ICIC Express Letters
Part B: Applications
Volume **7**, Number **9**, September **2016**

ICIC International ©2016 ISSN 2185-2766
pp. 1951–1956

AN IMPROVED FAST FRACTAL DECODING METHOD

Qiang Wang

College of Information Science and Technology
Dalian Maritime University
No. 1, Linghai Road, Dalian 116026, P. R. China
wangqiang2011@dlmu.edu.cn

Received January 2016; accepted April 2016

Abstract. *In order to accelerate the fractal decoding process, a fast fractal decoding method is proposed in this paper. By analyzing the transformation coefficients in the fractal encoding process, we propose a measure that can indicate how easily one range block can be reconstructed. Based on the measure proposed, the decoding order of range blocks will be adjusted and range blocks decoded ahead will help to reconstruct the following ones. Simulations show that the proposed method can shorten the fractal decoding process effectively.*

Keywords: Fractal encoding, Fractal decoding, Real-time decoding

1. **Introduction.** With the rapid development of multimedia technology, searching for new efficient image compression technology becomes very necessary. Due to the advantages of novel idea, potential high compression ratio, resolution independence and fast decoding, fractal image coding becomes a very competitive candidate and many researchers worldwide pay their attention to it [1,2].

In order to complete the fractal encoding process in a short time, many researchers proposed their fast fractal encoding methods [3-6]. Correspondingly, other researchers focused their attention on the fractal decoding process. One effective way to accelerate the decoding process is to select an initial image which can approximate the input image as much as possible. Therefore, instead of the conventional blank image, the range-averaged image, the collage image and the fitting surface image are gradually proposed [7-10]. The other way is to improve the iterating strategy [11-13]. In the conventional fractal decoding process, two buffers are used and the same transformations as the encoding process are mapped from one to the other. One Buffer Decoding (O.B.D) only uses one buffer and maps the transformations to itself. The range blocks established ahead will help to reconstruct the following ones. Thus, the decoding process can be shortened greatly. In our research, by analyzing the characteristics of transformation coefficients, we find that some range blocks can be reconstructed more easily than the other ones. Based on detailed analyses, a measure is proposed to determine the decoding sequence. The range blocks decoded ahead will help to reconstruct the following ones. Simulations show that compared with the O.B.D method, the proposed method can shorten the decoding process further.

This paper is organized as follows: The conventional fractal encoding and decoding is reviewed in Section 2. In Section 3, the proposed method will be described in detail. In Section 4, the performance of the proposed method will be compared with the O.B.D method. Finally, the conclusion and future research will be given in Section 5.

2. **Conventional Fractal Encoding and Decoding.** The aim of fractal image coding is to construct an iterated function system (IFS) whose fixed point can approximate the input image well. In the fractal encoding process, the input image is first partitioned into

range blocks and domain blocks and a domain block pool is established by performing eight isometric transformations on the domain blocks. For each range block, the best matched domain block and the corresponding affine transformation coefficients s and o can be obtained by minimizing the following function:

$$Error = \min_{s,o} \|\boldsymbol{R} - s\gamma(\varphi(\boldsymbol{D})) - o\boldsymbol{I}\|^2 \tag{1}$$

where $\gamma(\cdot)$ and $\varphi(\cdot)$ denote the isometric and contracting operations, respectively. $Error$ is the collage error for the range block $\boldsymbol{R}$ and its best matched domain block $\boldsymbol{D}$. All the above transformation coefficients constitute IFS which will be stored as fractal codes.

At the fractal decoding phase, after selecting an initial image, such as the blank image, the same transformations as the encoding process are performed on each range block in each iteration as follows

$$\boldsymbol{R} = s\gamma(\varphi(\boldsymbol{D})) + o\boldsymbol{I} \tag{2}$$

After about ten iterations, the fractal decoding process will be completed. Generally, in the fractal decoding process, two buffers are used and the transformations stored in the fractal codes are mapped from one buffer to the other. Correspondingly, the transformations in the O.B.D method are mapped to itself and only one buffer is needed. Therefore, memory is saved and the decoding process can be also accelerated. In this paper, in order to represent convergence speed conveniently, we first get the decoded image with the fractal decoding method and the following measure is used to describe the deviation of each iteration with respect to the decoded image,

$$Measure = \frac{1}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} \left|\boldsymbol{x}_{ij}^{k} - \boldsymbol{y}_{ij}^{Decoded}\right|, \ k = 1, 2, \ldots, n \tag{3}$$

where M and N denote the height and the width of the input image. $\boldsymbol{y}^{Decoded}$ and $\boldsymbol{x}^k$ denote the decoded image and the kth iteration, respectively. For the 256×256 Lena image, Figure 1 illustrates the comparison between the conventional fractal decoding method and the O.B.D method. We can see that the O.B.D method can provide faster convergence speed.

