ISSN 2618-1568 Vol. 6, Issue 12: 34-43, DOI: 10.25236/FAR.2024.061206

Fractal art pattern generation based on genetic algorithm

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Abstract: *Each fractal graph is an image of a set of numeric sets with fractal characteristics, its layout and organization form are generated by the fractal algorithm corresponding to it. In order to increase the randomness and regularity of the fractal design of art patterns, this paper based on the actual demand of fractal design of art patterns, has proposed a fractal art pattern generation method based on the genetic algorithm. The simulation experiment shows that the method proposed in this paper can complete the fractal design of art pattern better, and the design results have high artistic value.*

Keywords: *Genetic algorithm; fractal art; artistic pattern generation; pattern fractal*

1. Introduction

In the traditional art design process, if designers have inspirations and ideas, they must use tools to transfer their design to reality, which requires human labor, so the quantity and quality maybe limited (Wannarumon et al., 2006)[1]. And many works cannot be produced at the same time, which is the shortcoming of the traditional method of creation. Now, because computers provide the technical level needed in the field of art creation, they can help designers develop their inspiration and make their inspiration come true in a shorter time (Wei et al., 2006)[2]. The so-called evolutionary design refers to the use of new evolutionary computing methods in the concept of computer design, which can be fully applied in the field of design. The first computer evolution program in the history "BlindWatchmaker" is mainly used to simulate trees. Later researchers put forward the theory of using genetic algorithms in the process of improvement and optimization of design, and explained the theoretical framework of the whole design. In the field of art innovation, computer aided evolutionary design has been used to open a new door to the evolutionary (Togelius et al., 2011)[3]. In addition, some people have applied computer simulation technology to more fields, such as desk lamps and sculptures in art works, so that the application scope of the technology is more extensive. There are also genetic algorithms used in the architectural plan of the building (Xu et al., 2005)[4]. With the development of mathematics and computer science, the artistic form of digital fractal works generated by Recursion and iteration of formula develops very fast, fractal art works have also been well applied in the fields of plane, video, film, animation, compression and so on. Fractal theory mainly discusses the law of complex events in nature, and the fractal theory has become a very important interdisciplinary subject (Pang et al., 2010)[5].

2. Material and Methods

2.1. Fractal art pattern and artistic rule

At present, a class of graphics or modeling uses fractal principles and is created by computer fractal software called fractal art (Mena et al., 2003)[6] . These works of fractal art have unique aesthetic values and many artistic features, showing many art laws, as shown in Table 1. A study of the artistic principles embodied in fractal graphics can help us to make better use of fractal theory to design and create pattern modeling, Fractal graphics almost reflect all the art laws mentioned here.

