EDITORIAL

SPECIAL ISSUE ON ADVANCED FRACTAL COMPUTING THEOREM AND APPLICATION

SHUAI LIU

*Key Laboratory of Social Computing and Data Processing of Inner Mongolia
College of Computer Science, Inner Mongolia University
Inner Mongolia, Hohhot 010021, P. R. China
cs_liushuai@imu.edu.cn*

Published July 18, 2017

Abstract

Fractal represents a special feature of nature and functional objects. However, fractal based computing can be applied to many research domains because of its fixed property resisted deformation, variable parameters and many unpredictable changes. Theoretical research and practical application of fractal based computing have been hotspots for 30 years and will be continued. There are many pending issues awaiting solutions in this domain, thus this thematic issue containing 14 papers publishes the state-of-the-art developments in theorem and application of fractal based computing, including mathematical analysis and novel engineering applications. The topics contain fractal and multifractal features in application and solution of nonlinear odes and equation.

Keywords: Fractal Based Computing; Fractal Feature; Nonlinear Odes; Fractal Compression.

1. INTRODUCTION

Today, fractal based computing has been applied to a variety of research domains and applications because fractals is a fixed and special characteristic

for natural and functional objects.¹ Since the 1980s, theoretical research and practical application of fractal computing have been a hotspot in natural science and engineering. However, further issues

This is an Open Access article published by World Scientific Publishing Company. It is distributed under the terms of the Creative Commons Attribution 4.0 (CC-BY) License. Further distribution of this work is permitted, provided the original work is properly cited.

are still awaiting solutions in this domain, such as the generation mechanism of k-M set with complex exponent, fractal properties of complex functions, and fractal properties of natural objects, etc.

Fractal computing is a computing method that applies the self-similarity property of various information to improve classical computing method. By using fractal computing technology, researchers can seek fixed structure and property of complex dynamical process in engineering and improve the theoretical and practical system in these domains.

Fractal based information processing technologies also attracted many researchers for years, just like fractal compression, fractal based information classification and recognition and so on. In recent years, fractal computing is also used in various newer domains such as bioinformatics and geology.

Recently, there are also many theoretical and technological researches in the domain of fractal computing with more emerging methods. Moreover, fractal property acts as a feature component in many classifiers. The guest editors of this special issue have been working on this domain for many years,²⁻⁷ and yet there remains many unsolved areas. The objective of this thematic issue is to showcase state-of-the-art developments in fractal computing theorem and application, including mathematical analysis and novel engineering applications.

2. OVERVIEW OF WORKS IN THIS THEMATIC ISSUE

The papers of this issue revolve around a special topic covering fractal based computing in theoretical research and engineering application. They can be broadly divided into the following three groups.

The first group of papers focuses on fractal based physics and geology. There are 6 papers in this domain.

Tang *et al.* applied a fractal scaling law for cumulative pore volume to analyze the heat release and pore structure evolution in the hydration of cement pastes. The branching networks such as tree branches, leaf veins, blood vessels, bronchial tree etc abound in nature, and fractal theory has been used to characterize the topology and transport properties of natural and industrial branching networks.⁸ Sheng *et al.*⁹ introduced a random fractal algorithm based on Lindenmayer system to generate fracture networks according to the micro-seismic data, and evaluate the effective stimulated reservoir volume

in shale gas reservoirs. Lu *et al.*¹⁰ presented a fractal model for the net present value of multi-stage fractured horizontal wells in tight gas reservoir, where a fractal gas permeability model with slip-page effect was employed to characterize the apparent permeability of reservoir stratum. Xu *et al.*¹¹ introduced fractal dimensions to characterize the fracture aperture and length and presented a fractal dual-porosity model for the single-phase fluid flow through fractured porous media. The analytical expression for effective permeability was derived and an power law correlation between effective permeability and fracture fraction was also proposed. Chu *et al.*¹² studied the granularity distribution of power by fractal theory and performed fractal Monte Carlo simulation on coal particles. Lin *et al.*¹³ developed a fractal method to construct the digital cores with X-ray CT technology. They stated that this fractal method can provide an objective method to select representative rock samples and avoid some subjective errors.