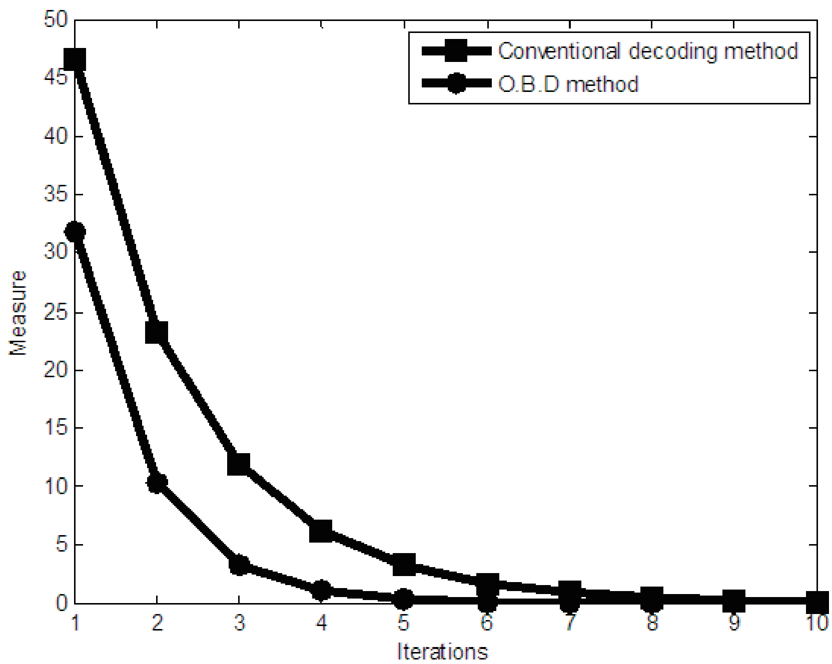

FIGURE 1. Comparison between the conventional fractal decoding method and the O.B.D method

3. **The Proposed Method.** In the fractal decoding process, the range blocks will be recovered one by one with the same transformations as the encoding process. From (2), we can see that some range blocks can be recovered more easily and they will help to recover the other ones. Generally, the range blocks having the following two characteristics will be recovered faster and should be decoded firstly.

1). The range blocks having small coefficient s. As we know, in order to guarantee the convergence of the fractal decoding, the coefficient s in the encoding process should be smaller than 1. Small s implies that the variance of the range block is small. There are more domain blocks that have the possibility to match the range block and the corresponding best matched domain block can approximate the range block better. Thus, small s implies that the range block will be recovered well and this will help to accelerate the fractal decoding process.

2). The range blocks having large coefficient o. If one range block has a large coefficient o, this implies that the range block will be changed quickly.

Based on the above analysis, we know that small s and large o will both help to recover a range block. Thus, we define a measure as follows:

$$M = o \times (1 - s) \tag{4}$$

From (4), we know that the range block with a large M will have a small s as well as a large o. Before fractal decoding, if we sort the range blocks by M from the largest to the smallest and encode them one by one, the range blocks with larger Ms will be decoded firstly and help to recover the following ones. Thus, the decoding process can be accelerated.

4. **Simulations.** In this section, four 256×256 images, Bridge, Zelda, Bird and Camera, and seven 512×512 images, Lena, Barb, Boat, Mandrill, Peppers, Sailboat and Zelda, are used as test images. We will combine the proposed method with the basic fractal coding method and the methods in [3] and [4], respectively. The procedures are listed as follows.

Step 1: Perform one fractal encoding method on one test image. We can get the fractal codes.

Step 2: Perform the conventional fractal decoding method on the fractal codes and we can get the final decoded image.

Step 3: Perform the O.B.D method and the proposed method on the fractal codes, respectively, and compare each iteration with the decoded image by (3).

For the 256×256 Lena image, Figure 2 illustrates the decoding process for the O.B.D method and the proposed method, respectively. We can clearly observe that the proposed method can accelerate the fractal decoding process.