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Table 1: Artistic rule

principle	concrete content	application principle
Unity and variation	As far as graphics are concerned, in some cases, the simpler the unity is, the more beautiful it is. But while maintaining unity, there cannot be any change. Only unity and no change, it is dull and monotonous, which cannot make people feel interested, and the beauty cannot last. But changes should also be regular and irregular changes will lead to confusion and miscellaneous. Therefore, the change must be carried out and produced in the unity.	From the basic properties of fractal geometry, we can know that fractal graphics not only have holistic similar self-similarity after local enlargement, but also maintain consistency between the local and the whole. Fractal graphics also have the characteristic of "very irregular", which is characterized by fine structure and infinite iterative transformation in graphics, which reflects changes. Therefore, fractal graphics perfectly follow the art rule of unity and change.
symmetry and equilibrium	For art design, symmetry and equilibrium means beauty and coordination, and it is also a very important art law in art design. Symmetry generally means that if one operation can transform the system from one state to another equivalent (undistinguishable) state, that is, the system's state is kept unchanged in this operation, and the system is symmetrical to this operation.	From the aesthetic point of view, equilibrium refers to the balance of the equal amount but unequal shape in the layout, and is to seek stability in the asymmetry. Equilibrium and symmetry are two aspects of mutual connection, and symmetry can produce a sense of equilibrium, and equilibrium also includes a symmetric stability factor. The beauty of fractal graphics is that almost every fractal image can find the stable and harmonious sense of beauty that is symmetrical and balanced, and this stability and harmony often contain changes, rather than stereotyped, dull and boring.
rhymes and Rhythms	Rhythm and rhythm are regular movements or changes, in pattern design; it can be expressed in the different degree of change and the ingenious combination of line length, thickness, color, position, to create a variety of "dynamic". Fractal graphics often have extremely fine structure and very irregular appearance.	Generation of fractal graphics that is a process of forming rhythm and rhythm by carry on the varying degrees of change and combination about the length, size, position, color of the basic graphic element. The realization of this process depends on the designer's understanding and control of the function parameters and the aesthetic qualities that they have. Excellent fractal graphic design must have wonderful rhythms and rhythms.
proportion and scale	In aesthetics, the relationship between proportion and scale is the degree of adaptation between objects and humans, when things have a reasonable s proportion and scale; they have the characteristics of harmony with human physiological feelings and environment where they are used.	For fractal graphics, the proportional feature is determined by the corresponding function relation and its parameters,when the function relation and its parameters are determined, the proportions between the constituent elements in the corresponding fractal graphics are also determined. Therefore, by using the relationship between the function and its graphics, the pattern modeling with appropriate proportions can be designed by adjusting the parameters.

2.2. Algorithmic element structural rule of art pattern fractal

(1) The rule of random element structure. In the process of scientific research, the structural rules of random elements are very important factors. We can often get many unexpected results by the use of random elements (Ming et al., 2016)[7]. For the study of natural plants, we use the IFS and L- system simulation and understand the effects of natural factors on plant growth. For plant growth, it cannot grow according to a certain rule, that is to say, it is necessary to introduce random factors to some extent.

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Pattern represents the pattern of fractal expansion; Method represents the original fractal algorithm, and Element represents random factors. The following formula represents the composition of random rules.

Pattern=Rand (Method, Element)

For IFS, it itself contains a random factor, that is, the probability P, and every iteration requires a calculation of the probability, through the obtained probability range, the final pattern can be obtained by the affine transformation and several iterations. The next expression represents the process:

Pattern=Rand (IFS, P)

In L- system, random control can also be carried out, and the effect of random Koch curve of Figure 1 can be obtained through random change of deflection angleδ, it is drawn by L- system.

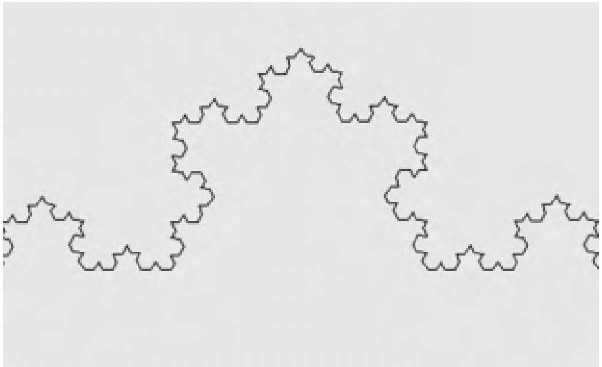

Figure 1: Random Koch curve

Figure 2: Boolean design collection

The process can be expressed in the following form:

Pattern=Rand (LSystem,δ)

For standard pattern, it has a fixed appearance, but because of random factors, it has diversity, which can fully show the charm of random factors.

(2) The rules of the structure of the Boolean element. The two set of parameters of the Boolean element structure rule are named SetA and SetB, and the collection operation is named Oper. Since SetA and SetB correspond to two different fractal patterns, this paper calls it SetA and SetB. The next formula is the composition formula for the rules of the Boolean element structure:

Pattern=Bool (SetA, SetB, Oper)

The corresponding parameter set of A is SetA, and the corresponding parameter set of B is SetB, in this way C can be expressed by the formula Patternc=Bool (SetA, SetB,), D can be expressed by the formula Patternd=Bool (SetA, SetB,). In the same way, we can solve the difference set between SetA and

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SetB. In Figure 2, A corresponds to Pattern=Bool (SetA, SetB, -), B corresponds to Pattern=Bool (SetB, SetA, -).

