Fractal Pattern Modeling Design Method Based on Computer-Aided Technology from the Perspective of Internet of Things

Wei Xiong[1], Xiaohui Zhang[2] and Rong Zeng[3,*]

[1]School of Media and Animation, LuXun Academy of Fine Arts, Liaoning 116650, China, beiki@163.com
[2]School of Media and Animation, LuXun Academy of Fine Arts, Liaoning 116650, China, 13940125392@126.com
[3]School of Media and Animation, LuXun Academy of Fine Arts, Liaoning 116650, China, zengrong@lumei.edu.cn

Corresponding author: Rong Zeng, zengrong@lumei.edu.cn

Abstract. In the era of the Internet of Things, the rapid development of computer technology has brought convenience to various industries. Fractal pattern styling is no exception. This paper discusses the method of pattern design using fractal geometry theory from the perspective of the Internet of Things. The two basic algorithms are mainly studied, and the realization process and application results are given, which have considerable application value in the design fields of art, clothing, decoration and so on. In this paper, the fractal design software of computer-aided design and its calculation principle are firstly discussed. Then, the composition method of fractal pattern and its application are analyzed from three perspectives: regular skeleton pattern of fractal pattern, fractal overall structural model composition, and fractal distribution pattern of pattern. Carry out thinking innovation in the thinking of these three kinds of composition, and develop these composition methods to have a better application and expansion in abstract painting works, decorative pattern works, flower works, creative works and so on. Then through the 3D image processing of fractal graphics, it is concluded that the combination of computer-aided design and fractal graphics under the Internet of Things perspective to design patterns makes fractal pattern design enter a new level.

Keywords: Internet of Things, Computer Aided Design, Fractal Graphics,
DOI: https://doi.org/10.14733/cadaps.2023.S2.56-66

1 INTRODUCTION

Computer-aided pattern modeling can be described as an artistic activity that uses computers to make artistic compositions. The traditional artistic pattern adopts the Euclidean geometric method,

through the application of aesthetic principles and composition rules, the pattern composed of basic geometric elements (points, lines, surfaces) is repeated in a systematic manner, and the cross combination, arrangement, layout and color of transformation or position changes, resulting in a variety of modeling patterns. Due to the tremendous development of computer technology, the traditional method of artistic composition has undergone fundamental changes. The use of trackballs, touch screens, and digitizers provides a variety of input methods for computer human-computer interaction. The emergence of raster graphics displays makes computer graphics more realistic, and the effects that were difficult to achieve or impossible to achieve have become possible due to the emergence of computers [1].

Fractal graphics are generated by computer, so that people can obtain novel and peculiar appearances and colorful patterns. Since Mandelbrot drew the first graph of the Mandelbrot set on the computer in 1980, people have shown great attention to this field, which is a brand-new idea source and method for flower design, with broad application prospects [2]. The traditional pattern design almost always uses points, lines, arcs, etc. in classical geometry to describe the patterns and patterns. Parts are treated with straight lines. This design method using Euclidean geometry is very limited. Generally, it can only draw a single pattern. In addition, it is also suitable for regular patterns composed of some basic patterns. Therefore, it is very limited in the application of some complex patterns and simulating natural scenes. Li [3] studied fractal graphics based on computer-aided design, and made good progress in clothing pattern design.

All artistic pattern generation and design have a soul, and composition technology is the key to computer-aided pattern design. The computer-aided art pattern design software currently used in the market still adopts the traditional Euclidean geometric design method in the basic pattern and the design principle and method of the pattern. That is, using aesthetic principles and simple composition rules, through orderly repetition, transformation or cross combination of positions, various arrangements, rotations, symmetrical layouts and color changes for the patterns composed of basic geometric elements (points, lines, surfaces, bodies), resulting in various pictures. This Euclidean geometry-based pattern generation and design method can draw complex single-pattern patterns or regular combined patterns composed of basic patterns. Many researchers have conducted extensive research on the graphic modeling design. Mostafa and Nafady [4] used fractal mathematical models to combine traditional patterns with new fractal art to create innovative designs for lacquer patterns. Qiao [5] has studied computer-aided graphic design. He believes that computer-aided design has brought innovation to graphic design. From the perspective of virtual reality technology, he has verified the rationality of computer-aided design. Zheng et al. [6] considered the human factors in computer-aided design systems, and conducted a design study on the shape of geometric figures. Bao and Shon [7] applied the idea of fractal geometry to the pattern design of the cheongsam.

