Proceedings of the 3rd International Conference on Computing Innovation and Applied Physics
DOI: 10.54254/2753-8818/14/20240915

The application of fractal theory in real-life

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Abstract. As a relatively new and mathematics-related discipline, fractal has had a certain influence on the development of many aspects of today's society. At the same time, the science of fractal geometry to explore and study the practical use of fractal properties and fractal geometry is called a fractal theory. What's more, the emergence of fractal theory has promoted the development of various fields, provided new solutions and methods for some problems, provided a both logical and rigorous reference basis for some decisions, and also facilitated people's lives. By observing actual life and consulting some relevant literature, this article discusses the application of fractal theory in real life mainly from the aesthetics, health, and safety, respectively from three angles which are aesthetic art, medical and health, and highway traffic, such as pattern, numerical reference, material selection and so on, to understand the value of fractal theory in academic development and life application.

Keywords: Fractal, Fractal Theory, Practical Application, Geometry.

1. Introduction

Fractal is a new mathematical geometric concept with self-similarity and fills the geometric space in a non-integer dimensional way. Fractal theory is also a pioneering new theory and is very popular in some fields besides mathematics. The famous mathematician and economist Benowar Mandebro at the French College in France first put forth the concept of fractal in 1973. Before the formal emergence of the fractal concept, many mathematicians in history also promoted the formation of fractal concepts and theories. In 1872, Calwei and Tesla created a continuous but inseparable function. After the advent of fractal theory, this function was considered a fractal. In 1904, the Swedish mathematician Koch created the famous Koch Curve and Koch Snow, two images that are still fractal examples.

Subsequently, in 1915 and 1916, Sherbinski invented the Sherbinski triangle and Sherbinski carpet, significantly promoting fractal development. In 1967, Mandebrero published a famous and classic article on the coastline in Science, an authoritative American academic journal. The coastline in nature is highly irregular, complex, and changeable curves, so there is no significant difference in the coast in general; that is to say, the irregularities and complexity are roughly the same, so the coastline can also be considered self-similar. There are many internal connections between mathematics and nature, and this article brings many inspirations. In addition to the coastline, there are many self-similar objects in nature, such as leaves, cauliflower, mountains, trees, etc. These patterns with self-similarity are finally called fractals by Mandabro. After this, in 1975, fractal geometry was formally established. Fractal theory is a science that explores the properties of fractal geometry and the practical application of fractal geometry

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based on fractal geometry. After decades of development, people have a deeper understanding and cognition of fractals in today's society. The fractal theory has brought new angles and new thinking of thinking and solving problems to talents in various fields. Since the 21st century, fractal theory has been integrated with other disciplines, which have formed fractal art, integrated with geology to assist geological exploration, combined with medicine to innovate a new image analysis method, and combined with material science to assist in selecting appropriate materials and background. In addition, fractal theory has been widely used in mathematics, physics, engineering, computer science, and other fields. In the future, according to the current development trend, fractal theory will have more and more far-reaching influence on more disciplines.

This paper adopts the method of literature research to find the relevant materials of fractals and expounds on the application of fractals from the three aspects of art, medicine, and transportation to explore the application value of fractals in real life.

2. Fractal theory

Fractal theory is a new theoretical discipline based on fractal geometry. Unlike classical mathematics, where things are usually one-dimensional lines, two-dimensional planes, and three-dimensional bodies, the fractal theory escapes the traditional idea and focuses on using the fractal dimension to describe and analyze the objective things. Fractal is some integer graphs; there are many characteristic and representative fractal, such as the Sherbinski triangle, Koch snowflakes, Koch curve, etc., they are typical from similar graphics, according to the fractal theory related to dimension, respectively, obviously detached the typical integer dimension, fractal dimension can be more flexible and effectively reflect the characteristics of some graphics and part and the overall similarity, its whether for mathematics or other disciplines have significant influence. At the same time, fractal theory has many applications in various aspects, such as aesthetic pattern design, fashion design, image analysis in the medical field, traffic-related property analysis of pavement materials, and freight index analysis etc.

For artistic aesthetics, fractal theory has developed rapidly under the addition of computer technology and has produced fractal art, a new form of fractal theory with integration. Fractal art can also be regarded as the art of nature because the fractal theory was discovered from the natural things at the beginning, so from the perspective of Taoism, fractal art contains the characteristic of "learning from nature." Fractal art combines modern graphics, art, and geometry, generating a series of visual fractal figures through computers. At the same time, because of the participation of mathematical operations, these fractal figures have certain rigor, regularity, and infinite subdivision, and at the same time, they have the unique beauty of complex, layered, and complex fantasy that artists cannot describe [1].