2.3. Art pattern fractal of structure rule of layout element

(1) The structure rules of symmetric elements. For a long time, people's aesthetic appreciation of nature has been examined through "symmetry" and created many kinds of artworks, which are related to "symmetry", such as buildings, costumes and sculptures. In this paper, axisymmetric is the focus of introduction, and the next formula is given to express the composition formula of the structural rules of axisymmetric elements.

Pattern=AxialSym(SetA,Axis)

In the upper form, SetA represents the set of parameters, the fractal pattern can be obtained, and the Axis is a symmetric axis. The center of screen is taken as the origin, the X axis is horizontal, and the Y axis is vertical. In this way, the coordinate system is constructed, and the direction of the upward and the right is set as the positive direction of the coordinate axis, as shown in Figure 3. Of course, the symmetry rules can be recursive, and the following form will appear.

Pattern=AxialSym(AxialSym(SetA,y=ax+b),y=cx+d)

Figure 4 is a symmetric pattern, which is a symmetrical figure of the X and Y axis, and then the next formula can be obtained.

Pattern=AxialSym (AxialSym(SetA,y=0),x=0)

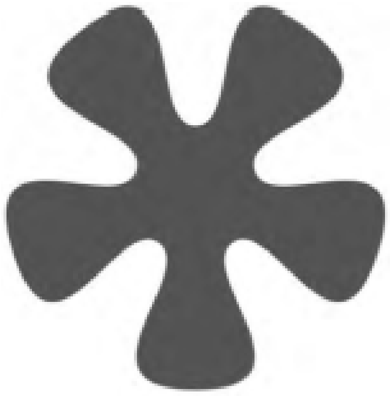

Figure 3: Simple axisymmetric design

Figure 4: Four symmetric mode

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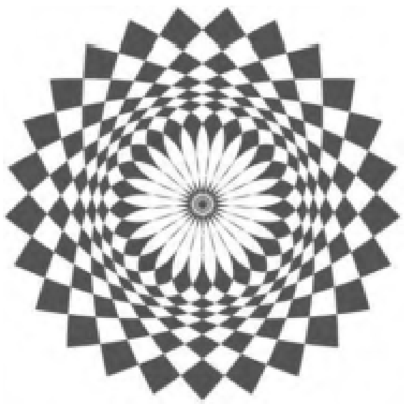

Figure 5: Extended crack mode

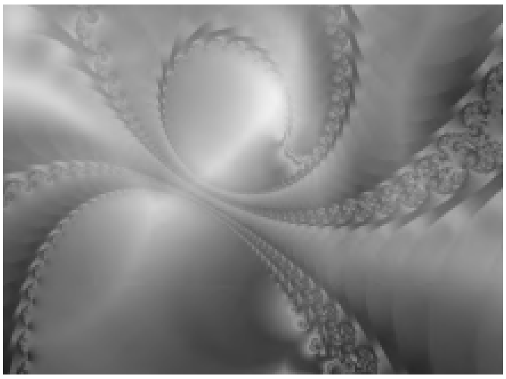

Figure 6: Color Fusion Rule Element Structure Design

(2) The structure rule of the shape element. According to the boundary constraint, the fractal pattern can be controlled and make the pattern be displayed only to some of the patterns. Shape control is also limited by the region, allowing fractal patterns to be displayed in a daily form. To set such a rule, we can make full use of the fractal pattern to make the decorative design be better used. The next Formula represents the structural rules of a shape element:

Pattern=Form(SetA,Shapes)

Form stands for shape rules, and Shapes represents a specific shape type that can be seen in Figure 5. The pattern in Figure 5 is only part of it, and we can also set shapes to build different shapes to expand the fractal pattern according to our preference.

