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The Fractal Artistic Design Based on Interactive Genetic Algorithm

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Abstract. The art work with personal aesthetic requirement and innovation has great influence on the aesthetic standard as well as business value. The fractal artistic design is the combination of mathematical technology and tradition art design. The combination of interactive genetic algorithm is a further exploration with more specific direction on the fractal image generation. During this automatic and parameter design process, the evaluation feedback from user has been involved in effectively, which is easier to design a image with the satisfaction of customer. The design process is more efficient and the design outcome is more targeted and personal. The application of interactive genetic algorithm could support the faster and better define on the requirement of user. The specific procedures of the application could be divided into generation of fractal images by genetic algorithm model, then calculate the consensus criteria by fitness function and satisfaction evaluation from user. The following paper focus on the principle theory and the mathematical procedure of the application of interactive genetic algorithm in fractal artistic design.

Keywords: Fractal Artistic Design, Interactive Genetic Algorithm, Fitness Function, Evaluation System.
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1 INTRODUCTION

The art is originated from life, while it could reflect the real requirement of life. Babbar-Sebens et al. Introduced that the artistic form is evolved from the traditional cave painting into various of form [1,2]. With the development of technology, the limitation of art form, content and presentation method become less and less, which means that artistic design plays a increasing significant role in contemporary society. Fractal method is a assistant tool of geometric study, which requires the basic mathematics knowledge. This mathematics method has great advantage in color calculation, gradient adjustment, layer application, function change and image rendering, which could be used in artistic image design, related results proposed by Cho et al. [3-5].

Fractal artistic design based on interactive genetic algorithm prove the possibility of the combination between the art and technology. Even though, the fractal image is the outcome of the function calculation, the artistic character such as order, symmetry, rhythm and random is correspond to the public aesthetic attitude, which is still attractive. The following paragraph will discuss the fundamental theory and specific procedure of the application of interactive genetic

algorithm in fractal artistic image design. The Interactive Genetic Algorithm (IGA) which is proposed by Lai et al. [6-7] in computer science is applied to the field of fractal art design to explore the application of genetic algorithm in fractal pattern generation. The process of human-computer interaction is added on the basis of genetic algorithm, so that the user's preference is better integrated into the genetic process.

By introducing more customer demand information into the algorithm, we have evolved fractal art works that are more user-friendly, or more "personalized." It provides strong support and help for better and faster planning of the user's design needs. Genetic Algorithms (GA) is a global random search algorithm is proposed by simulating Darwin's genetic selection, natural elimination and the evolutionary process of Mendelian genetics. Azadeh et al. Introduced that an interactive genetic algorithm that combines evolutionary concepts with logical ideas [8-10] is a novel genetic algorithm developed on the basis of basic genetic algorithms. It replaces traditional genetic algorithms with user-to-individual assessment through interactive means. The process is of automatically calculating the fitness function value. Interactive genetic algorithm is a combination of human-computer interaction and genetic algorithm. Its purpose is to combine human intelligence with computer technology to solve the inadequacies in genetic operation.

Nowadays, the application research of interactive genetic algorithm is very active, such as in the fields of graphic image processing, voice information processing, database retrieval [11, 12], however, due to the design (especially the creative design of the person The strong dependence of intelligence, how to combine human intelligence and computer application organically, is still an attractive research topic. During this automatic and parameter design process, the evaluation feedback from user has been involved in effectively, which is easier to design a image with the satisfaction of customer. The design process is more efficient and the design outcome is more targeted and personal. The application of interactive genetic algorithm could support the faster and better define on the requirement of user.The rest of this paper is organized as follows. Section 2 discusses the foundamental theory and principle, followed by the Genetic algorithm procedure for the fractal artistic design Section 3. Section 4 shows the application of interactive genetic algorithm in fractal color design, and Section 5 concludes the paper with summary and future research directions.

2 THE FOUNDAMENTAL THEORY AND PRINCIPLE

Genetic algorithm is a global random search algorithm proposed to simulate the genetic and natural selection of Darwin and Mendel's genetic theory about biological evolution process. Interactive Genetic Algorithm is a new genetic algorithm developed based on basic genetic algorithm that organically combining the evolutionary concept and logical thinking. The fractal artistic design has been widely used in mathematics, biology and environment science even some social studies and literature in the recent twenty years [13]. Because of its particular presentation form, the fractal art has been applied in the design industry as well. Only with few training, the designer could add aesthetic opinion in the function calculation to selection of outcome, then the unique art work with personal aesthetic opinion could be created.