For modern medical treatment, fractal theory can provide more reference parameters for different diseases and make a more scientific and comprehensive analysis of images. When analyzing medical image data and exploring image information, it is often necessary to use the box dimension: assuming that N boxes can cover a bounded subset of the measurement space with edge length A, the box dimension is:

For medical images, the most classical calculation method of box dimension is the box-counting method (BCM), differential box-counting method (DBCM), extended BCM, and segment correction box counting are also included in the literature [2].

Regarding transportation, fractal theory and fractal dimension are closely related to road conditions. Taking asphalt as an example, the greater the transverse force coefficient of the green pavement, the greater the fractal dimension of the road surface. If the load frequency increases, the fractal dimension will generally decrease [3]. At the same time, various fractal dimensions of fractal theory, such as overall fractal dimension (D), coarse particle size fractal dimension (Dc), and fine particle size fractal dimension (Df), assist in the selection of self-luminous paint formula on the road [4].

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3. Application of fractal theory

3.1. Application of fractal theory in aesthetics

Fractality is self-similar because it conforms to aesthetics, and most of the graphic structure is exquisite, so it is very suitable for pattern patterns to enhance the aesthetic degree and appreciation value. Fractals can be used as a separate pattern for independent use, suitable, or continuous pattern connecting the combination of separate patterns [5]. Most fractals are complex and regular, characteristic and natural and beautiful, so the fractal patterns are also very suitable for decorating some ethnic costumes, and the fractal theory is also used in some plant patterns or other patterns. There is no lack of fractal thinking in the plant pattern design of Xinjiang Uygur artists. They often use the methods of repetition, combination, disassembly, deformation, and other methods of fractality so that the overall pattern is full of vitality, showing the beauty of layers of flowers and harmonious and natural. However, although the traditional Uyghur plant decoration has fractal thinking, the design mode is still limited to the field of artificial creation, and compared with the real fractal geometry formed by computers, it needs a rich and disordered change sense. However, with the development of computer information technology, through the program of fractal pattern design is the use of a wide range of fractal pattern production techniques, designers are more skilled in using all kinds of computer software to help pictures. Among them, fractal art, as a critical pattern design category, design software Ultra Fractal, Apophysis, Mandelbulb3D, Xeno Dream, etc., all include fractal design. However, the specific functions of each software and the final presentation effect have specific differences, and the fractal pattern categories they are good at also have different emphases. Various pattern factors can be extracted through reading literature and field research; based on pattern factors, different fractal software can be applied to construct more beautiful and innovative Uyghur plant decoration design models conforming to the fractal art principle. Finally, these models can be applied to national costumes [1]. At the same time, there are similar applications of fractal theory in Guizhou batik. Guizhou batik patterns are mainly divided into two types: natural patterns and geometric patterns. Natural patterns mainly include plant and animal patterns, while geometric patterns are abstract patterns in nature, common in mountains, water, stars, swirls, birds, fish, butterflies, bronze drums, etc. It has a variety of composition forms, and the layout is full of beauty, borrowing animals or plants in nature, making the pattern rich and full of nature. Many of the patterns are also symmetrical forms, making the whole look more orderly and not chaotic. Guizhou batik also has a unique "ice pattern," which has no fixed composition form but is only the feeling and reflection of nature in the batik process. It will have different effects in different environments. In order to make the Guizhou batik pattern more refined and highlight its characteristics, designers can apply the fractal theory. After refining the pattern elements, designers can select the appropriate elements as skeleton elements applied in fractal pattern drawing and creation; both retain the essential characteristics of the original pattern and traditional forms and contain the designer himself for the pattern structure and outline through the line outline of the pattern modeling, makes people can more intuitively feel the unique aesthetic feeling of different patterns [6].

3.2. Application of fractal theory to healthcare

Because fractal dimension can be used as a parameter and measurement indicator, fractal theory is also used in practical medical treatment, such as osteoporosis research, magnetic resonance, etc. Osteoporosis is a systemic bone disease characterized by reduced bone strength and increased fracture risk, with a very high incidence in the elderly [7]. A decrease in bone strength means a decrease in bone hardness, and the change in bone strength can be measured by both unit mineral salt mass (BMD) and bone quality. Bone quality is often affected by factors such as bone microstructure, bone transformation, injury accumulation, and bone mineralization, in which the application of fractal theory and fractal dimension can analyze bone microstructure with bone as an essential part of the tissue [7]. The traditional method has high accuracy and rigor for detecting bone microstructure and osteoporosis, but this method only applies to some patients because it requires puncture and cannot be widely used. At present, CT, HRCT, and other advanced equipment can also be used to check and analyze bone

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microstructure, but due to the high use cost of this equipment and more radiation of some equipment, the analysis of jaw images using computer graphics technology is beneficial to the effective identification of jaw bone microstructure. It is necessary to study the fractal dimension and pattern of bone microstructure through fractal theory to judge and predict osteoporosis more accurately,

