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Application and Study of Fractal Graphics in Packaging Design

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Abstract. As the degree of market competition increases, packaging design is no longer a basic requirement for products, and simple graphic design can no longer meet people's ever-increasing aesthetics and requirements for visual effects. The previous graphic design software is mainly based on the Euclidean geometry algorithm to achieve the graphic drawing, which shows poor adaptability in the description of irregular natural scenes. The fractal theory is able to describe the irregular scenes well, and show the exquisiteness and naturalness, and its rich hierarchy and beautiful transformation effects are more in line with the needs of packaging design artistry. Therefore, this paper proposes the application and research of fractal graphics in packaging CAD design, and introduces Markov chain in iterative function IFS algorithm to improve its line distribution and stiffness problem. The experimental results show that the algorithm in this paper can realize the drawing of natural scene graphics and adjust its morphological changes by setting the parameters, iterative function matrix and accompanying probability. In addition, the random number processing added in the algorithm improves the naturalness of the fractal graph lines, which is closer to the actual natural scenes.

Keywords: Fractal Graphics; Package Design; CAD Design; Iterative Function Ifs.
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1 INTRODUCTION

In the era of rapid development of information technology, text description and simple packaging design can no longer meet people's requirements for visual effects, and the requirements for both the composition of the design and the fineness and naturalness of the graphics have been greatly improved when packaging design is carried out. With the development of image graphics technology, AutoCAD, Photoshop, 3DMAX and other software development of a high level of maturity, in many areas have been widely used. However, most of the drawing methods used in previous software applications are based on the Euclidean geometry theory, which shows good performance for drawing smooth surface and regular shape, but shows low applicability for drawing natural scenes with high surface roughness and irregularity, mainly because most of the natural scene shapes are difficult to be expressed precisely by equations [1]. In the past, for irregular shapes that could not be described by drawing software, designers might draw the desired shapes by means of computer software simulating interaction or by hand [2]. However, such a way is often limited by the technology and the imagination of the designer, and the presentation effect in packaging creation cannot reach the expected requirements.

The exploration of irregular shapes in nature was gradually developed in the mid-19th century, and in this context, mathematician Benoît Mandelbrot proposed the theory of fractal geometry, which divides nature into different scales and maintains the self-similarity of the shapes at each scale, and this fractal shape shows a fine structure with a hierarchy of wireless nesting [3]. This theory is known as the geometry of nature and has been used in many fields because of its ability to better describe natural scenes [4]. The development of computer technology nowadays provides a more effective and expressive way of implementing graphics and packaging design, which, combined with fractal theory, can produce variable, high-resolution graphics with fine structure and self-similarity characteristics, improving the artistic and visual effect of graphics [5]. With the development of fractal theory, the drawing of graphics can be achieved by different fractal models, which have their own characteristics and ultimately show a certain variability in the graphical effect. Among the fractal models, the iterative function IFS shows high performance and can be well adapted to the description of natural scenes, but the fractal graphics drawn by the traditional iterative function IFS have poor line distribution and show a lack of natural flexibility of graphics, which is difficult to adapt to the needs of packaging design. Therefore, this paper introduces Markov chain in the iterative function IFS to obtain the set of non-deterministic states through its accompanying probability, so as to improve the naturalness of the final fractal graphics. Finally, the performance of the iterative function IFS algorithm combined with Markov chain and the fractal graph drawing effect are experimentally verified.

2 DEVELOPMENT AND STATUS OF FRACTAL THEORY RESEARCH

Fractal theory began to be studied abroad in 1872. At the beginning of the study, there was no systematic research framework. The research results of many scholars have laid the foundation for the development of fractal theory, such as the Cantor three-fractal set constructed by the German mathematician Cantor and the Koch curve constructed by Koch. After 1975, fractal theory entered a comprehensive development stage and formed an independent discipline at this stage. Mandelbrot's "Fractal object: shape, opportunity and dimension" comprehensively and systematically expounds the meaning, core idea and significance of fractal for the first time, and includes charts of irregular natural phenomena (such as clouds) in fractal geometry.