2.1 Interactive Genetic Algorithm

The research on interactive genetic algorithm is began at 1986, and there are two research directions. One of topic is the generation of artistic image and music, and the other is after 1990s about the personal and emotional information handling. The interactive genetic algorithm is an automatic process of fitness function value calculation to replace the traditional genetic algorithm by individual evaluation of customers. It is a combination of human-computer interaction and genetic algorithm, which aims to combine human intelligence and computer technology to solve the deficiency of genetic operation [14]. Nowadays, the application of interactive genetic algorithm is very active in the fractal artistic design, such as image processing, voice information processing and database retrieval, etc. Nevertheless, due to the design, especially creative design, strongly

depends on a personal intelligence, the method that organic combination between the human intelligence and computer application is a very attractive research topic in the future.

2.2 Fractal Artistic Design

The composition of artistic image includes the structure of pattern and the composition of picture. In fractal artistic image, mainly focuses on the layout and organization form of the images. The common forms include the skeleton composition rules based on fractal patterns, integral structure of fractal image composition, and irregular patterns distribution composition. In artistic theory, the fractal images remain the traditional way of two-dimensional image composition, and make full use of advanced technology that computer has in pattern appearance modeling and color selection, to provide a new artistic form in the simulation of design concept and its implementation. In addition to the similar rules and regulations the ordinary artistic has, the most prominent character of fractal artistic image generation and the basic design principle is the capacity of self-similarity and the self-imitation. In the process of modeling or composition, the fractal artistic image would introduce the recursion or iteration, and the random disturbance of partly process. The basic techniques of the generation of fractal artistic design includes that firstly, composition of the pattern mainly adopts the function iteration and the repeated application algorithm based on geometric process - intersection point. Second adopted method of coloring technology combining the algorithm with the human-computer interaction concept [15]. In addition, image layout is based on the combination of traditional and fractal methods. There is no doubt that fractal artistic images are more innovative than traditional ones, while fractal artistic image itself is constantly innovating. There are countless number of functions, endless kinds of coloring schemes, and a infinite number of generation methods, which lead to the endless methods combination and creation, as a consequence the fractal art world is infinite.

3 3.GENETIC ALGORITHM PROCEDURE FOR THE FRACTAL ARTISTIC DESIGN

3.1 Chromosome Coding

The iterative function of the fractal artistic image could be regarded as the individual in the genetic algorithm population, which is the principle of the iterative function coding process. Due to the great flexibility of the mathematical expression application about binary tree structure, the solution of the problem is expressed as a binary tree by using the structural encoding method and each tree is a single chromosome. A binary tree represented by mathematics is a finite set of nodes composed of mathematical operands and mathematical operators. This method of encoding conventions that the operation of the expression is in the terminal node of the binary tree. The operand can be a variable or a constant, and the operator is located in the middle node of the binary tree. The order traversal sequence of binary tree is a valid mathematical expression.

3.2 The establishment of Fitness Function

The evaluation about the degree of genetic evolution chromosome is based on the fitness of genetic function in the genetic manipulation. Therefore, the comment from users such as ‘satisfaction’ and ‘consensus’ are used to measure the quality of the genetic chromosome. The group co-evaluation model has been adopted in fitness function. There are three categories ‘satisfaction’, ‘general’ and ‘dissatisfaction’ has been adopted to evaluate the preference of user, where the ‘satisfaction’ corresponding to the 3 points of user, ‘general’ corresponding to 2 points, while ‘dissatisfaction’ is 1 point. The final satisfaction scores of user could be calculated by adding the score of each user. If there is n users were involved in the scoring, the interval of satisfaction score was [0, n]. If the satisfaction score is the same, the fitness function can be determined by calculating the consensus criteria. For example, in the following table, although the satisfaction score of both design work and design image one are 13, the design image two has no "dissatisfaction" comment, which means the the consensus criteria of evaluation is higher that design image one. Therefore, the Image two is more popular by audience. Differently, the total

score of image three and image four are same, and the distribution of the score from different audience are same as well, which means the consensus criteria are same. When there is no difference between the total score and consensus criteria, the evaluation from audience could not become the standard of selection. In that the situation, the evaluation process should be more personal with the unique aesthetic attitude from artist. That is a purely step of art without the involvement of mathematics. The Scope Situation about the Comment of Design Work is shown in table 1.