The second group of papers focuses on fractal based electronics and computer science. There are 5 papers in this domain.

Tang *et al.*¹⁴ derived the electrical impedance of porous constructed cube with 3D pore fractal networks, and pointed out that phase of impedance reveals the relaxation of ion and is associated with the ion friction. With the advantage in characterizing multi-scale structure, fractal theory has been proposed for fractured porous media. Aiming at accurately extracting the individual characteristics of the radiation source for the increasingly complex communication electromagnetic environment, a novel feature extraction algorithm for individual characteristics of the communication radiation source based on the fractal complexity of the signal is proposed by Wang *et al.*¹⁵ Simulation results demonstrate that the algorithm can achieve higher recognition rate in worse environment. Fractal encoding method becomes an effective image compression method because of its high compression ratio and short decompressing time. But one problem of known fractal compression method is its high computational complexity and consequent long compressing time. To address this issue, Liu *et al.* distance clustering in high dimensional sphere surface is applied to speedup fractal compression method.¹⁶ Correctness and effectiveness properties of the mentioned method are analyzed. Also, positive performance is shown by experimental results. Multiple sclerosis (MS) is a severe

brain disease. Early detection can provide timely treatment. Fractal dimension can provide statistical index of pattern changes with scale at a given brain image. So Zhang *et al.* used susceptibility weighted imaging technique to obtain 676 MS slices and 880 healthy slices with synthetic minority oversampling technique to process the unbalanced dataset, Canny edge detector to extract distinguishing edges, Minkowski-Bouligand dimension (a fractal dimension) to estimate and extract features from edges.¹⁷ Their method achieved a sensitivity about 97.78%, a specificity about 97.82%, and an accuracy about 97.80%. Magnetic resonance imaging (MRI) is the most sensitive method to detect chronic nervous system diseases such as multiple sclerosis. Karaca and Cattani study Brownian motion Holder regularity functions (polynomial, periodic (sine), exponential) for 2D image, as multifractal methods were applied to MR brain images, aiming to easily identify distressed regions, in Multiple Sclerosis (MS) patients.¹⁸ They propose a MS classification based on the multifractal method by using the Self Organizing Map (SOM) algorithm and obtain a cluster analysis by identifying pixels from distressed regions in MR images through multifractal methods.

The third group of papers focuses on fractal based mathematical issues analysis. There are 3 papers in this domain.

Srivastava *et al.* studied a family of the special functions via the celebrated Mittag-Leffler function defined on the Cantor sets.¹⁹ The nonlinear local fractional ODEs (NLFODEs) are presented by following the rules of local fractional derivative (LFD). The exact solutions for these problems are also discussed with aid of the non-differentiable charts on Cantor sets. The obtained results are important for describing the characteristics of the fractal special functions. The new Boussinesq-type model in a fractal domain is derived based on the formulation of the local fractional derivative. The novel traveling wave transform of the non-differentiable type is adopted to convert the local fractional Boussinesq equation into a nonlinear local fractional ODE.²⁰ The exact traveling wave solution is also obtained with aid of the non-differentiable graph. The proposed method, involving the fractal special functions, is efficient for finding the exact solutions of the nonlinear PDEs in fractal domains. In the study of Lu *et al.*, the period- n steady regions of McMullen family M sets are discussed.²¹ The calculation methods of the numbers of period- n steady regions are

presented and the center points and boundaries of period-1 are studied by complex dynamical system theory. In addition, the problem about the free critical points is discussed. The experimental results show that the free critical points do not influence the distributions of period- n steady regions when $m = d$, which is proved theoretically.

3. CONCLUSIONS

In this thematic issue, 14 papers based on fractal computing from different research domains are published. These studies represent the latest state-of-the-art fractal research today and will also initiate new fractal-based research domains. The guest editors hope that this work will further advance this multidisciplinary endeavor.

ACKNOWLEDGMENTS

The research is supported by the National Natural Science Foundation of China [No. 61502254].