Packaging design plays an important role in attracting consumers' attention and generating consumers' expectations, which will affect consumers' cognition and decision-making on products. Tirpude et al. [6] studied different parameters to observe consumers' views on the development of new packaging based on a) three-dimensional modeling of product dimensions b) all variants c) graphics formed based on key observations of design research. The technical specifications are based on prototypes. Vasileiadis et al. [7] analyzed the conceptual design of products and packaging that meet customer needs. This paper introduces some research tools, marketing/brand principles and product development technologies. This research analyzed and demonstrated the whole design process from concept to final/3D rendering model by using a large number of tools and methods, namely mind map, emotion board and sketch. Convert the raw data obtained from customers into 3D CAD (computer-aided design) modeling products. CAD technology is applied to the process of product packaging design, and the process of using various design software to assist product packaging design is proposed. In order to solve the problem of backward and inefficient numerical control programming of complex parts of marine diesel engine in the actual production of enterprises. Based on the comprehensive investigation and analysis of the status quo of CADDCAM integration in diesel engine manufacturing enterprises. Yu et al. [8] put forward a solution to the problem of planar labels after 3D mapping and data transmission between different software during packaging design. The sales of agricultural products changed from extensive to intensive. Packaging appearance has the function of transmitting agricultural product information, inducing consumption and spreading culture. In view of the limitations of the existing agricultural product packaging, this paper takes the main consumer groups of agricultural products as the research object, and Zhao et al. [9] has constructed a packaging design framework. On the basis of transferring the value of local agricultural products and the original ecological concept, the overall model of computer aided packaging design was constructed. According to the characteristics of agricultural products, carry out packaging design planning, including packaging materials and technology, packaging structure, packaging visual design. With the development of economy, the sales of agricultural products have changed from extensive to intensive. Packaging appearance has the function of transmitting agricultural product information, inducing consumption and spreading culture. In view of the limitations of the existing agricultural product packaging, Zhao et al. [10] took the main consumer groups of agricultural products as the research object and constructed the framework of packaging design. On the basis of transferring the value of local agricultural products and the concept of primitive ecology, the overall model of computer aided packaging design was constructed.

3 FRACTAL GRAPHICS PRODUCTION METHOD

The traditional Euclidean geometry cannot be described accordingly in the field of irregular geometry with complexity, especially for figures existing in nature, and fractals emerged to fill this part of the gap. The mathematical definition of fractal is not yet consistent, and the term where it was coined contains the meaning of broken, irregular, and fractional. According to the descriptive definition of the mathematician Falconer, the definition of a fractal should be done from the point of view of the biologist's definition of "life" as a set with fine structure, irregularity, self-similarity and self-affine. In addition, the fractal set usually has a higher fractal dimension than its topological dimension, which can be determined in a simple way, such as an iterative approach.

3.1 Fractal Graph Drawing Theory

Fractal geometry can solve the description of graphs with complex shapes by the idea of simple repetition, i.e., combining fractal and state-determining systems to iterate simple graphs to draw complex graphs, so the graphs themselves need to have a relatively high degree of self-similarity. The self-similarity of a graph means that there is morphological similarity between the whole and the local, between the whole and the whole, and between the parts and the parts. However, it is not a scaling up and down of the multiplicative relationship between the parts and the whole, but an iterative drawing of the sub-part of the graph and the sub-part of the sub-part, based on the scaling factor of the initial shape as a whole.

Based on the fractal similarity, the key of its drawing is to describe the target graph through a suitable model. According to the algorithm of fractal graph model, its generation methods can be divided into complex fractal generation method, L-system generation method, iterative function IFS generation method and so on. Among them, iterative function IFS generation method is one of the more effective methods to simulate the branching structure in the fractal structure of natural scenery, and it is also the fractal graph generation method with better vitality in the application of fractal theory. The core idea of iterative function IFS generation method is to consider the target figure as a structure composed of different small pieces, and each small piece is similar to the whole and collapsed together after certain transformation, the transformation method is the self-projective transformation. The affine transformation can be described by the traditional linear transformation relations, which are rotation, reflection and other transformations while maintaining the position of the origin of the figure unchanged, while the affine transformation is based on a certain translation, so its transformation is described as shown in Equation (1).

$$y = \lambda x + c \tag{1}$$

Where the original coordinate point of the graph is denoted as x and the linear transformation is described as λ , then λx represents a linear transformation of x and the translation distance is denoted as c .

The matrix form of the above equation is shown in equation (2).

$$\begin{bmatrix} y \\ 1 \end{bmatrix} = \begin{bmatrix} \lambda & c \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ 1 \end{bmatrix} \tag{2}$$

The affine transformation of low dimensions can be achieved by dimensional transformation, i.e., adding another dimension to the original affine transformation can achieve the purpose of linear transformation of high latitude, and completing the transformation between formulaic form and matrix form.