Fractal Artistic Design Image	Scope of Individual User	Final Satisfaction Scores
Image One	1; 3; 2; 2; 3; 2	13
Image Two	2; 2; 2; 2; 3; 2	13
Image Three	1; 1; 3; 2; 1; 2	10
Image Four	2; 1; 2 ;3; 1; 1	10
Image Five	1; 2; 1; 1; 1; 3	9

Table1: The Scope Situation about The Comment of Design Work.

If the series of the user satisfaction score $\{V_i\}(i=1,2,...n)$, and $V_{\max}=\{V_j;V_j\geq V_i,i=1,2,...,n\}$, $V_{\min}=\{V_k;V_k\leq V_i,i=1,2,...,n\}$, then the value of Vi after $[0,1]$ standard could be presented as following:

$$S(V_i)=(V_i-V_{\min})/(V_{\max}-V_{\min}) \tag{1}$$

Then the consensus criteria T calculated by the standard deviation method could be presented as following formula:

$$T=1-\frac{\sqrt{\sum_{i=1}^{n}(v_i-\bar{v})^2}}{n} \tag{2}$$

The satisfaction of user could be presented in the following formula:

$$\bar{S}(V_i)=\sum_{i=1}^{n}\frac{S(V_i)}{n} \tag{3}$$

in where, the $\bar{V}$ is the average value of comment score from all users; i and n are positive integer, and 1≤i≤n. If the proportion of consensus criteria T and satisfaction $\bar{S}(V_i)$ are u and v(u+v=1) respectively, then the consensus criteria of fitness function could be calculated by following formula:

$$F=u\bar{S}(V_i)+vT \tag{4}$$

In traditional genetic algorithms, the fitness value F is determined by the fitness function. However, since the subjective evaluation of each user is different, there could be no objective fitness function, so the fitness value should be reflected by the user scoring (Qian et al, 2001). This kind of 'satisfaction' and 'consensus' from users score to express the satisfaction is the full embodiment of the interactive thought.

4 THE APPLICATION OF INTERACTIVE GENETIC ALGORITHM IN FRACTAL COLOR DESIGN

At present, fractal artistic design theory is developing extremely rapidly with improvement of interactive genetic algorithm, which has become an independent research direction. By combining

fractal theory with computer graphics, a large number of beautiful fractal images can be generated by simple iterative formula. In particular, the drawing of complex mapping on complex power system can produce strange fractal images that are very applicable to assist the artistic design. During the designing of fractal image, the color selection directly influences the quality of fractal image. Generally, the computer graphics design is mainly choose the RGB color model to represent the pixel, but compared with the IHS color model, the latter one is more suitable for human eyes due to the better consistency with human color vision. A large number of experiments show that the use of HIS color model could capture the satisfactory fractal shape. Therefore, the following paragraph attempts to demonstrate the application of interactive genetic algorithm in fractal artistic design, especially in the transforming from RGB into IHS color model.

4.1 The Specific Procedure of Genetic Algorithm

HIS color model is commonly used in color perception with the foundation of visual character of human eyes that using three relatively independent and predictable color psychological properties to represent color. H (tone) is the characteristic of red, yellow, green and other colors. Different wavelengths determine different hues, which are measured in angles of 0~ 2. I (brightness) is the characteristic of the surface of the object that is relatively bright and dark, which is proportional to the energy of the light wave, and the sense of the human eye is the brightness of the color light that is not related to the color. S (saturation), also known as chrome, refers to the depth of the color or shading degree, it indicates that the color of light in the pure spectrum wavelength diluted by white light, the more general white composition, the lower the saturation.

Firstly, the generation and selection of initial population have a great influence on the efficiency of genetic algorithm. In this case, the initial population is generated by random methods of computer. The computer randomly generated six of HIS combinations as the initial color of the fractal graph, and then the different shapes were generated according to the same iteration formula of the fractal graph. In the specific application, the user could choose the image and combining with the random generation from the database to generate the initial population. Secondly, for genetic code, the values of HIS components are defined respectively, the values of S and I is [0,1], and the values of H are in [0,2]. All those three values are real numbers, and all the number in coding process should be real number. Thirdly, the fitness function is difficult to be given explicitly, because the value of the fractal graph is related to the user's preferences. In this case, the score given by user could define the value of fitness function, and then combined with the calculation of a fitness function, to calculate the value of the images. For routine design, a fitness function is determined by the objective function firstly, and then the new group could be selected according to the fitness function value. Generally, a product has multiple characteristics, because of the different design requirements from different application fields. If there are N characteristics that could be represented as s(i=1,2,…N) and g is the value of expectation, then the fitness function could be represented as following formula:

$$d = \sqrt{\sum_{i=1}^{n} a_i \left(s_i - g_i \right)^2} \tag{5}$$

in where the ai and si are average value to emphasis the importance of this characteristic. The minimal value d calculated by formula (5) is the data required for design.

