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13—31 Application of Hybrid Fractal Image Compression Method for Aerial Photographs

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Abstract

This paper proposes a method to improve the performance of Fractal Image Compression (FIC) technique by combining FIC (lossy compression) and another lossless method (in this case Huffman coding is used). This proposed method takes advantage on each techniques, the high compression ratio that can be provided by FIC and the infinite peak-to-peak signal to-noise ratio (PSNR) that can be provided by lossless compression method. The experiment results show that with this hybrid FIC, we can get an infinite PSNR (no data losses) with higher compression ratio comparing to usual lossless method. It is expected that this method is suitable for compressing aerial photograps in terms of image reconstruction quality, compression ratio and processing time. This improvement is considerably interesting because we can save the storage space and data transmission time without any data losses.

1. Introduction

Nowadays, the use of aerial photographs is increasing, especially for city planning, or monitoring the existing area in a country. The information contained in an image data, especially in aerial photographs, has inevitably enormous numbers of bit representation. This fact causes problems in storage media capacity and time required for data transmission. To solve this problem, we need to choose a suitable image compression method. The method we choose should be the one that has three basic characteristics :

a. The ability to provide high compression ratio.
b. The ability to maintain the whole information in the original images (no data losses). This point can be determined by its high value of peak-to-peak signal to noise ratio.
c. Short processing time.

Basically, image data compression can be concerned with reducing the number of bits required to represent images without any appreciable loss of information [1]. This compression process can be possibly done because of redundancies in image data.

There are two types of compression method :

a. Lossless compression
   This method retains the whole information contained in an image. This method allows an exact reconstruction of the original image.
b. Lossy compression
   This method causes data losses.

FIC is a lossy compression method, so there will be data losses in compressed image [2]. The peak-to-peak signal to noise ratio (PSNR) will have a low value. This is the weakness point of FIC, concerning our objective to compress aerial photographs.

But, beside the weakness point in its PSNR, FIC has the advantage in term of its ability to provide a very high compression ratio. Compression ratios of 10,000:1 have been claimed by researchers in this field [3].

2. Basic Concept of FIC

FIC is an emerging technique for compressing images [4]. This method takes advantages on self-similarity within images and see it as redundancies that can be reduced. Image blocks are then seen as rescaled and intensity transformed approximate copies of blocks found elsewhere in the image [5]. It yields a self-referential description of image data.

The basic idea of FIC is a copy machine that reduces the image to be copied by a half and reproduces it three times on the copy, as in Figure 1 [2]. Then we feed the output image back as input. The infinite successive of this iteration process in a feedback loop will converge to a final image that will not change anymore by the process. This final image is called *attractor*.

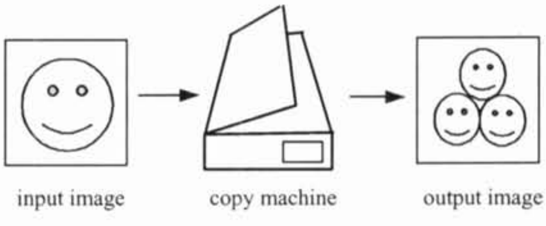

Figure 1. A copy machine that makes three reduced copies of the input image

The final result of the process above is determined by the way the input image is transformed. Different transformations lead to different attractors. Such transformations called *affine transformations* can be used to skew, stretch, rotate, scale and translate an input image. Storing images as collections of these transformations could lead to image compression.

A typical feature of all attractors formed this way is that in the position of each squares in an image, there is a transformed copy of the whole image. Thus, each image is formed from transformed and reduced copies of itself and hence it must have detail at every scale. That is, the images are *fractals*.

2.1 Self-similarity

The property of objects where magnified subsets appear similar or identical to the whole and to each other is known as self-similarity. This property is a basic characteristic of fractal. Figure 2 shows another type of self-similarity, that is *local self-similarity*.

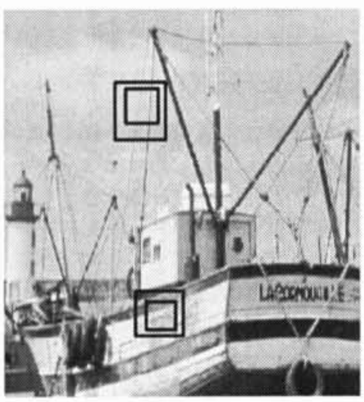

Figure 2. Local self-similarity within an image

Figure 2 above shows two areas with different scale which are self-similar. This image is formed of properly transformed *parts* of itself. However, these transformed parts do not fit together to form an exact copy of the original image, so we must allow some error in our representation of an image as a set of self-transformations. It means that the encoded image as a set of transformations is not an identical copy but an approximation. Hence, FIC is a lossy compression method.