Introducing the affine transformation matrix in the iterative function IFS, the result is shown in Equation (3).

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} \lambda & \alpha & c \\ \beta & \gamma & d \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \tag{3}$$

where the linear transformation of the graph is described by $\lambda, \alpha, \beta, \gamma$ and the translation of the graph is expressed by c, d

The description of the equation for the parameter modulation mode of the linear transformation is shown in Equation (4) as follows.

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} a\cos\varphi & -b\sin\theta \\ a\sin\varphi & b\cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} c \\ d \end{bmatrix} \tag{4}$$

Combining equation (3) yields.

$$\begin{cases} a = \sqrt{\lambda^2 + \beta^2} \\ b = \sqrt{\alpha^2 + \gamma^2} \\ \varphi = \arcsin(\lambda \big/ \sqrt{\lambda^2 + \beta^2}) \\ \theta = \arcsin(\alpha \big/ \sqrt{\alpha^2 + \gamma^2}) \end{cases} \tag{5}$$

The scaling factor in the direction of the coordinate axis x, y is a, b and the counterclockwise rotation angle is φ, θ .

The IFS code plays a key role in the iterative function IFS, which contains a large number of parameters that can be changed to obtain different fractal graphs. In addition, in this method, the affine transformation is able to determine the attractor of the graph. Although there is no theoretical correlation between the attractor and the probability, the probability plays an important role in the actual graph drawing process, and the control of the probability means the control of the density of the falling points of each part of the graph, which makes the graph present different hierarchical effects.

3.2 Fractal Graph Drawing Algorithm Combining Markov Chain

External events can determine the trigger states of the state function, when the generation of fractal graphs using only their self-similarity cannot meet the needs of describing irregular objects with high complexity, such states will trigger the state function to exhibit chaotic motion-like states. The natural domain contains random, deterministic, and chaotic states of motion, and although chaotic states of motion do not have strict periodicity, their complex states exhibit a rich orderliness, i.e., many of them still evolve according to certain regularities. The chaotic irregular motion in a deterministic system leaves the system as a whole in a stable state, but with increased local uncertainty. The affine transformation in the operation of the deterministic state system does apply only to the initial set, and the new set of points obtained is used to generate the desired graph by several iterations. In this process, if the coefficient matrix of the affine transformation remains the same, the final obtained graph is the same regardless of the increase in the number of iterations. In addition, the ability of the deterministic state system to describe the graph is affected by the limited number of state transfer functions, and only a smaller number of paths can be used to describe the curve segments deterministically, which makes the graph rawer.

By introducing Markov chains into the fractal graph generation system, it is possible to use its concomitant probability to generate a non-deterministic set of states and to realize the operation of the fractal system in that state. Compared with the deterministic state system, the non-deterministic state system generated by Markov chain has chaotic characteristics, and the state in the current moment of the process is only related to the performance state in the previous moment, and there is no correlation between the state and the other moments, which makes the non-deterministic process of the deterministic state function have certain regularity. The distribution function of the probability of the affine transformation matrix is added to the non-deterministic state, so that any affine transformation row has a probability value, and the initial point set is affine transformed based on the probability distribution to obtain a new point set. Finally, the required fractal graph is obtained after several iterations, as shown in Figure 1, which shows the flow of the fractal graph drawing algorithm combined with Markov chain.

Let the coefficient matrix be M and the number of its rows be i , the size is determined by the graph, i.e., the same as the number of graphs being divided, each row is a form of data processing, and there is a positive correlation between the number of rows and the richness of the graphs. The number of columns represents the coefficients of a,b,φ,θ,c,d , respectively $m_{j1},m_{j2},m_{j3},m_{j4},m_{j5},m_{j6},\ j=1,2,...,i$, and the coefficient matrix determines the final result presented by the algorithm. The matrix M is a two-dimensional coefficient matrix, and by adjusting each of its row vectors to the 2×3 military array, we obtain the $2\times 3\times j$ three-dimensional matrix $B^{[j]}$, whose transformation process is shown in equations (6) and (7).

$$M=\left[m_{j1},m_{j2},m_{j3},m_{j4},m_{j5},m_{j6}\right] \tag{6}$$

$$B^{[j]}=\begin{bmatrix} B_{j1} & B_{j3} & B_{j5} \\ B_{j2} & B_{j4} & B_{j6} \end{bmatrix}=\begin{bmatrix} m_{j1}\cos(m_{j3}) & -m_{j2}\sin(m_{j4}) & m_{j5} \\ m_{j1}\sin(m_{j3}) & m_{j1}\cos(m_{j4}) & m_{j6} \end{bmatrix} \tag{7}$$

The scaling factors of the coordinate axis are expressed as x,y m_{j1},m_{j2} , the rotation angles in the counterclockwise direction are expressed as m_{j3},m_{j4} , and the translation coordinate values are expressed as m_{j5},m_{j6} .