With the development of fractal geometry and the application of fractal geometry theory, "fractal art" also developed. Fractal art can be said to be a new type of research that integrates fractal geometry and art, and has an interdisciplinary nature. Since fractal geometry is not a subject with a long history of development, the development history of the application of fractal geometry in pattern design also belongs to a relatively new field, so the theoretical knowledge of fractal geometry and the application of fractal geometry are relatively large. In terms of theoretical knowledge and application level, the development space has infinite possibilities and extensibility. Fractal is a self-similar pattern design, it is a shape with infinite details in the sense of no scale, showing the disordered beauty and infinite beauty of nature. The design content of fractal pattern is similar to ordinary design, mainly including pattern shape, pattern color and composition elements. and other components. Patterns are the basis of patterns, and their basic unit is called a unit pattern. In the fractal pattern modeling design, the free pattern after fractal geometry processing can be used as a unit pattern, which can be combined under certain fractal algorithm conditions. Color is an effect obtained by mixing, contrasting and reconciling different shades, brightness and purity. The composition of the color is related to the value and operation of the color variable. As a set of images with the fractal features, colors also have their own fractal properties [8]. Composition here refers to the design layout and combination of pattern shapes.

Through IFS and L-system algorithm, this paper discusses several fractal expressions suitable for pattern modeling design, which can be widely used in design fields such as clothing, art, and decoration.

2 FRACTAL DESIGN SOFTWARE AND CALCULATION PRINCIPLE

There are dozens of software for fractal pattern modeling design and generation, among which the most popular and widely used software are Apophysis and Ultra Fractal. Since these characteristics of Apophysis software are in line with the research and discussion in this paper and the problems to be solved, this topic chooses to use this software system in the application research part. Apophysis is developed based on the theory of iterative function system (IFS) generation method. The main features of the software are: the software has many built-in function plug-ins, and there are also many function plug-in resources on the Internet. These function plug-ins can be used to achieve Countless wonderful graphic transformations make the pattern produce dazzling and shocking light and shadow effects. While infinitely possible artistic patterns can be designed, the requirements for designers in mathematics are not high [9].

The complex dynamical system is a nonlinear iterative function.

$$Z_{N+1} = F\left(Z_N\right) \tag{1}$$

Iterate the initial value Z_0 to obtain trajectory points such as Z_1 and Z_2, and represent these points on the complex plane. Its chaotic set is a fixed set that tends to zero in each iteration and an escape set that tends to ∞ in each iteration. separate. In order to generate colorful patterns, the escape set of the external structure can be filled with different colors according to the speed of escape speed; the periodic orbit of the internal structure can be recorded with an array, and different periods can be used with different colors, so as to draw a beautiful M set and J set.

The iterative function system draws graphics through IFS code, for example: define the affine transformation of two-dimensional Euclidean space as ω: $R^2 \rightarrow R^2$, (X, Y) is a point in the two-dimensional Euclidean space, and its affine transformation maps is (X', Y'), written in matrix form:

$$\begin{bmatrix} X' \\ Y' \end{bmatrix} = \omega \begin{bmatrix} X \\ Y \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \times \begin{bmatrix} X \\ Y \end{bmatrix} + \begin{bmatrix} e \\ f \end{bmatrix} \tag{2}$$

In the formula: ω represents the six parameters of a, b, c, d, e, and f. When a graph is divided into N local subgraphs, the overall-to-local compression map set ω_n and its corresponding probability P_n form the IFS. code, denoted as{X: ω_n, P_n ,n=1,2,3,N}, and then use the method of solving the equation to find the coefficient and analyzing the relative position relationship of the subgraph to determine the IFS code, and draw the graph through the random iterative algorithm. Figure 1 shows the process of generating the fractal pattern matrix.