Self-similarity is a type of redundancies in an image which is trying to be reduced or eliminated by FIC technique.

2.2 Iterated Function Systems (IFS)

Fractal coding used in this image compression process is based on the mathematical theory of *Iterated Function Systems* (IFS). IFS is used to represent a set of contractive affine transformations. These affine transformations are used to show relationship between parts of an image and define the intricate details of a picture. Compression can be done because the system only stores the transformation coefficients.

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

Figure 3. Affine transformation

3. Encoding-Decoding Process

There are always two main processes in image compression techniques : encoding and decoding. The encoding process is more complex comparing to decoding process.

3.1 Encoding

In this process, we firstly partition the image by some collections of non-overlapping range blocks R_i ; then for each R_i, seek from some collections of image pieces a domain block D_i that has a low rms error when mapped to R_i. The task of a fractal coder is to find a domain block D_i from the same image for every range blocks R_i such that a transformation of the domain block is a good approximation of the range block. The domain size is larger than the range blocks. If we have known the $R_i - D_i$ pairs , then we can define the coefficients of the appropriate affine tranformations. Finally, we get the transformation $W = \cup w_i$ that code the image approximation.

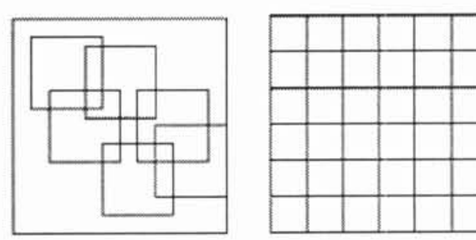

Figure 4. Image partitioning
(a).Domain blocks (b) Range blocks

Image Partitioning Method: Quadtree Partitioning

One important step in FIC is partitioning an image into range blocks and domain blocks. The objective of this process is to search self- similar parts in an image that can be related by affine transformations. How an image is partitioned directly defines the quality and the coding time.

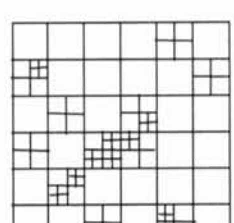

Figure 5. Quadtree Partitioning

An example of image partitioning method is *quadtree partitioning*. In a quadtree partition, a square in the image is broken up into four equal-sized subsquares when it is not covered well enough by some domains. This process repeats recursively starting from the whole image and continuing until the squares are small enough to be covered within some specified rms tolerance. Other image partitioning methods are HV partitioning and triangular partitioning.

3.2 Decoding

Decoding process is much simpler. Starting from any initial image, we repeatedly apply the w_i until we approximate the fixed point. For each w_i, we find the domain D_i, shrink it to the size of its range R_i, multiply the pixel values by s_i, add o_i and place the resulting pixel values in the position of range R_i which is determined by the orientation information. This is one decoding iteration. This process is iterated until the fixed point is approximated, that is, until furher iteration doesn't change the image or until the change is below some small threshold value.

4. Hybrid Fractal Image Compression Method

As mentioned earlier, FIC is a lossy method. Meanwhile, aerial photographs need compression technique that can retain the whole information exist in an image data. To solve this problem, we can combine FIC with other lossless method, such as Huffman coding.

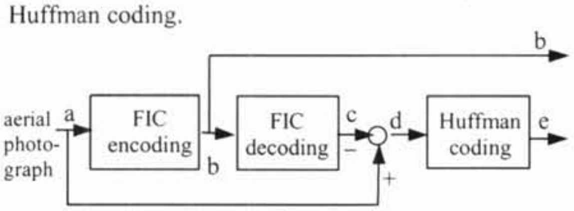

Figure 6. Block Diagram of Hybrid FIC Method (Fractal – Huffman Compression System)

Compressed image : b and e

Compression Ratio = $\frac{\text{number of bits of an aerial photograph}}{\text{number of bits b + number of bits e}}$

Image error = d = a - c

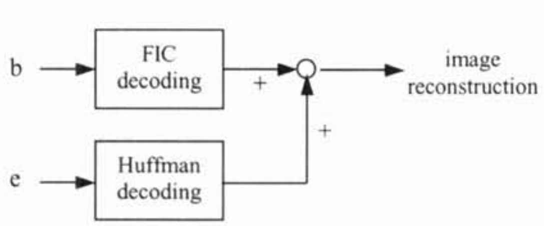

Figure 7. Block Diagram of Hybrid FIC Method (Fractal – Huffman Decompression System)

The objective of this hybrid compression system is to take advantage from each techniques, that is, high compression ratio that can be provided by FIC and lossless method that can be provided by Huffman coding. Finally, we can get a lossless method with higher value of compression ratio comparing to usual lossless method.

