signal in resolution 2^{j+1} contains all the similarity of signal in resolution. That is:

(2) $V_{2^j} \subset V_{2^{j+1}}, \forall \mathrm{j} \in Z$

(3) The closed space in different resolution meet: $\bigcup_{i=-\infty}^{+\infty} V_{2^j} = L^2(R)$ and $\bigcap_{i=-\infty}^{+\infty} V_{2^j} = \{0\}$.

(4) The signal scale changes in the approximate space. It is consistent between the change of function which is approximate

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to orthogonal wavelet and the change of space. That is: $f(t) \in V_{2^j} \Leftrightarrow f(2x) \in V_{2^{j+1}} \forall j \in Z$.

(5)The signal $f(t)$ is approximate to $A_{2^j} f(t)$ in the resolution 2^j , which can be dispersed by the 2^j samples on each length.

Generally speaking, assume that the original signal $f(t)$ has the highest spatial resolution when $j = 0$ and its spatial resolution is 2^j . A function $\phi(x) \in V_{2^0}$ is present for $\{\phi_{j,k}(x)\}$ to structure an orthogonal radix in V_{2^j} . $\phi_{j,k}(x) = 2^{\frac{j}{2}} \phi(2^j x - k)(j,k \in Z)$ is called the scale function of $\phi(x)$.

Wavelet transform decomposes the N × N image into two parts which respectively represent low frequency L and high frequency H. And then each sub-images is to be decomposed into low-frequency (LL) and high-frequency components (HL, HH, LH) according to rows or to lines. Images are divided into four 1 / 4 sizes of sub-images in each transform level.

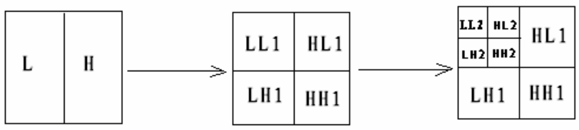

Figure. 1 two level decomposition of wavelet

The Fig.1 demonstrates the process: the image is decomposed into different space (horizontal, vertical and diagonal directions) and different frequencies sub-images by multi-resolution analysis, and then sub-images is coded. Wavelet transform itself does not have compression functions. It is applied to image compression based on the fact that image coefficients mainly concentrate in low-frequency after wavelet transform and high frequency has few energy. Take an image for example, the main contours information is in the low-frequency, and details information is in high-frequency.

2.2 Image Coding Based on Fractal Method

In the year 1975, a United States mathematician called Mandelbrot established fractal theory. As a geometrical target, the process and state of fractal is chaotic, but its essence is very simple. The basic character of fractal is the structure of overall image and the part region has some similarity or correlation. Barnsley proposed the coding method of fractal image compression and gave the concept of IFS (Iterated Function System). IFS regards the images divided into many non-overlapping range blocks which are similar to the overall region (self-similar) or are similar to overall region (self-affine) after certain transform (rotation, affine, displacement, etc.). The core of fractal image compression method is how to identify a group of compression affine transform parameters. The basic theory of fractal image compression is the iterative function system and the collage theorem [7, 8].

There are two pivotal technologies for fractal image compression:

1. Structure iterated function system (IFS) by mining the self-similarity of original image. That is to use a sub-block being close to another sub-block in image through self-affine transform. Only transmit or store corresponding IFS code to achieve image compression.

2. The image decoding process, according to compression mapping theorem, any mapping is able to converge at an attractor after repeated operation. If the mapping is correct, the final decoding image will be very close to the original image after finite iteration.

The steps of fractal coding:

(1) The original image N × N will be segmented into B × B sizes of value domain Ri and D×D sizes of definition domain Dj; usually let D = 2B; the block of Ri can't overlap each other, the block of Dj can overlap.{Dj}forms a searching domain.

(2)Search the best match with the definition domain blocks Dj for each value domain blocks Ri in the range of the whole domain. The matching criterion is the MSE standard. All the value domain blocks find the corresponding definition domain blocks, and making each image value domain blocks can be covered with definition domain blocks. So the corresponding affine transformations which are image fractal coding are got.

2.3 Fractal Encoding Based on Wavelet Domain

The basic idea of this paper's fractal coding based on wavelet domain is to carry out fractal coding compression on every level wavelet coefficients after wavelet transform for the original image. The method adopts wavelet transform on image for n levels decomposition. Each level includes one low-frequency sub-band and three low-frequency sub-bands of different directions. Between high-frequency bands of every directions uses fractal coding. In this paper, the concrete processes of images fractal coding based on wavelet domain high-frequency sub-band is as following:

(1) After n levels wavelet decomposition of the image, all the bands are LL_{n0}、HL_{n1}、LH_{n2}、HH_{n3}.Towards N × N sizes of images, different level sub-images has the corresponding structure of the similarity. The high frequency sub-images $HL_{n-1,1}$、$LH_{n-2,2}$、$HH_{n-3,3}$ respectively segments and matches with the higher high-frequency region HL_{n1}、LH_{n2}、HH_{n3} .Finally, the high frequency region of every level is segmented and composed of the same sizes of non-overlapping sub-block.

(2) The searching windows double narrow from the junior level to senior level, and the junior level blocks search for senior level correlation coefficient of the corresponding high-frequency blocks. These correlation coefficients make up of the IFS between two frequency domains.

In the process of decoding, the high level of the sub-band images iterative resume the low level sub-band images according to compression mapping. The three lowest sub-images in wavelet domain can be iterated and got with the stored fractal coding. After that, the image can be reconstructed via wavelet transform inverse.