The next step is the application of genetic operator adopt the method of combining elite selection strategy and sorting selection. The selection of adaptive values is selected by the elite selection strategy, and then the graphs are selected based on the adaptive values. The coding of the H, I, S of two fractal images are crossed linearly. If the G1 and G2 are father generation, and r is the random value between [0,1], then the filial generation could be represented as follows:

$$\begin{aligned} G_1 &= r \times \left(1 - r\right) \times G_2 \\ G_2 &= \left(1 - r\right) \times G_1 + r \times G_2 \end{aligned} \tag{6}$$

Finally, the condition of convergence is that when the use find out the satisfied fractal artistic image, the operation could be stopped.

However, the disadvantage of this evaluation system is the heavy work for the artificial score process. If there are thousands of fractal images generated by interactive genetic algorithm, the audience would spend a lot of time in scoring those image. This process is not effective and the audience would be very tired. The repeat of the aesthetic work might lead to unclear judgment. The feeling about the beautiful has great relevance with emotion. Only when the target user or audience are relaxed, those score could be effective. At the moment, there is no way to replace those heavy evaluation work by interactive genetic algorithm because the fundamental principle of the selection process is the evaluation system.

4.2 The Specific Procedure of Fractal Artistic Image Generation

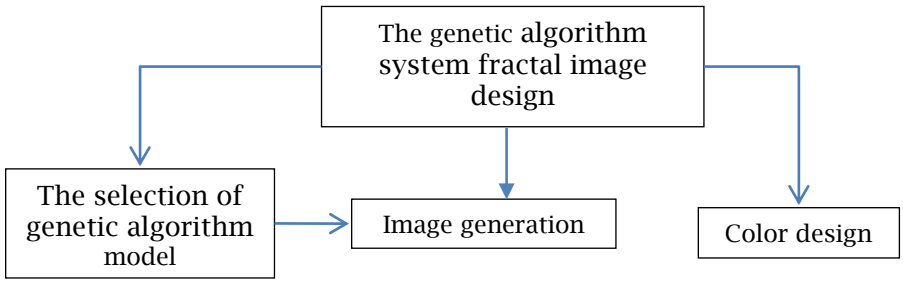

Figure 1: The Procedure Diagram of Fractal Artistic Image Generation Based on Interactive Genetic Algorithm.

The Procedure Diagram of Fractal Artistic Image Generation Based on Interactive Genetic Algorithm as shown in Figure 1. This system is composed by three different parts, the selection of genetic algorithm model, color design and image generation. Firstly, the RGB color model generated randomly could be regarded as the initial color. The theformula that transform the RGB color model into HIS could be expressed as following:

$$I = (R+G+B) \div 3 \tag{7}$$

$$S = 1 - \frac{3}{(R+G+B)}\left[\min(R,G,B)\right] \tag{8}$$

Where G≥B,H=θ when G<B,H=2Л; when G=B=R, H=(0~2Л), in where the

$$\theta = \arccos\left\{\frac{\left[(G-R)+(R-B)\div 2\right]}{\left[(R-G)^2+(R-B)(G-B)^{\frac{1}{2}}\right]}\right\} \tag{9}$$

After transform the RGB color model into HIS color model by the above formula, the value of H, I, S should be crossed.

The fractal artistic image could be generated by the changing into RGB color model from HIS color model. If the value of S and I is between [0,1], then the value of R, G, B is between [0,1] as well, when the value of H is between $\left[0, \frac{2\pi}{3}\right]$, then

$$\text{B=I(1-S);}\ R = I\left[1+\frac{S\cos\left(H-\frac{2\pi}{3}\right)}{\cos\left(\frac{\pi}{3}-H\right)}\right];\ B = 3I-(R+G) \tag{10}$$

where the value of H is between $\left[\frac{2\pi}{3},\frac{4\pi}{3}\right]$, then

$$\text{B=I(1-S);}\ R = I\left[1+\frac{S\cos\left(H-\frac{2\pi}{3}\right)}{\cos\left(\frac{\pi}{2}-H\right)}\right];\ B = 3I-(R+G) \tag{11}$$

where the value of H is between $\left[\frac{4\pi}{3},2\pi\right]$, then

$$\text{B=I(1-S);}\ R = I\left[1+\frac{S\cos\left(H-\frac{4\pi}{3}\right)}{\cos\left(\frac{5\pi}{3}-H\right)}\right];\ B = 3I-(R+G) \tag{12}$$

Based on the scarification system mentioned before, the images could be evaluated by the scores, the six images with the preference of user could be selected. If there is a image that corresponds to the artistic standard, then the genetic algorithm could be completed, if not, the crossing would be continue until there is a satisfied artistic image design. The Fractal Artistic Image Generated by Interactive Genetic Algorithm Technology as shown in Figure 2.