3 COMPUTER REALIZATION OF FRACTAL PATTERN MODELING DESIGN

Fractal composition is the design of the combination form and structure of pattern modeling. Excellent composition skills can fully reflect the creativity of artistic design. In the existing fractal pattern modeling design, there are two main methods of pattern combination: one is to synthesize the fractal pattern by traditional skeleton positioning; the other is based on computer-aided combination technology. This paper proposes three combined methods on the technology of these two methods [10].

3.1 The Rule Skeleton Diagram of Creative Works

Creative works can best reflect a designer's creativity, innovation ability and imagination. However, these abilities are limited. If fractals are used to design creative works, there are infinite possibilities. When creating creative works, it is often necessary to carry out the regular skeleton

drawing method on the fractal pattern, which can fully demonstrate the creativity, innovation and imagination of the designer.

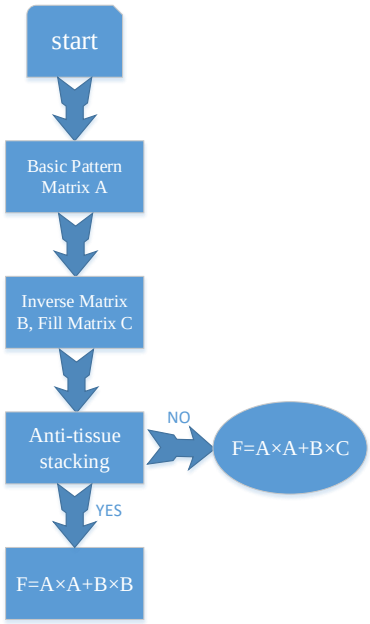

Figure 1: Fractal pattern matrix generation process.

In the creative design of the pattern, it is usually necessary to focus on the organizational structure of the pattern, the most important of which are the outline design and the frame pattern. It provides a standard for unit layout design of weave patterns. In the combination of fractal patterns, the regular skeleton in traditional pattern design can be used, such as individual patterns, fitting patterns, etc. The combination form and proportion of fractal patterns are shown in Figure 2. At the same time, using the principle of computer algorithm and the interactive ability of computer, the composition skeleton of combined fractal pattern can be realized by grid technology. The composition skeleton of the creative works includes three types: oblique mesh grille, square mesh grille and ring mesh grille. The organization of fractal patterns can be used to determine the distribution form of scatter points through interaction with the aid of computer grille design. Depending on the specific positions, the system uses various methods to generate the specified fractal patterns at these positions.

With the wider application of fractal geometry and the use of computer-aided design, computer fractal geometry is used to depict many patterns in nature, such as flowers, white lotuses, peonies, carnations, and other creative patterns. With the aid of computer design, it is expressed through fractal, and its design effect is quite amazing, even more refined and eye-catching than traditional design. The visual impact and appeal contained in it are very strong. Figure 3 is a schematic diagram of the design process of these texture patterns.

3.2 Fractional Overall Composition Model of Decorative Pattern Works

The feature of this composition method is that the overall fractal structure of the pattern is carried out according to the IFS algorithm model. to produce pictures with ("infinite") self-similar properties. Weaving patterns generated by Fractal matrices and Fractal magic squares are typical examples of this approach. Overall composition A common composition model is the recursive algorithm model.