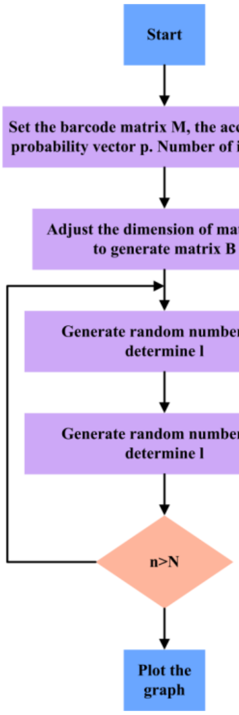

Figure 1: Flow of fractal graph drawing algorithm combined with Markov chain.

Let the probability of the transfer function in the state of $B^{[j]}$ be P_j , then its corresponding vector p can control the distribution of the sparsity of the graph, and there is a positive correlation between the probability P_j and the fineness of the graph. Let the iteration matrix be G and the number of iterations be n , the iteration matrix is $2\times n$ and all the elements have initial value 0. The column vector obtained after each iteration of the matrix is recorded as the position information of the corresponding point in the image and substituted in the matrix column vector one by one until the set of termination states appears. Let Q be the grid matrix, the element values contained in each column vector and the element values of the corresponding column vector of the vector p correspond to each other, and after taking down its triangular matrix, the row vector summation is performed to obtain the probability accumulation results, as shown in Equation (8).

$$Q=\begin{bmatrix} p_1 & + & 0 & + & 0 & + & 0 \\ p_1 & + & p_2 & + & 0 & + & 0 \\ p_1 & + & p_2 & + & p_3 & + & 0 \\ p_1 & + & p_2 & + & p_3 & + & p_4 \end{bmatrix} \quad (8)$$

Also $\sum_{j=1}^{i} p_j = 1$, if any value h is chosen in the interval $[0,1]$ and the vector Q to make the difference, the result will definitely exist that the values after a certain line are all negative, and the number of sequences in that line is l , as shown in equations (9)-(11).

$$Q_{l-1} < h < Q_l \tag{9}$$

$$Q_{l-1} = \sum_{j=1}^{l-1} p_j \tag{10}$$

$$Q_l = \sum_{j=1}^{l} p_j \tag{11}$$

The length of the sequence that can be obtained for any number of rows corresponding to the sequence number l h is shown in equation (12).

$$Q_l - Q_{l-1} = p_l \tag{12}$$

The assignment of the iteration matrix G can be performed according to equation (13).

$$G_{n+1} = \begin{bmatrix} x_{n+1} \\ y_{n+1} \end{bmatrix} = B^{[l]} \times \begin{bmatrix} x_n \\ y_n \\ 1 \end{bmatrix} \tag{13}$$

This leads to

$$x_{n+1} = B^{[l]}(1,1) \times x_n + B^{[l]}(1,2) \times y_n + B^{[l]}(1,3) \tag{14}$$

$$y_{n+1} = B^{[l]}(2,1) \times x_n + B^{[l]}(2,2) \times y_n + B^{[l]}(2,3) \tag{15}$$

4 EXPERIMENT ON THE APPLICATION OF FRACTAL GRAPHICS IN PACKAGING CAD DESIGN

Before applying fractal graphics in packaging CAD design, it is necessary to draw the corresponding image by fractal graphics generation algorithm, and then adjust the parameters and colors of the obtained graphics. Therefore, it is necessary to realize the basic graphics through the fractal graphics drawing algorithm combined with Markov chain first, and then adjust and enrich the graphics on this basis.

In this paper, a set of leaves is selected for corresponding experiments, and the leaves are divided into four parts in the fractal process, i.e., the upper and lower parts and the left and right parts, and the parameters of these four parts are adjusted and controlled. As shown in Figure 2, it is the leaf affine transformation matrix.