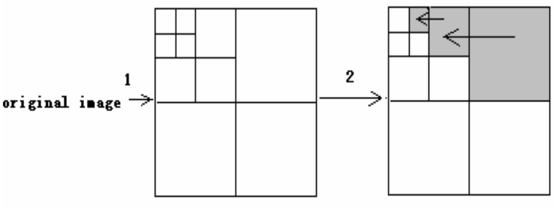

Figure.2 Fractal coding based on wavelet domain

2.4 An Improved Method

It is well known that the encoding time for searching matching domain block for every range block is definitely long and encoding speed is accordingly rather slow. To improve the fractal coding method by reducing the searching regions, the new method proposed considers the characteristics of small windows selected in the domain blocks and range blocks, which almost should have the similar pixel values when satisfying the characteristics of self-similarity. For example, if the range blocks are similar with the domain blocks, the pixel values above the given threshold should also have the similar numbers between them. Therefore, using threshold to select the windows may meet the characteristics of self-similarity mostly, and then calculating the parameters of Iterative Function System to carry out fractal compression coding, which can reduce the times of search and calculation, consequently achieve to improve the speed of encoding.

This paper mainly improves the fractal coding using wavelet domain transform and the threshold. The specific coding process can be described by the following steps:

(1) Firstly, wavelet transformation changes the original image into wavelet domain and then the low-frequency sub-bands and the high-frequency sub-bands in three directions can be formed.

(2) Secondly, search the best value domain block matching with the definition domain block in the range of the corresponding high-level sub-band. Then, calculate the number of pixels that meet the conditions in the value domain blocks and definition domain blocks respectively according to a set of specified values. Finally, compute the corresponding parameters of affine transformation to get the image fractal coding while the conditions are satisfied; and then goes to the next estimation directly and need not to compute the fractal coding.

(3) When obtain the corresponding fractal coding of each range block, the fractal image in wavelet domain will be formed through gradual iteration. So that the most similar image can be reconstructed by the way of inverse wavelet transformation

3. EXPERIMENTAL RESULTS AND ANALYSIS

TM remote sensing image of 512 × 512 pixel sizes is selected in this paper using Haar wavelet for five levels decomposition. Low-frequency region is retained to maintain the overall image profile, and high-frequency regions are coded and decoded by fractal method. Experiments chose the efficient segmentation means which is convenient for fractal coding .The number of the segmented blocks are 16×16, 32×32, 64×64, 128×128, 256×256 pixels respectively from the top level to the low level ; the corresponding searching windows of high-frequency regions are 1×1,2×2,4×4,8×8 pixels. During the searching process, the improved method is applied. Experimental results show that images PSNR is close to a stable value after the iteration times of image high-frequency coefficient matrix achieves five. Take a TM remote sensing image for example, it is shown in figure 3.

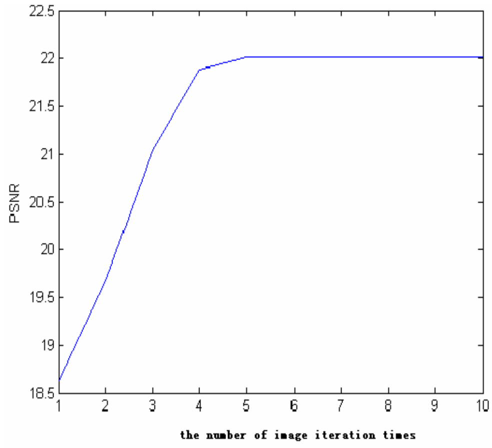

Figure.3 The relationship between the times of TM image iteration and PSNR

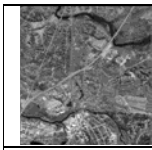			
(a)original image	(b)one time iteration	(c)5 times iteration	(d)10 times iteration

Figure.4 TM original image and image reconstruction after iterative

The results can be evaluated by the following aspects: the time of coding, compression ratio and the quality image decoding. The improved method put forward in this paper has been compared with the traditional fractal image compression method [8] and fractal coding method based on wavelet domain through experiment. And, the comparative effect is shown in Table 1.

	the time of coding cost (s)	PSNR	compression ratio
traditional fractal coding method	3600	22.78	4:1
fractal coding method based on wavelet domain	306	22.02	7:1
improved fractal coding method based on wavelet domain	120	22.00	7:1

Table 1 The comparison of the three different coding methods

From the Table1, it can be shown that the improved coding method can solve the problem of the slow searching speed found on pixel moving in the fractal image compression algorithm and it can also be seen that the coding time of the improved method has been significantly shortened while the PSNR has been few decreased.

4. CONCLUSIONS

In this paper, the study and analysis can attain the following conclusions:

(1)The fractal coding method based on wavelet domain unites the similarity between the sub-bands after multi-resolution analysis of wavelet and the object's self-similar characteristic in fractal geometry. Thereby the redundancies in images between frequency bands are eliminated.

(2)Remote sensing images are produced the sub-band similarity by wavelet transform, and then fractal encoding method is used for the adjacent sub-bands which are similar or correlative. The steps of searching by block instead of researching by pixel improve the image encoding efficiency. Then the image reconstruction is effective through the high level sub-images structuring the corresponding level sub-images.

(3)Fractal image compression method has a potential high compression ratio, and high-efficiency.

(4)The method proposed can ensure the signal-noise ratio of the image , meanwhile, the encoding time for searching matching domain block for every range block can be shorten largely.

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