(3) Structural rules of color fusion elements. Similar to the structure rules of Boolean elements, the structure rules of color fusion elements pay more attention to the difference of color, while the structural rules of Boolean elements pay more attention to the appearance. For color fusion element structure rules, we also need two pattern parameter sets SetA and SetB, assuming that SetA indicates the color of point (x, y) is ColourA, SetB indicates that the color of point (x, y) is ColourB, then the final color of the point (x, y) is a linear combination of ColourA and ColourB, which can be seen in Figure 6. FuseStyle represents a linear combination, and the next represents the structure rule composition formula of the color fusion element:

Pattern=Fuse(SetA,SetB,FuseStyle).

3. Results

3.1. Genetic operator optimization

(1)Cross mutation operator optimization based on dynamic adjustment. Genetic algorithm is a way to explore the excellent group step by step, this approach is achieved by constantly changing the composition of the original population to create a new population, the speed of the formation of the new species will have a certain effect on the convergence, the main variables related to it are the probability

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Pc of the crossover and the probability Pm of the mutation. If Pm is too small, the speed of exploration will be slow, if Pm is too big, then a new individual will be formed very quickly, but at the same time, it may be that individuals with better quality were destroyed. If there's too small Pm value, the speed of producing individual is relatively slow; if Pm is too big, the algorithm will evolve into an ordinary algorithm for random search. The Pc and Pm in the algorithm have been set ahead of time, this does not make the searched value an optimal value, and it will lead to the early completion of the whole algorithm.

In this article, we find a way to automatically get Pc and Pm values to solve the above problems, and the basic idea of this solution is to automatically adjust the values of the two indicators in the process of computing, depending on the dynamics and characteristics of the population. The cross probability and mutation probability in this article need to be automatically adjusted according to the following two formulas, the cross probability and mutation probability in this article need to be automatically adjusted according to the following two formulas

$$P_c = \begin{cases} P_{c1} - \dfrac{P_{c1} - P_{c2}}{f_{\max} - f_{avg}}(f' - f_{avg}), f' \geq f_{avg} \\ P_{c1} \qquad\qquad\qquad\qquad f' < f_{avg} \end{cases}$$

$$P_m = \begin{cases} P_{m1} - \dfrac{P_{m1} - P_{m2}}{f_{\max} - f_{avg}}(f_{\max} - f), f \geq f_{avg} \\ P_{m1} \qquad\qquad\qquad\qquad f < f_{avg} \end{cases}$$

In the upper formula, the meaning of f 'is that: in the process of intersect, use degree value reaches the maximum; the meaning of fmax is that: the maximum fitness in a group; the meaning of favg is that: average fitness for each generation of groups; the meaning of f is that: the use degree of a variant of the individual. We can see from the above two equations, if the value of the fitness is not concentrated during the process of optimization, Pc and Pm in the formula will shrink values themselves; If the value of the fitness is more concentrated during the optimization process, then the two values will increase automatically, the quality of the group can be improved by this method. If the value favg is larger than the adaptive value of any individual, and then there's the value of Pc and Pm get bigger with it; or it will be smaller, this method allows individuals in the older generation to continue into the new population.

(2) Selection operator optimization based on individual fitness assignment. The selection operator of the genetic algorithm is based on the fitness of the artificial evaluation, and the fitness of an excellent individual is the same, this paper uses the optimal individual preservation method and the class simulated annealing method to realize the selection operator of the genetic algorithm. This method ensures that the coding of each generation of the optimal individual in the population will not be destroyed, guaranteed the convergence of the algorithm. The class simulated annealing method is to establish a dynamic database includes all the optimal individuals, and its selection probability is dynamic with the increase of algebra. Because artificial selection is noisy, making the selection probability for each k generation be same, so its probability presents a step change, the formula for calculating the probability function is as follows:

$$F(x) = \frac{(x^4 + 1 - \cos(x\frac{\pi}{2}))}{2}$$

Set the current algebra as t (starting counting from the 0 generation), so the probability of the use of the optimal individual for i generation is:

$$F_s = F(a) - F(b)$$

Among which,

$$a = ([\frac{t-1}{k}] - [\frac{t-i}{k}] + 1) / ([\frac{t-1}{k}] + 1)$$

$$b = ([\frac{t-1}{k}] - [\frac{t-i}{k}] + 1) / ([\frac{t-1}{k}] + 1)$$

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3.2. Clustering optimization of illustration based on K-GA

This paper is based on K-medoids algorithm, improving GA algorithm, by random selection of data, the algorithm can choose to represent the specific category, this method can find a certain number of cluster centers in the data of multiple clusters, and then other objects can be divided into the corresponding categories according to the distance between the centers. In the cost function, you can see the distance difference between the data and the cluster center, so as to judge the quality of the cluster quality. Through the following four different situations, the difference between the non-cluster centers t can be found. It can be seen from Figure 7 that the process of clustering algorithm. The variance E in the cost function will change because of the reclassification of the data. If the cost function of the output is not suitable, then we need to change the way of clustering. By comparing the size of the value to the zero, if it is less than zero, then it means that this change is meaningful, or the center of the original clustering is the right center, and there is no need to change.

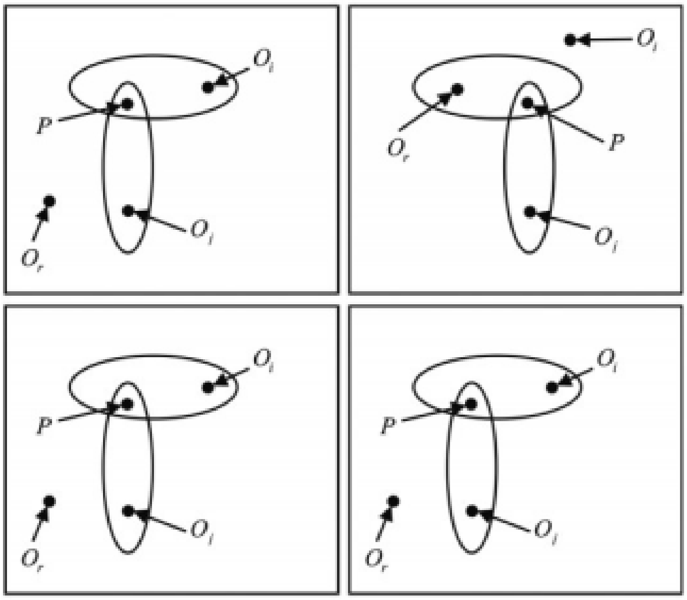

Figure 7: Schematic diagram of clustering algorithm

The formula of cost function:

$$\Delta E = E2 - E1$$

In the formula of the cost function, the symbol E1 represents the sum of the mean square variance of the unknown cluster center and the original data; the symbol E2 represents the sum of variance of the central data. So the specific operation of the model is as follows: A. obtained characteristic matrix:

$$\begin{pmatrix} a_{11} & a_{12} & \cdots & a_{18} & a_{19} \\ \cdots & \cdots & & \cdots & \cdots \\ a_{k1} & a_{k2} & \cdots & a_{k8} & a_{k9} \end{pmatrix}$$

B. The population matrix can be obtained by using the random function, the center of clustering is an element, and the element of an individual is a line. C. formulating the fitness functions as shown in the following formula:

$$E = \sum_{i=1}^{k} \sum_{p=C_i} |p - m_i|^2$$

In the upper formula, E represents all the data and the sum of the mean square variance between the corresponding cluster centers, the letter P represents one of the points in one of the categories, and the symbol Mi represents the average of the clustering. D. using roulette to realize the selection operator:

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$$p(a_j) = \frac{f(a_j)}{\sum_{i=1}^{k} f(a_i)}$$

In the upper formula, the symbol f (ai) means the probability of being selected for I individual, the meaning of a symbol f (aj) is the function value of the fitness of j individual, the letter n represents the number of individuals contained. E. Calculating the size of the individual population to the next population; F. Using the K-medoids algorithm to optimize the individual; G. Achieving Pc and Pm.