Huffman Coding

The basic principle of Hufman coding is as follows: data that occurs the most is coded with the shortest number of bits and data that occurs the least is coded with higher number of bits. The resulting codes are unique.

5. Experimental Results

The aerial photographs that will be examined here are 8-bit grey scale images.

a. Landscape

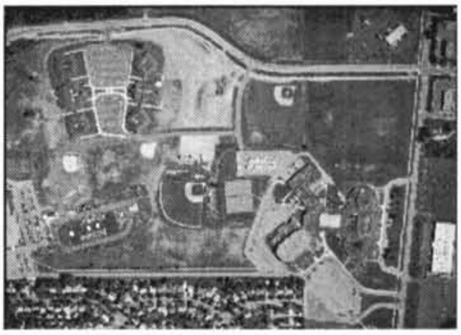

Figure 8. Landscape image
File size : 737,280 bytes
Resolution : 1,024 x 720 pixels

b. Airport

Figure 9. Airport image
File size : 262,144 bytes
Resolution : 512 x 512 pixels

The formula to measure PSNR :

$$PSNR = 10\log_{10}\frac{255^2}{\frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}\left|f(x,y)-g(x,y)\right|^2}$$

where :

$f(x,y)$ = original image
$g(x,y)$ = image reconstruction
M x N = image resolution

Table 1. Experimental result of FIC method for aerial photographs

	Landscape	*Airport*
Compression ratio	556.44	550.72
PSNR (dB)	16.99	15.56
Encoding time (seconds)	19.67	2.8
Encoding (clocks)	$4{,}563 \times 10^6$	649.6×10^6
Decoding time (seconds)	8.96	3.85
Decoding (clocks)	$2{,}078 \times 10^6$	893.2×10^6

Table 2. Experimental result of Huffman coding for aerial photographs

	Landscape	*Airport*
Compression ratio	4.04	4.24
PSNR (dB)	Infinite	infinite

Table 3. Experimental result of FIC - Huffman system for aerial photographs

	Landscape	*Airport*
Compression ratio	9.73	9.17
PSNR (dB)	Infinite	infinite

From the tables above, we can compare the compression ratio achieved in hybrid FIC-Huffman system and Huffman coding.

We can see that hybrid FIC-Huffman system has (9.73 / 4.04) = 2.41 larger values of compression ratio for landscape image and (9.17 / 4.24) = 2.16 larger values of compression ratio for airport image comparing to Huffman coding.

The result indicates that hybrid FIC – Huffman system is suitable to compress aerial photographs. The proposed method, hybrid FIC – Huffman system, is lossless, which means that there won't be any data losses and the compression ratio is larger than usual lossless method.

6. Conclusion

1. An image compression system for aerial photographs is supposed to be a lossless method with high values of compression ratio, so the system can retain whole information exist in the image without wasting too much storage space.
2. FIC is a lossy method with a very low PSNR but it can provide a very high compression ratio. Meanwhile, Huffman coding has a very low compression ratio but it can provide an infinite PSNR (lossless method).
3. By combining FIC and Huffman coding, we can get a new system that takes advantage on each techniques, that is, a very high compression ratio that can be provided by FIC and infinite PSNR that can be provided by Huffman coding. So the whole system is lossless with higher values of compression ratio comparing to usual lossless method. This hybrid FIC – Huffman system is suitable to compress aerial photographs.

References

[1] Anil K.Jain , "Fundamentals of Digital Image Processing", Prentice Hall, 1989.

[2] Yuval Fisher, "Fractal Image Compression, Theory and Application", Springer-Verlag, New York, 1995.

[3] M.F. Barnsley, A.D. Sloan, "A Better Way to Compress Images", BYTE , Jan 1988, p. 215-223.

[4] H.O. Peitgen,D.Saupe, H.Jurgens, "Chaos and Fractals: New Frontiers of Science", Springer-Verlag, New York, 1995.

[5] D.Saupe, Raouf Hamzaoui, Hannes Hartenstein, "Fractal Image Compression, An Introductory Overview", SIGGRAPH '96 Course Notes XX, New Orleans, 1996.

[6] Maaruf Ali, Prof.Trevor G.Clarkson, "Fractal Image Compression", proceeding 1st Seminar in Information Technology and its Applications, Leicester U.K. , 1991.

[7] Lenni Yulianti, "Penerapan Teknik Fraktal Dalam Kompresi Citra Digital untuk Data Foto Udara", Tugas Akhir, ITB, 1999.

[8] John R. Jensen , "Introductory Digital Image Processing, A Remote Sensing Approach".

[9] Lillesand / Kiefer, "Penginderaan Jauh dan Interpretasi Citra", Gajah Mada University Press, 1979.

[10] MA Sid-Ahmed, "Image Processing"; McGraw Hill,Inc; Singapore; 1995.