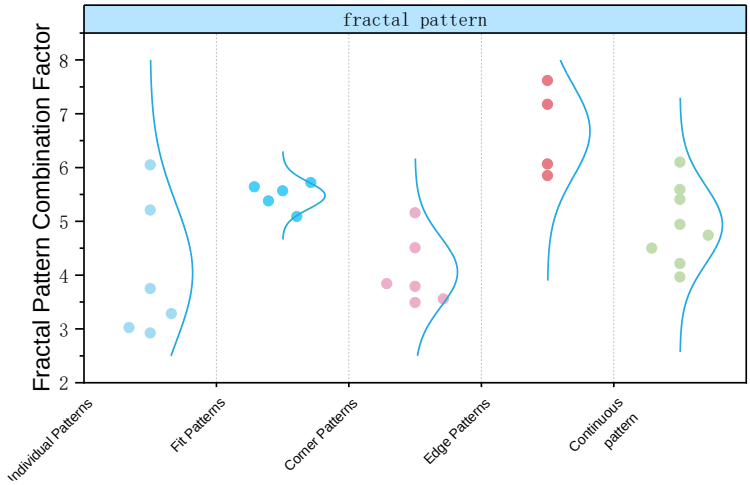

Figure 2: Fractal pattern combination.

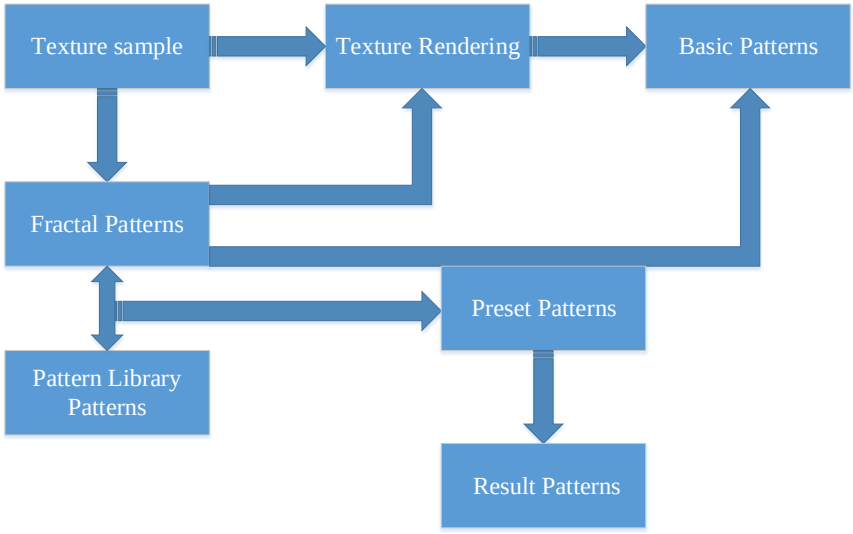

Figure 3: Texture pattern design process.

Fractal graphics have self-similar, self-replicating and self-nesting characteristics that are compatible with recursive algorithms. Therefore, the extraction of self-similar fractal graphics can generally be achieved by recursive algorithms. In general, the method of calling the result of a previous operation during the operation of a function itself is called recursion. It can split a complex problem into a simple operation process through step-by-step recursive transformation. The calculation flow of the recursive algorithm model is shown in Figure 4.

The steps of recursive calculation are as follows: (1) Determine the entire window as the format of the pattern, set the background color, and store the geometric parameters in the linked list according to the clockwise order of the polygon vertices of the format. (2) For any two sides of the polygon, use a pair of parallel lines to divide the polygon into two sub-polygons at random

positions, and the obtained polygon vertices store the geometric parameters in the linked list in clockwise order.

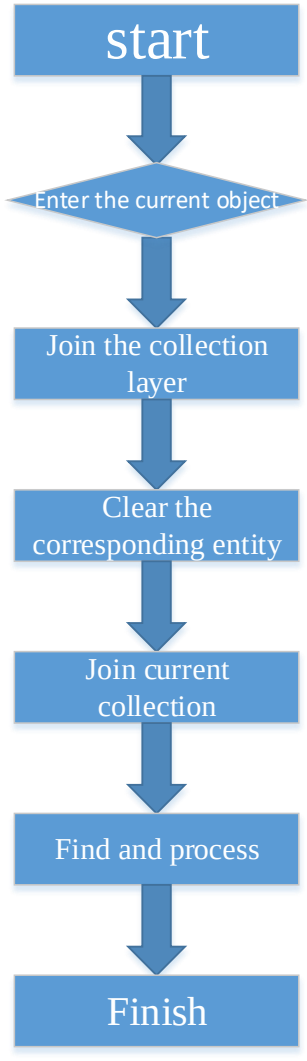

Figure 4: Basic flow of recursive algorithm.