Because there is still a risk of osteoporosis when the BMD index is qualified, only the bone microstructure, bone quality, and bone strength are more reliable. The application of fractal theory analysis can present the heart, its structural characteristics, and its functions. In the heart structure, the myocardial trabecular tissue has a critical role and is very close to the cardiac beat and blood output. In particular, whether the myocardial trabecular structure is abnormal is very important for predicting and judging myocarditis, and the fractal dimension can be effectively judged as an essential parameter of the myocardial trabecular structure. Each layer's myocardial trabecular filling space can be analyzed and measured by fractal theory, resulting in a continuous variable fractal dimension with non-integer values ranging from 1 to 2. The size of the fractal dimension can reflect the difference in the endocardial complexity of the left ventricle. The fractal dimension of the trabecular left ventricle varies from the base to the apex of the heart, which is related to race, age, gender, body mass, and left ventricular mass [8]. In the clinical aspect, the fractal theory and analysis are promising. If applied to more image analysis, the final judgment and prediction of the patient's situation will be more transparent and accurate.

3.3. Application of fractal theory in traffic

Fractal dimension is often closely related to material properties, texture, anti-skid resistance, etc. Take asphalt as an example; asphalt is a typical traffic pavement material. Its performance is related to many people's safety; using asphalt with strong anti-skid properties can reduce unnecessary traffic safety accidents. In research, it is found that, in general, the fractal dimension of the road surface is proportional to the transverse force coefficient of the road surface and inversely proportional to the number of loads, which is of great help to improve the anti-skid performance of the road surface [3]. At the same time, the ratio of asphalt and concrete needs to be considered and valued, which is also closely related to the fractal dimension. Through systematic research on the actual situation of densely graded asphalt concrete on several expressways, characterizing the gradation characteristics of ore materials combined with fractal theory, understand the fractal dimension and the ratio distribution of the mixed ore materials commonly used in existing engineering, and then construct the estimation equation of the design index based on AC-13 and AC-20 asphalt concrete. Finally, different fractal dimensions of dense-graded asphalt concrete can be characterized by a unique hierarchical dimension, and the fractal dimension of dense-graded asphalt concrete used in the project is between 2.44 and 2.54 [9]. In addition to materials such as asphalt concrete, traffic surfaces also require self-emitting paint for reminders or marking. Good energy storage and high afterglow brightness can paint can play a better role. To explore this issue, The researchers applied the fractal theory to establish the particle size distribution function.

Moreover, it obtains three practical dimensions: overall fractal dimension, coarse size fractal dimension, and fine size fractal dimension. Subsequently, according to the law, the prediction model of the particle size distribution of rare luminous fill based on fractal dimension is established, verified, and finally found. With the increasing fine particle size fractal dimension and acceptable particle content, the afterglow brightness and skid resistance of the material all declined; if the coarse diameter packing content is significant, the afterglow brightness and anti-skid performance of the self-luminous road markings will be improved [10].

4. Conclusion

The unique self-similarity and complexity of the fractal make the fractal have an irreplaceable role in some disciplines and some directions. With the development of fractal theory, fractals in art, medicine, transportation, and other aspects, at the same time, the fractal theory model or fractal dimension can make people complete some traditional methods is challenging to achieve the goal: drawing both complex and rich and beautiful pattern, more comprehensive analysis of bone and tissue structure, choose the suitable material or mixed proportion of different materials, etc. The widespread use of

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fractals also makes people's life more convenient. Designers can draw the patterns they want more quickly, more patients can enjoy more accurate medical services at more affordable prices, and people can have safer roads and more transparent and brighter traffic instructions. In a word, the various characteristics of fractals have their application value in different fields and promote the development of various fields. The application of fractals has gradually become a part of society, and the fractal theory has a broad and far-reaching impact on people's lives.

References

[1] Jiang Y 2022 Master's Thesis Jiangnan University
[2] Cuihong Y, Luwen Z, Zixing Z and Jingmei J 2021 Medical Review 16 3256-3262
[3] Chunjian S and Yumei H 2022 J. of Shandong Communications Uni. 02 89-93
[4] Siwei S, Xin J, Changning D, Naisheng G and Yu Y 2022 Mater. Guide S1 204-210
[5] Xiaoling D 2023 Chem. fiber and Textile Tech. 05 138-140
[6] Yusu X 2022 master's thesis Guizhou Normal University
[7] Shu L, Zitong L and Tiemei W 2013 Oral Medic. Res. 07 682-684
[8] Xin Z, Tian Z, Jinyang W and Lianggeng G 2021 Chinese J. of Med. Imag. 04 404-407
[9] Zhi C 2020 Research on Transportation 05 28-37
[10] Zueva Marina V., Ieva Antonio D and Pyankova S 2022 Frontiers in Network Physiology