In order to solve the problem of difficult manipulation caused by the sensitivity of chaotic initial values, it is necessary to introduce attractors into the system, as shown in Figure 3, which is an explanatory diagram of the attractor transformation of the tree leaves. From the figure, it can be seen that the four partial parameters can be adjusted and controlled to obtain new generated lines with different angles, or to achieve transformations such as rotation of the graph through the adjustment of parameters, and a single factor can control multiple elements in the graph.

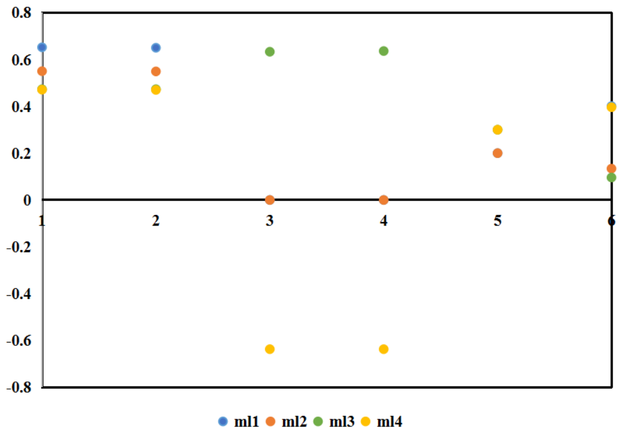

Figure 2: Scatter plot of the basic tree-leaf affine transformation matrix.

This shows that the fractal graph drawing algorithm combined with Markov chain can realize the drawing of tree leaf graph and change its morphology accordingly, and after adding random number processing, the obtained tree leaf graph obtains more natural lines on the basis of basically following self-similarity, which is closer to the morphology of real tree leaves in nature.

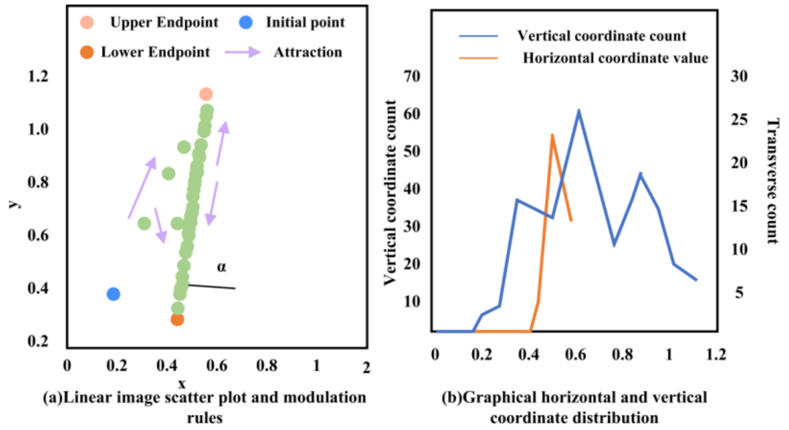

Figure 3: Explanation diagram of leaf attractor transformation.

In order to further verify the adjustment and control performance of the algorithm for fractal implementation, the experiments took the initial state of the leaves as the reference, and the leaves were rotated and scaled, as shown in Figure 4 for the comparison results of the distribution of the transverse coordinates of the leaves under the three forms. The data in the figure show that the distribution of the tree leaf coordinates in the three total states is in a non-uniform state, and even a slight change of angle will cause a significant difference in the distribution state of its whole coordinates. This indicates that the fractal graphs obtained after arbitrary adjustment of the affine matrix parameters are not the same, which also verifies the initial value sensitivity of the chaotic system.

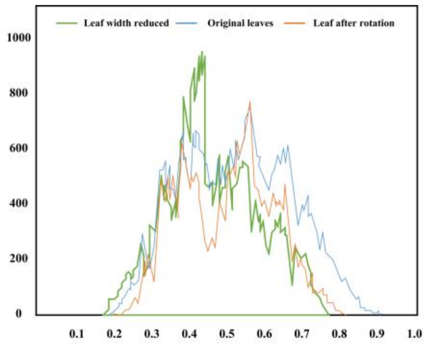

Figure 4: Comparison results of the distribution of leaves in the three forms in the horizontal coordinates.