4. Discussions

To verify the feasibility of the algorithm, Using single peak function and multi peak function to test the standard genetic algorithm GA and optimal algorithm K-GA proposed by this text. The single peak function is as follows:

$$\min f_1(x,y) = 100 \bullet (y - x^2)^2 + (x-1)^2$$

The multi peak function is as follows:

$$\max f_2(x,y) = 21.5 + x\sin(4\pi x) + y\sin(20\pi y)$$

The results of the average running algebra tested by the standard genetic algorithm GA and optimal algorithm K-GA proposed by this text are for these two functions are like table 2. As you can see from table 2, for 2 functions, when taking the cross probability as 1, for any test function, average running algebra is the least, and the average running algebra decreases with the increase of the cross probability. Therefore, the bigger the cross probability is, the possibility of producing excellent individuals is also increasing, which improved the performance of the genetic algorithm.

Table 2: Simulation result function of test function algorithm

Function method		f1		F2	
		GA	K-GA	GA	K-GA
Cross probability	1	56.28	7.32	12.67	4.71
	0.9	57.03	7.84	13.61	5.38
	0.8	60.05	8.09	13.88	6.37
	0.7	61.44	8.67	15.58	6.94
	0.6	62.49	9.52	19.71	7.54
	0.5	63.58	10.49	20.85	8.06

To verify the improved model proposed in this paper, the following simulation experiments are put forward. Any rule is set to be independent and unable to form a specific fractal expansion pattern. By combining the rules of the algorithmic element structure, the structure rules of the colored elements and the structure rules of the layout element, the following formula can be obtained, expressing the combination of this rule:

Pattern=ComRule(AR,LR,CR)

In the upper formula, using ComRule to represent rule combination; using CR to represent the set of structural rules of the colored elements; using AR to represent the set of rules of the algorithm element structure; using LR to represent the set of rules for layout elements. By using the various combinations described above, we can do fractal design for artistic design, and the results show good artistic value and effect through Figures 8 and 9.

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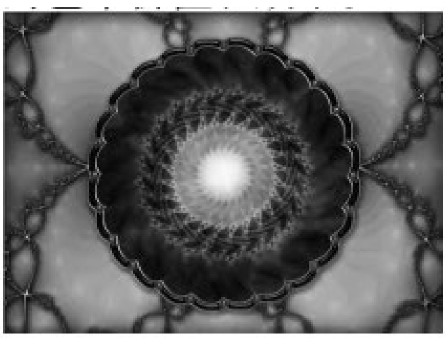

Figure 8: Fractal design example 1 art design

Figure 9: Fractal design example 2 art design

5. Conclusion

The fractal graphics generated based on the classical fractal set almost reflect all the art rules, it seems to be innate and artistic. There is mathematics in the place where there is beauty, the relationship between number and quantity is the basic attribute of all things and the foundation of forming beauty. In this paper, the generation of fractal art patterns based on genetic algorithms is analyzed and studied. On the basis of the existing algorithm rules, adding the rules of random elements and the rules of the structure of the Boolean elements to change the drawing effect, finally we get a large number of patterns different from the traditional ones, then aiming at the layout structure, putting forward the rules of the structure of symmetric elements and the rules of the structure of the shape elements, and putting forward the structural rules of color fusion elements, finally, the combination of the above rules is applied to the fractal design of artistic patterns.

Acknowledgement

This content is the research achievement of the Sichuan Media College Ministry of Education Industry-University Cooperation Collaborative and Human Project - "Internet" Perspective under the University Art Design Teaching Reform Platform (22107149081638).

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