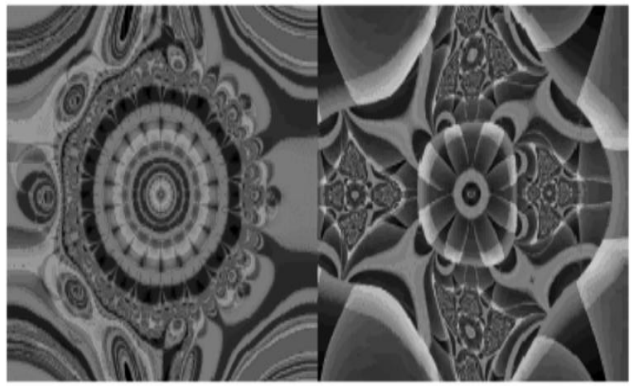

Figure 2: The Fractal Artistic Image Generated by Interactive Genetic Algorithm Technology.

4.3 Example Simulation

This section uses an example to illustrate the application of genetic algorithm in the fractal pattern generation method of LS grammar composition method. First, we construct the initial population using the "turtle map method" mathematical model in the LS grammar, and encode the rules using the encoding method of the variable length chromosome genetic algorithm.

For example, grammar A, grammar B, and grammar C are three individuals in the initial group constructed by us according to the single-rule LS grammar. Their generation rules are PA, PB and Pc. The generated fractal art pattern is shown in Figure 3, Figure 4, and Figure 5.

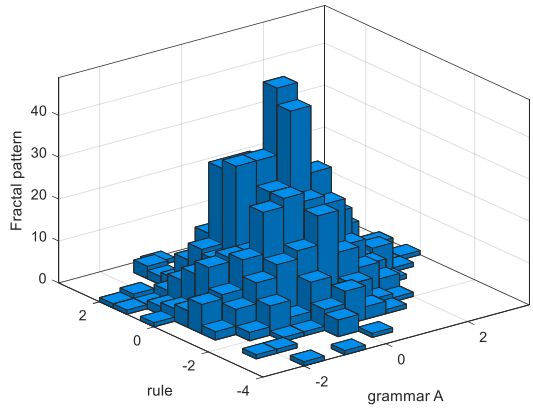

Figure 3: Fractal pattern generated by grammar A.

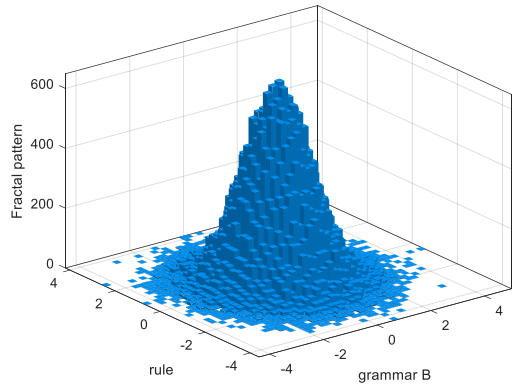

Figure 4: Fractal pattern generated by grammar B.

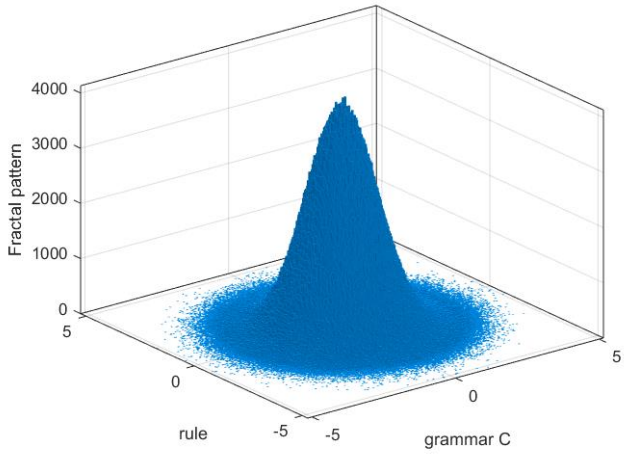

Figure 5: Fractal pattern generated by grammar C.