REFERENCES

1. B. M. Yu, Analysis of flow in fractal porous media, *Appl. Mech. Rev.* **61**(5) (2008) ID050801.
2. S. Liu, Z. Zhang, L. Qi *et al.*, A fractal image encoding method based on statistical loss used in agricultural image compression, *Multimedia Tools Appl.* **75**(23) (2016) 15525–15536.
3. S. Liu, X. Cheng, W. Fu *et al.*, Numeric characteristics of generalized M-set with its asymptote, *Appl. Math. Comput.* **243** (2014) 767–774.
4. S. Liu, X. Cheng, C. Lan *et al.*, Fractal property of generalized M-set with rational number exponent, *Appl. Math. Comput.* **220** (2013) 668–675.
5. S. Liu, W. Fu, L. He *et al.*, Distribution of primary additional errors in fractal encoding method, *Multimedia Tools Appl.* **76**(4) (2017) 5787–5802.
6. S. Liu, Z. Pan, W. Fu *et al.*, A novel fractal generation method and fractal research based on asymptote family of generalized Mandelbrot set, *J. Nonlinear Sci. Appl.* **10**(3) (2017) 1148–1161.
7. S. Liu, M. Lu, G. Liu *et al.*, A novel distance metric: Generalized relative entropy, *Entropy* **19**(6) (2017) 269, doi:10.3390/e19060269.
8. S. W. Tang, R. J. Cai, Z. He *et al.*, Continuous microstructural correlation of slag/superplasticizer cement pastes by heat and impedance methods via fractal analysis, *Fractals* **25**(4) (2017) 1740003.
9. G. Sheng, Y. Su, W. Wang *et al.*, Application of fractal geometry in evaluation of effective stimulated reservoir volume in shale gas reservoir, *Fractals* **25**(4) (2017) 1740007.

10. H.-L. Lu, J.-J. Zhang, X.-H. Tan *et al.*, A fractal analysis for net present value of multi-stage hydraulic fractured horizontal well, *Fractals* **25**(4) (2017) 1740011.
11. P. Xu, H. Liu, A. P. Sasmitoc *et al.*, Effective permeability of fractured porous media with fractal dual-porosity model, *Fractals* **25**(4) (2017) 1740014.
12. H. Chu, F. Ren, Z. Zheng *et al.*, Study on granularity distribution of powder by fractal models, *Fractals* **25**(4) (2017) 1740009.
13. W. Lin, Z. Yang, X. Li *et al.*, A method to select representative rock samples for digital core modeling, *Fractals* **25**(4) (2017) 1740013.
14. S. W. Tang, L. Wang, R. J. Cai *et al.*, The evaluation of electrical impedance of three-dimensional fractal networks embedded in a cube, *Fractals* **25**(4) (2017) 1740005.
15. H. Wang, J. Li, L. Guo *et al.*, Fractal complexity based feature extraction algorithm of communication signals, *Fractals* **25**(4) (2017) 1740008.
16. S. Liu, Z. Pan and X. Cheng, A novel fast fractal image compression method based on distance clustering in high dimensional sphere surface, *Fractals* **25**(4) (2017) 1740004.
17. Y. Zhang, Y. Zhang, P. Phillips *et al.*, Synthetic minority oversampling technique and fractal dimension for identifying multiple sclerosis, *Fractals* **25**(4) (2017) 1740010.
18. Y. Karaca and C. Cattani, Clustering multiple sclerosis subgroups with multifractal methods and self organizing map algorithm [J], *Fractals* **25**(4) (2017) 1740001.
19. X. Yang, F. Gao and H. M. Srivastava, Non-differentiable exact solutions for the nonlinear odes defined on fractal sets, *Fractals* **25**(4) (2017) 1740002.
20. X. Yang, J. A. Tenreiro Machado and D. Baleanu, Exact traveling-wave solution for local fractional Boussinesq equation in fractal domain, *Fractals* **25**(4) (2017) 1740006.
21. Z. Lu, Y. Sun and X. Hu, Period region distributions of McMullen family M sets, *Fractals* **25**(4) (2017) 1740012.