(3) Repeat Step2 and Step3 for the obtained sub-polygons until the preset recursion depth N is reached. (4) Take out a sub-polygon generated by the last layer in turn, and use the Bézier curve to round each vertex. (5) figure out the turtleback block display area after the fillet corner, and outline the boundary of the turtleback block with the front scenery or fill the area. (6) repeat Step4, Step5 and Step6 for the remaining sub-polygons until all sub-polygons are processed.

The construction model of this algorithm can be fully used in decorative patterns, including modern art design, clothing design, interior decoration, etc. These designs are integrated with human aesthetics, natural aesthetics, and have an inseparable relationship with human life. Human imagination is limited, and the structural model pattern of fractal whole can create art that human brain can't imagine. The application of fractal geometry to decorative design works will bring infinite possibilities and surprises to the art world, as well as infinite inspiration and art.

3.3 Abstract Painting Works of Grain Type Distribution Composition

In computer-aided graphic modeling design, the layout and organization of patterns on the computer screen is the main design creation. The design of the regular skeleton pattern lacks natural beauty and layering. Fractal distribution composition according to some iterative model, the pattern (fractal or ordinary) is distributed on the calculated position of scattered points, forming a pattern with randomness in layout, but subject to statistical self-similarity. The combination form and evaluation coefficient are shown in Figure 5. Therefore, fractal distribution composition has more artistic creativity, and its works have more appreciation value.

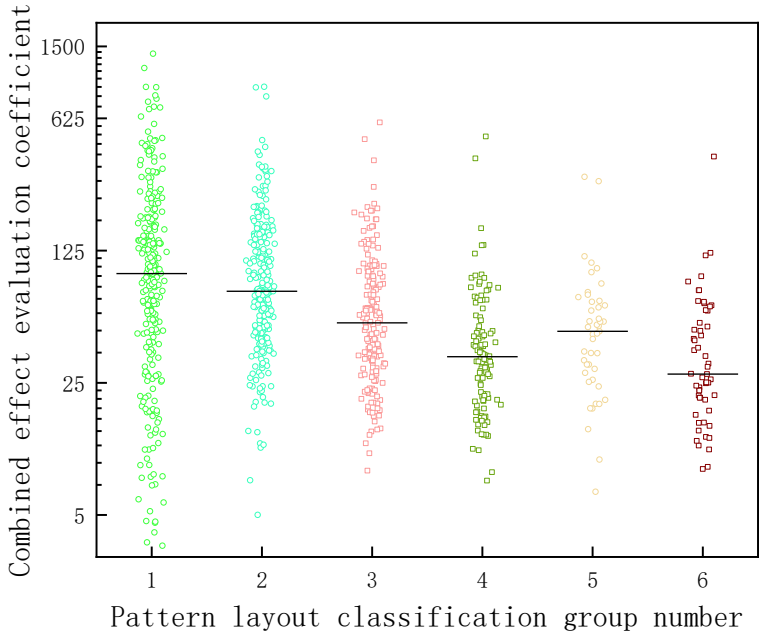

Figure 5: Pattern combination layout form and evaluation index.

The self-similar structure of the algorithm in the process of transformation is transformed and compressed by functions. The process of producing fractal graphics begins with simple composition and is completed through a series of repeated iterations. The iteration process is as follows: Let E_0 be the initial graph, and a total of N compression transformations are acted on E0 at the same time to generate N output objects. Let the N output graphs be E, which can be expressed as:

$$E_1 = W(E_0) = \omega_1(E_0) Y \omega_2(E_0) Y \cdots Y \omega_N(E_0) \tag{3}$$

In the next iteration, E_1 is the input graph, and finally we get five output objects of E_2. And then you iterate.