As shown in Figure 3, Figure 4, and Figure 5, a plurality of users score the fractal art patterns generated by the grammar A, the grammar B, and the grammar C. The fitness value of each fractal design pattern is calculated by the degree of compatibility and satisfaction. The chromosomes with excellent performance are selected, and the fitness values obtained by the user's scoring of the crossover probability and the mutation probability are adaptively adjusted according to Formula 8-12, thereby generating the next generation.

Crossing and mutating the selected chromosomes to generate individuals in the new population. It is worth noting that since the chromosome has a restricted grammatical structure from the LS grammar rule, it contains multiple characters and is a variable length chromosome. Therefore, when we perform cross-operation and mutation operations, the parts that produce changes must be guaranteed between a pair of "[" symbols and "]" symbols, that is, no parentheses are matched. For example, we cross-over the grammar A and grammar C generation rules Pa and Pc. This generates two new individuals, which we write as grammar D and grammar E. The fractal pattern generated according to the grammar D and the grammar E is as shown in Figure 6 and Figure 7.

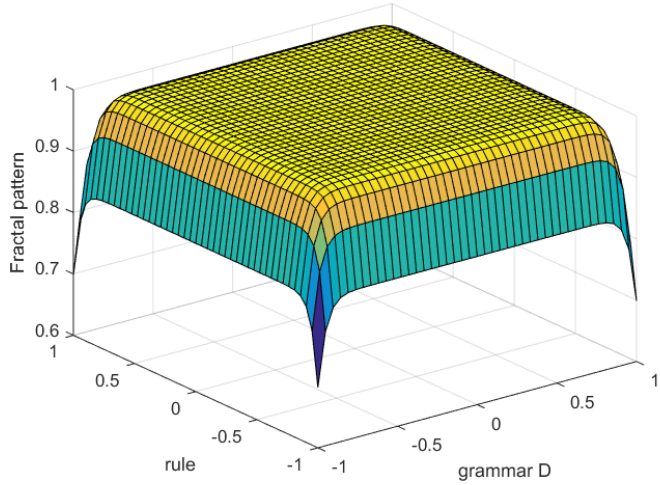

Figure 6: Fractal pattern generated by grammar D.

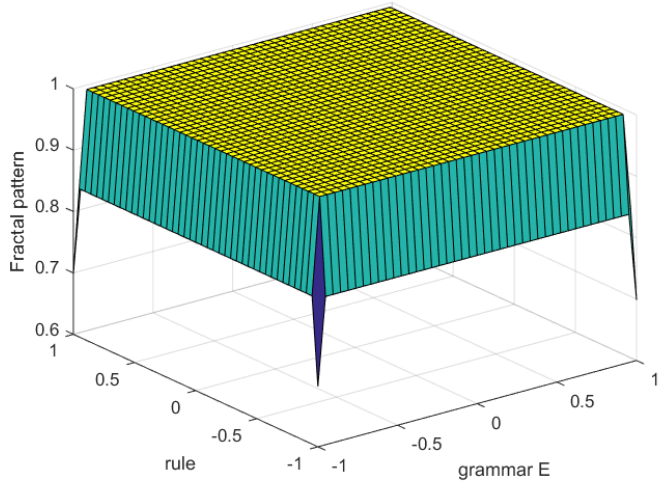

Figure 7: Fractal pattern generated by grammar E.

As shown in Figure 6 and Figure7, in the mutation operation, a single character in the rule may be subjected to a mutation operation or a corresponding mutation operation may be performed on the character string. However, it is also necessary to abide by the grammatical structure of the LS grammar rules. After the above steps, if the fractal art design that the user is satisfied is generated, the genetic operation is stopped, otherwise the return is continued. In this way, the fractal pattern that the user is interested in can be captured in time and accurately, and the design requirements are realized quickly and well.

5 CONCLUSIONS

The history of fractal design is merely twenty or thirty years that already been widely used in all kind of art design such as the appearance of building, product packaging even fashion design. Compared with the traditional design method, if fractal is different in both design tools and presentation approach. However, the combination between art and technology is a great and successful attempt to prove the artistic character of mathematics as well as a innovation of artistic design method and presentation. With the discussion and exploration in the above paragraph, the interactive genetic algorithm could be applied in fractal artistic design with the satisfaction evaluation system of users. The further improvement about fractal artistic design relies on the cooperation between artist and mathematician to explore the possibility of interactive genetic algorithm.

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