Tables 1, 2, and 3 illustrate the performance comparisons between the O.B.D method and the proposed method, respectively. In each table, with respect to the decoded image, the deviations of the first five iterations for the above two methods are listed. We can observe that for either the basic fractal coding method or the fast fractal coding methods in [3] and [4], the proposed method can always provide smaller deviations in each iteration than the O.B.D method.

5. **Conclusions and Future Work.** In order to shorten the fractal decoding process, an improved fractal decoding method is proposed in this paper. By analyzing the characteristics of transformation coefficients, we adjust the decoding order of range blocks by the proposed measure in the decoding process. Simulations show that the proposed method can effectively improve the convergence speed of the decoding process. In future research, we will continue to explore other useful information that can help to shorten the fractal decoding process.

FIGURE 2. Comparison between the O.B.D method and the proposed method. (a) (b) (c) (d) First four iterations of the O.B.D method, (e) (f) (g) (h) First four iterations of the proposed method.

TABLE 1. Comparison between the O.B.D method and the proposed method for the basic fractal coding method

Test images	Methods	Iterations				
		1	2	3	4	5
Bridge 256×256	O.B.D	51.37	21.73	8.86	3.54	1.39
	Proposed	42.63	16.89	6.72	2.66	1.05
Zelda 256×256	O.B.D	17.85	5.56	1.77	0.57	0.19
	Proposed	16.98	5.24	1.65	0.51	0.16
Bird 256×256	O.B.D	54.13	19.49	6.64	2.23	0.75
	Proposed	38.69	12.87	4.35	1.48	0.50
Camera 256×256	O.B.D	60.17	30.02	14.89	7.37	3.64
	Proposed	47.61	22.64	11.12	5.52	2.74
Lena 512×512	O.B.D	46.26	15.79	5.40	1.86	0.64
	Proposed	36.31	11.70	3.90	1.32	0.45
Barb 512×512	O.B.D	45.70	18.44	7.39	2.88	1.09
	Proposed	38.35	14.82	5.61	2.10	0.78
Boat 512×512	O.B.D	58.74	23.14	8.74	3.27	1.21
	Proposed	47.24	17.53	6.59	2.48	0.93
Mandrill 512×512	O.B.D	61.49	29.82	14.95	7.57	3.84
	Proposed	53.18	25.64	12.76	6.42	3.24
Peppers 512×512	O.B.D	39.64	13.58	4.53	1.54	0.53
	Proposed	32.02	10.42	3.49	1.19	0.41
Sailboat 512×512	O.B.D	64.61	29.45	12.41	5.16	2.15
	Proposed	53.65	22.47	9.34	3.89	1.62
Zelda 512×512	O.B.D	30.98	10.14	3.47	1.22	0.43
	Proposed	24.50	8.10	2.81	0.98	0.34

Table 2. Comparison between the O.B.D method and the proposed method for the method in [3]

Test images	Methods	Iterations				
		1	2	3	4	5
Bridge 256×256	O.B.D	46.41	18.87	7.43	2.83	1.05
	Proposed	39.71	14.87	5.62	2.12	0.79
Zelda 256×256	O.B.D	16.65	5.03	1.59	0.52	0.17
	Proposed	13.40	3.90	1.20	0.38	0.12
Bird 256×256	O.B.D	37.84	10.03	2.71	0.77	0.23
	Proposed	27.89	6.98	1.90	0.55	0.17
Camera 256×256	O.B.D	38.73	12.22	3.74	1.15	0.36
	Proposed	28.43	7.95	2.34	0.71	0.22
Lena 512×512	O.B.D	39.09	12.06	3.83	1.24	0.40
	Proposed	31.68	9.38	2.93	0.93	0.30
Barb 512×512	O.B.D	40.20	15.26	5.78	2.10	0.75
	Proposed	35.92	12.99	4.63	1.62	0.57
Boat 512×512	O.B.D	47.53	15.76	5.13	1.68	0.55
	Proposed	38.91	11.97	3.81	1.24	0.41
Mandrill 512×512	O.B.D	51.99	22.44	10.09	4.55	2.05
	Proposed	48.55	21.36	9.64	4.37	1.99
Peppers 512×512	O.B.D	32.90	9.15	2.57	0.74	0.22
	Proposed	25.90	7.15	2.07	0.62	0.19
Sailboat 512×512	O.B.D	48.84	17.48	6.04	2.06	0.70
	Proposed	40.50	13.62	4.60	1.56	0.53
Zelda 512×512	O.B.D	26.67	8.17	2.69	0.90	0.30
	Proposed	21.62	6.64	2.18	0.72	0.24