Fractal graphs have different expressions from the previous Euclidean geometry. Euclidean geometry makes all scales in the fractal set maintain all characteristics of the whole by iterative operations, and there is no correlation between its target point set and initial points, but only regularity between iterations, so its applicability in fractal images is relatively low. The algorithm in this paper can achieve different fractal graphics by changing the iteration function. In terms of graphics processing, the algorithm in this paper does not separate the points, lines and surfaces existing in the graphics but treats them as a whole, which has more advantages. As shown in Figure 5 and Figure 6, respectively, are the comparison of the distribution of the horizontal coordinates of the four kinds of tree leaf graphs after the adjustment of the algorithm in this paper. The results in the figures show that there are large differences between the affine matrices of the four different tree leaf graphs, and even if only the distribution of the accompanying probabilities changes, it will make a significant gap between them. The adjustment of the columns in the iterative function matrix can also obtain different fractal shapes of the tree leaves. Therefore, this shows that the algorithm in this paper can obtain different complex shapes in the natural domain through the parameters, iterative function matrix and concomitant probability settings, and shows that the algorithm in this paper not only obtains images with higher refinement and naturalness, but also has less operational difficulty in debugging.

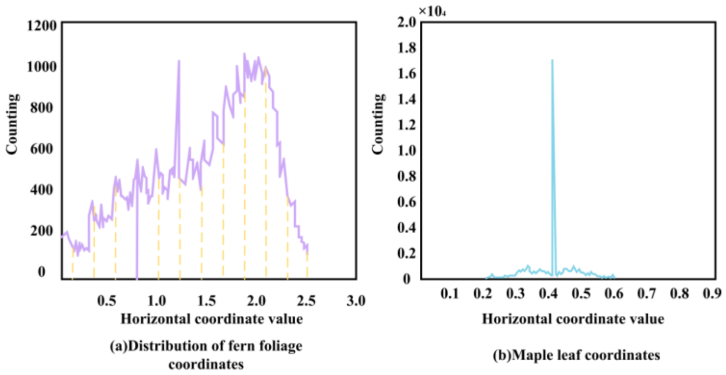

Figure 5: Distribution of fern and maple foliage in transverse coordinates.

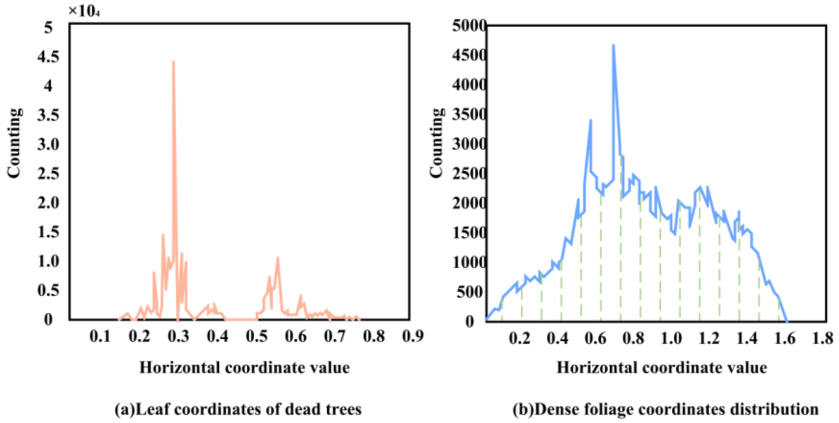

Figure 6: Distribution of leafy and dead trees by horizontal coordinates.

Fractal graphics have characteristics such as varied and brilliant colors, and have high artistic characteristics. At the same time, paying attention to the balance of graphic composition in the design process can obtain high visual effects and show a more free and flexible dynamic balance beauty, which is obviously different from the static balance beauty in the previous graphic design. In addition, the color richness and harmony of fractal graphics are higher, which can make the color between the whole and the part more integrated through clever overlap, and also can show the beauty of color in the natural field. For example, Figure 7 shows the fractal graphics drawn by the algorithm of this paper, and designed the handbag packaging based on this graphic. From the visual effect, the algorithm of this paper can simulate the plant images in nature, and generate several graphics with higher fineness to achieve the description of the natural radial.