In each iteration, projection (affine) and compression transformation are performed. The specific pattern of fractal distribution composition process is as follows :(1) the window is defined as a rectangular area, set the background color. (2) Make a diagonal line (main diagonal or sub-diagonal) of the rectangular area, and define a golden section point on it (0.618 or 0.382 distance from an endpoint of the diagonal). (3) Determine a random perturbation point near the golden

section point whose distance from the point is no more than a constant range. (4) Make horizontal and vertical lines respectively through random disturbance points, and divide the window into four small rectangular areas. (5) Repeat step 2-Step5 for each small rectangular area until the predetermined depth of recursion. (6) Select the predetermined algorithm to draw the fractal pattern or paste the selected bitmap pattern on the perturbation scattered point.

Abstract art occupies a very important position in decoration design. It is the interior decoration that can be most reflected. For example, in hotels and restaurants, especially in more advanced places, abstract decorations often appear. Abstract painting design in the traditional way has certain limitations. If fractal geometry is introduced into the creation and design of abstract painting, it can reach a height unmatched by traditional design. Fractal art looks chaotic, but the logic and mathematical rationality contained in it are infinite.

4 3D IMAGE PROCESSING OF TYPED IMAGES

To create a fractal pattern, the fractal image should be drawn by computer first, and its fineness can be set by parameters, and the fractal calculation result is saved for compound editing. The plane processing of fractal graphics can use the software photoshop to adjust the color and the transparency of the layer. But the plane software can't get the real and changeable space effect. To this end, you can consider the use of 3D and rendering software such as 3ds max to obtain the effect of spatial transformation. For example: 3ds max has a variety of texture coordinate functions, free lighting effects and arbitrary camera view angles, which can be used for special effects processing of patterns. Figure 6 shows the three-dimensional shape and spatial surface processing accuracy of different software.

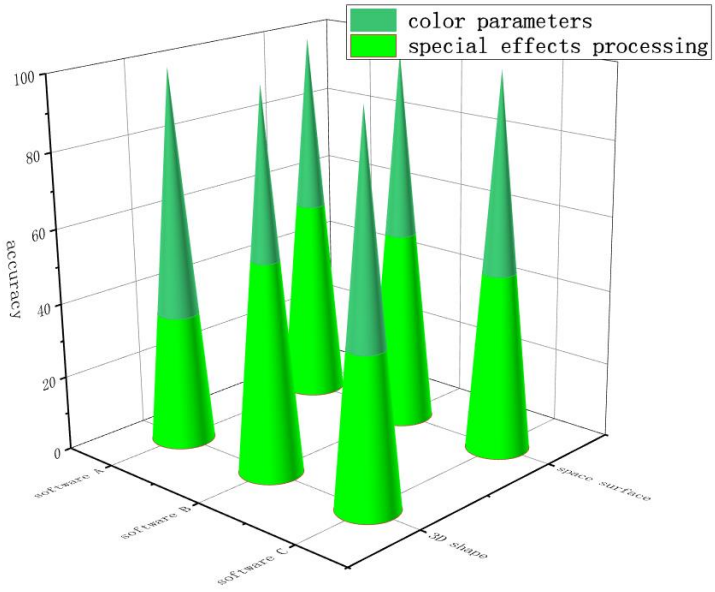

Figure 6: 3D shape and spatial surface processing accuracy of different software.

It is very easy to make 3D shape or space surface sheet in 3dsmax. This step is realized by 3D software. Then, specify different texture selection coordinates and transformations such as: Box, Cylindrical, Face, Planar, ShrinkWrap, Spherical, etc. Then, select the fractal map. The advantage of fractal as a texture is that it is scale-free and can be infinitely fine. General objects have their own texture coordinates when they are generated, and some objects need to specify UVW map coordinates. You can also adjust the repetition of the UV direction through TLING, adjust the offset

through OFFSET, and adjust the rotation angle in the W direction through ANCLE. This spatial transformation is different from the simple translation and rotation on the plane. 3D effect, there are many changes. Of course, the effect generated after mapping also depends on the complexity of the shape and the exquisiteness of the fractal image. The modeling of 3D shapes can be easily modified in 3ds max.