Table 3. Comparison between the O.B.D method and the proposed method for the method in [4]

Test images	Methods	Iterations				
		1	2	3	4	5
Bridge 256×256	O.B.D	54.86	25.09	11.10	4.82	2.08
	Proposed	46.35	19.62	8.36	3.56	1.52
Zelda 256×256	O.B.D	19.86	6.65	2.24	0.76	0.26
	Proposed	15.98	5.06	1.66	0.55	0.18
Bird 256×256	O.B.D	40.76	11.46	3.18	0.91	0.27
	Proposed	30.67	8.00	2.19	0.63	0.19
Camera 256×256	O.B.D	40.37	13.06	4.13	1.31	0.43
	Proposed	31.61	9.56	3.00	0.97	0.32
Lena 512×512	O.B.D	60.90	28.88	13.77	6.72	3.35
	Proposed	53.99	25.00	12.03	5.95	3.01
Barb 512×512	O.B.D	58.78	30.77	15.66	7.79	3.83
	Proposed	54.21	26.64	12.99	6.32	3.08
Boat 512×512	O.B.D	70.69	33.94	15.87	7.35	3.38
	Proposed	62.47	28.78	13.17	6.02	2.75
Mandrill 512×512	O.B.D	73.47	41.12	23.06	12.92	7.22
	Proposed	67.70	37.06	20.55	11.45	6.40
Peppers 512×512	O.B.D	45.55	18.16	7.17	2.86	1.16
	Proposed	37.88	14.29	5.52	2.18	0.87
Sailboat 512×512	O.B.D	65.42	31.16	14.62	6.93	3.35
	Proposed	55.50	25.29	11.83	5.64	2.73
Zelda 512×512	O.B.D	43.05	19.21	8.38	3.64	1.59
	Proposed	36.97	15.86	6.87	3.01	1.34

Acknowledgement. This work is partially supported by the Fundamental Research Funds for the Central Universities (Grant No. 3132014090). The author is grateful to the anonymous referees for their helpful comments and suggestions.

REFERENCES

[1] B. Wohlberg and G. Jager, A review of the fractal image coding literature, *IEEE Transactions on Image Processing*, vol.8, no.12, pp.1716-1729, 1999.

[2] A. E. Jaquin, Image coding based on a fractal theory of iterated contractive image transformations, *IEEE Transactions on Image Processing*, vol.1, no.1, pp.18-30, 1992.

[3] C. J. He, X. Z. Xu and J. Yang, Fast fractal image encoding using one-norm of normalized block, *Chaos, Solitons & Fractals*, vol.27, no.5, pp.1178-1186, 2006.

[4] C. M. Lai, K. M. Lam and W. C. Siu, Improved searching scheme for fractal image coding, *Electronics Letters*, vol.38, no.25, pp.1653-1654, 2002.

[5] X. Y. Wang, X. Guo and D. D. Zhang, An effective fractal image compression algorithm based on plane fitting, *Chinese Physics B*, vol.21, no.9, pp.149-155, 2012.

[6] Y. Y. Sun, R. D. Xu, L. N. Chen, R. Q. Kong and X. P. Hu, A novel fractal coding method based on M-J sets, *Plos One*, vol.9, no.7, pp.1-11, 2014.

[7] Y. Moon, H. Kim and J. Kim, A fast fractal decoding algorithm based on the selection of an initial image, *IEEE Transactions on Image Processing*, vol.9, no.5, pp.941-945, 2000.

[8] C. S. Tong and M. H. Pi, Fast fractal image encoding based on an adaptive search, *IEEE Transactions on Image Processing*, vol.10, no.9, pp.1269-1277, 2001.

[9] Q. Wang, S. Bi and D. Liang, A novel selection of initial image for fast fractal decoding, *ICIC Express Letters, Part B: Applications*, vol.4, no.5, pp.1253-1258, 2013.

[10] S. Bi and Q. Wang, Fractal image coding based on a fitting surface, *Journal of Applied Mathematics*, vol.2014, pp.1-11, 2014.

[11] R. Hamzaoui, A new decoding algorithm for fractal image compression, *Electronics Letters*, vol.32, no.14, pp.1273-1274, 1996.

[12] R. Hamzaoui, Ordered decoding algorithm for fractal image compression, *Proc. of International Picture Coding Symposium*, Berlin, pp.91-95, 1997.

[13] H. S. Kang and S. D. Kim, Fractal decoding algorithm for fast convergence, *Optical Engineering*, vol.35, pp.3191-3198, 1996.