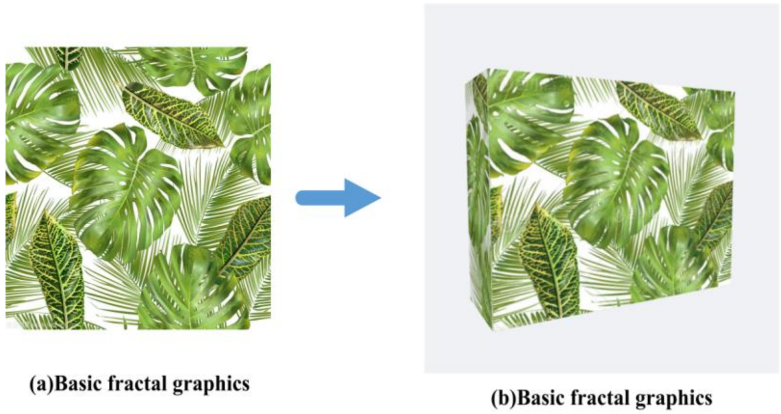

Figure 7: Handbag packaging design based on leaf fractal graphics.

5 CONCLUSION

With the improvement of visual technology, people's demand for packaging design is no longer simple graphic design, but also the demand for natural scene simulation, hoping to show the natural and dynamic composition on the basis of design. Most of the previous graphic drawing software is based on Euclidean geometry algorithm, which has relatively low applicability in the simulation of natural scenery and cannot meet the current demand for packaging design. Fractal theory can improve this phenomenon and better describe the natural scenery. Therefore, this paper introduces Markov chains into the fractal graph drawing algorithm, so that the fractal graph generation algorithm can draw more natural fractal graphs. The experimental results show that the fractal graph plotting algorithm combined with Markov chain can obtain more refined and natural foliage graphs by setting the parameters, iteration function matrix and concomitant probabilities, and can obtain significantly different foliage graphs even if the relevant data are changed to a lesser extent, which indicates that the algorithm in this paper is more adjustable and controllable for fractal graphs. Compared with previous plotting algorithms, the operability of the settings in this paper is relatively less difficult, and there is sensitivity to the initial values of the graphs.

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REFERENCES

[1] Ayağ, Z.: An Intelligent Approach to Evaluating CAD Software Packages Through Hesitant Fuzzy AHP, Journal of Advanced Manufacturing Systems, 21(02), 2022, 317-335. https://doi.org/10.1142/S0219686722500056

[2] Condruz, M.-R.; Voicu, L.-R.; Puscasu, C.; Vintila, I.-S.; Sima, M.; Deaconu, M.; Dragasanu, L.: Composite material designs for lightweight space packaging structures, INCAS Bulletin, 10(1), 2018, 13-25. https://doi.org/10.13111/2066-8201.2018.10.1.3

[3] Marwee, N.-N.; Masrol, S.-R.: Design and Development of Satay Delivery Packaging Box, Progress in Engineering Application and Technology, 2(1), 2021, 1018-1029. https://doi.org/10.30880/peat.2021.02.01.099

[4] Nguyen, V.; Nguyen, N.; Schumacher, B.; Tran, T.: Practical application of plan–do–check–act cycle for quality improvement of sustainable packaging: a case study, Applied Sciences, 10(18), 2020, 6332. https://doi.org/10.3390/app10186332

[5] Rodríguez, P.-L.; Mayuet, P.-F.; Gámez, A.-J.: Custom design of packaging through advanced technologies: A case study applied to apples, Materials, 12(3), 2019, 467. https://doi.org/10.3390/ma12030467

[6] Tirpude, R.; Alam, T.; Saha, N.-C.: Effect of Package Design of Handloom Products to Influence Consumer Perception, Journal of Packaging Technology and Research, 3(2), 2019, 169-179. https://doi.org/10.1007/s41783-019-00065-w

[7] Vasileiadis, T.; Tzotzis, A.; Tzetzis, D.; Kyratsis, P.: Combining product and packaging design for increased added value and customer satisfaction, Journal of Graphic Engineering and Design, 10(2), 2019, 5-15. https://doi.org/10.24867/JGED-2019-2-005

[8] Yu, W.; Sinigh, P.: Application of cad in product packaging design based on green concept, Computer-Aided Design and Applications, 19(S2), 2021, 124-133. https://doi.org/10.14733/cadaps.2022.s2.124-133

[9] Zhao, Z.; Zheng, H.; Liu, Y.: The appearance design of agricultural product packaging art style under the intelligent computer aid, Computer-Aided Design and Applications, 19(S3), 2021, 164-173. https://doi.org/10.14733/cadaps.2022.S3.164-173

[10] Zhao, Z.; Zheng, H.; Liu, Y.: The appearance design of agricultural product packaging art style under the intelligent computer aid, Computer-Aided Design and Applications, 19(S3), 2021, 164-173. https://doi.org/10.14733/cadaps.2022.S3.164-173