Set different lights, backgrounds and other effects in the scene, and through rendering, you will end up with beautiful and varied patterns. The more layers in the initial fractal calculation, the more beautiful it will be under the same coordinates. The selection of parameters such as the angle selected for the three-dimensional modeling of the space, the color of the light and material, whether the material is self-illuminating, and whether the double-sided material is used will also have an impact. In order to get the desired effect, it is necessary to repeatedly adjust, such a method is to be followed regularly.

5 ADVANTAGES OF COMPUTER AIDED FRACTAL PATTERN DESIGN

The traditional pattern design method is generally that the designer first composes the picture in his head, and then relies on paper and pen or computer hand-drawn tools to express the idea in the brain with sketches. The pattern designed by this design method has several defects: 1. The quality and quantity of the works are limited by the imagination and hand-painting ability of the human brain and cannot be fully utilized; 2. The subsequent modification process will be very cumbersome; 3. Design The pattern and modeling works created by the teacher are easy to be copied or copied by others. These defects have become a bottleneck in the artistic innovation design of most products; 4. Although there are many design software and various digital technologies for pattern drawing and processing, these are only auxiliary tools and cannot achieve "incredible" Creation cannot achieve the effect that fractal software creation can achieve. This is determined by the characteristics of fractal graphics and the different ways of generating them. Under the conditions of different design steps, the effects of traditional design and computer-aided fractal design are completely different, as shown in Figure 7.

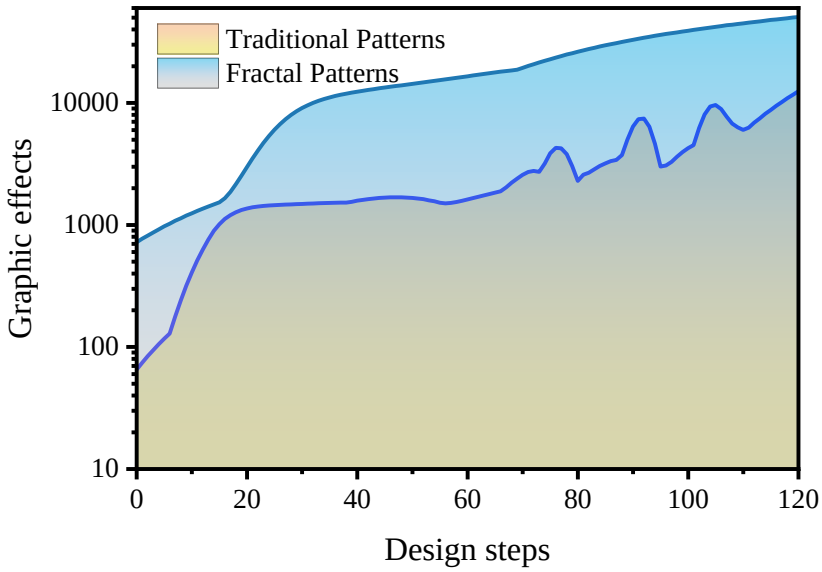

Figure 7: Pattern comparison of two design forms.

Fractal pattern design has great advantages compared with traditional pattern design. The properties of the patterns are different, and the fractal pattern has the characteristics of self-similarity, scale-free, and self-radiation that traditional patterns do not have. On the other hand, fractal pattern design is closely related to mathematical thinking, and the combination of the two can collide with infinite possibilities of artistry. 1. The designer's graphic creation is no longer limited by the imagination and hand-painting ability of the human brain, especially when facing the complex pattern design, the parametric design method through the computer is easier and more efficient; 2 . Provides an adaptable adjustment space for the design, and the subsequent modification of the graphics can be very convenient through parameter adjustment and automatic computer generation; 3. It can be efficiently connected with advanced manufacturing and production technologies, such as the combination of fractal structure and 3D printing technology , which can quickly create some infinitely beautiful and complex modeling works that are difficult to complete by hand.

To sum up, the fractal pattern modeling design is a generation process using nonlinear mathematical theory, which is completely different from hand-drawn pattern modeling and general "computer painting". Manual drawing and computer drawing use the artist's art skills, skills, aesthetics, specific image conception and the operation ability of computer drawing tools. For the fractal pattern design, in addition to having good aesthetic and design ability, the creator must also have a certain mathematical foundation, fractal theory knowledge base, programming ability, etc.

6 CONCLUSION

In the age of Internet of Things, fractal geometry is an emerging subject, it is linked with computer graphics to create peculiar and changeable patterns, and these patterns are formed by a series of affine transformations using geometric formulas, and are designed with computer-generated fractal graphics. Pattern is a novel pattern-aided design method. In this paper, this method is discussed in a certain range, and a useful attempt is made, and a novel spherical mirror reflection technology is proposed, which has achieved satisfactory results.

The use of computer aids in the design of fractal graphics makes the design of fractal patterns enter a new level. This paper studies the methods and principles of fractal pattern design, and innovatively proposes to combine fractal pattern design with image processing software, especially with 3D modeling and rendering software, to obtain a convenient method for obtaining spatial transformation effects. Fractal pattern design approach. The whole process here is realized on the computer. This new design idea and method with the development of computer application technology, which combines mathematics, computer application and art, has considerable practical significance.

Wei Xiong, https://orcid.org/0000-0002-9234-7719
Xiaohui Zhang, https://orcid.org/0000-0002-4955-8836
Rong Zeng, https://orcid.org/0000-0002-0123-4066

REFERENCES

[1] Tian, G.; Yuan, Q.; Hu, T.; et al.: Auto-generation system based on fractal geometry for batik pattern design, Applied Sciences, 9(11), 2019, 2383-2403. https://doi.org/10.3390/app9112383

[2] Çimen, M.-E.; GARİP, Z.; Boyraz, Ö.-F.; et al.: An interface design for calculation of fractal dimension, Chaos Theory and Applications, 2(1), 2020, 3-9. https://dergipark.org.tr/en/pub/chaos/issue/53876/689145

[3] Li, P.: Research on visual art design method based on virtual reality, International Journal of Gaming and Computer-Mediated Simulations (IJGCMS), 13(2), 2021, 16-25. https://www.igi-global.com/article/research-on-visual-art-design-method-based-on-virtual-reality/279053
[4] Mostafa, M.-E.; Nafady, D.-A.: Fractals between theory and practice and its use in enriching the field of design, International Design Journal, 11(3), 2021, 31-45. https://ieeexplore.ieee.org/abstract/document/8991142
[5] Qiao, G.: Computer-Aided Design of Fine Art Graphics Based on Virtual Reality Technology, Computer-Aided Design & Applications, 19(S5), 2022, 54-64 https://doi.org/10.14733/cadaps.2022.S5.54-64
[6] Zheng, J.-M.; Chan, K.-W.; Gibson, I.: Desktop virtual reality interface for computer aided conceptual design using geometric techniques, Journal of Engineering Design, 12(4), 2020, 309-329. https://doi.org/10.1080/09544820110085931
[7] Bao, Y.-X.; Shon, Y.-M.: An Innovative Design Method of Pattern Art Based on Fractal Geometry Applied to Cheongsam Pattern Design, The journal of Humanities and Social Sciences 21, 11(5), 2020, 2577-2586. https://papersearch.net/thesis/article.asp?key=3833025
[8] Jiang, W.; Zhang, Y.: Application of 3D Visualization in Landscape Design Teaching, International Journal of Emerging Technologies, 14(06), 2019, 53-62. https://doi.org/10.3991/ijet.v14i06.10156
[9] Kulsum, U.: Grading Women's Clothing Patterns with the CAD Pattern System to Improve Student Learning Outcomes and Competencies, Journal of Education Technology, 4(2), 2020, 187-194. http://eprints.unm.ac.id/id/eprint/12661
[10] Long, Y.: Research on art innovation teaching platform based on data mining algorithm, Cluster Computing, 22(6), 2019, 14943-14949. https://doi.org/10.1007/s10586-018-2461-z