Parametric design experiment of cultural and creative patterns based on "Grasshopper" plug-in

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ABSTRACT

The experiment is based on plug-in construction design and pattern adaptation design,explore the design methods and processes of cultural and creative patterns with preliminary intelligence. The experimental team designed a plug-in based on Grasshopper by programming, using Grasshopper as the running platform and the Bird-and-Insect as the theme, controlling and automatically generating basic patterns with parameter values.The purpose of the experiment is to reduce the repetitive and heavy workload of pattern designers, and improve the cultural attributes of patterns through digitization and personalization.This experiment has proved the feasibility of using parametric technology to pattern the cultural creation of Bird-and-Insect, and has been verified by the design and application of related cultural creation products.

Keywords: Parametric Design, Grasshopper, Patterns Design, Cultural, Experiment

1. INTRODUCTION

The organic integration of science and art contributes to the design presentation of cultural and creative theme products, which is an interesting topic in the field of art design.Parametric design has many characteristics and advantages different from the traditional design process. Its bottom-up design method allows the output scheme to be tried and error for many times, and the visual modeling method and results are adjustable, which makes the parametric design method more flexible in design activities and makes more changes.Relevant principles from domains of science and philosophy, mathematics and computer science have introduced new ways of thinking and morphogenetic processes[1]. The consumption of cultural and creative products has become a current boom, but serious homogenization has constrained market demand. The limited research budget of the cultural and creative industry makes it difficult to invest in the creation of patterns on related themes. The popularization of parametric technology provides new design ideas and imagination space for pattern design[2]. Drawing on the successful application of Rhino and Grasshopper in architectural design, can parametric technology provide impetus for the development of pattern design? Can the contingency, order, and life-like features of parametric design form become the new vitality of cultural and creative patterns?

The “Pattern” means “a decorative pattern or graphic with a neat and well-proportioned structure.”[3] As an important visual element of cultural and creative products, the innovation and application of patterns can solve the problem of single and homogeneous current cultural and creative products from the source. Serious problems, thereby improving the artistry, personalization and diversification of related products. As an important visual element of cultural and creative products, the innovation and application of patterns can solve the current problem of single type and serious homogenization of cultural and creative products from the source, thus improving the artistry, personalization and diversification of related products. National traditional patterns are important design resources. The originality, aesthetics, and culture of national patterns embody regional characteristics and historical latitude and longitude and carry the philosophical views of the Chinese nation in all dynasties [4]. Therefore, the practice of patterns on specific themes such as “Bird-and-Insect Script” is an important means of marking the cultural identity of cultural and creative products, and it is also the result of the inheritance and development of intangible cultural heritage.

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The advantages of the parametric design method can be used in the design of cultural and creative patterns to achieve the effect that one tool outputs multiple schemes, thereby changing the limitation that each drawing needs to be designed separately in the traditional plane pattern design, and greatly increasing the design efficiency.Pattern decomposition and remodeling [5], positive and negative shapes [6], modeling factor extraction [7], and simple element extraction and abstraction [8] are common creation methods of cultural and creative patterns. On the one hand, parametric technology can partially realize intelligent pattern design and improve work efficiency [9]. On the other hand, by giving technical aesthetics and meaning connotations, the specificity (theme) of pattern information is enhanced, which has important application value for the design and development of cultural and creative products. How to expand the visual boundary of creative patterns in the context of parametric technology? How does the basic logic of design work change? These problems are both difficulties and opportunities. By solving these problems, the ecological chain of creativity, design, production, and sales of cultural and creative products can be smoother. Some design cases have made beneficial attempts to integrate digital technology into visual design. Some use 3D and AR technology to create products [10], and some use artificial intelligence technology for pattern cultural and creative product design [11], and some involve artificial intelligence technology in the design of Chinese characters [12]. However, there are few experiments in the design of cultural and creative patterns based on digital technology, and it is still unable to stimulate the attention and thinking of the cultural and creative design industry. The continuous growth of traditional patterns requires intervention in life. This parametric experiment shows new possibilities for expanding the innovative paths and application scenarios of traditional patterns.

2. RESEARCH BASIS

The traditional pattern design method requires designers to invest a lot of time and energy, which is inefficient. The parametric design follows the established operation logic, iterating, deriving, and fractalizing the initial shape through mathematical and logical relationships, and setting and adjusting parameters to explore the optimal effect of the pattern[13]. In parametric systems, differentiation is unique as a design strategy[14]. In the design process, the vector parameters can be controlled to perform reversible operations for any link, so as to quickly meet people's individual needs and create more possibilities for artistic design while improving work efficiency [15]. The problem-centered logic algorithm is the core of the parametric design. Efficient, personalized, and diversified pattern design is achieved through scripting or matching algorithms. The common operational forms of parametric patterns are continuous lines, lattice sets, polygonal meshes, etc. These algorithmic logics enhance the mathematical rationality and beauty of order, systematicness and structure, as well as vitality and rhythm of the pattern. These algorithmic logics enhance the mathematical and orderly beauty, systematic and structural beauty, and vital and rhythmic beauty of the patterns.

2.1 Mathematical rationality and order beauty

The word "Mathematics" comes from the Book of Changes. "Number" is an important concept in ancient Chinese philosophy, and it has evolved into the "art" of studying mathematical laws, that is, "numeracy". It is not only a superficial understanding of the "art" itself, but also contains philosophical thinking about the laws of change of things. The "Book of Changes" thought that everything in the world has a number. The French poet Charles Baudelaire believed that all that is noble and beautiful is the result of reason and calculation. All that is noble and beautiful, according to the French poet Charles Baudelaire, is the result of reason and calculation.Mathematical laws and the artistic sense of form are inseparable like two sides of a coin. The variable relationship caused by parameter control will inevitably form the changing law of the mathematical model, which is expressed as a pattern style with an orderly beauty [16].
Algorithmic rules can control formal aesthetics. The aesthetic intrinsic of mathematical graphics may be, as Mandelbrot put it, due to "we see the interaction between order and sudden change [17]. According to Mandelbrot, the aesthetic intrinsic of mathematical graphics may be due to "we seeing the interaction between order and sudden change"Connecting the diagonals of the golden rectangle not only forms an elegant spiral shape, but also generates a Fibonacci recursive sequence formula (Fn+2=Fn+1+Fn, F1=F2=1), which constitutes the beauty of graphic order. The beauty of order, as a basic formal law, satisfies the audience's psychological needs for "beauty". "Orderly beauty, as one of the laws of formal beauty in artistic creation, is constantly discovered and refined in life and nature [18]." The golden ratio brings the harmony and unity of patterns, and the Fibonacci sequence allows us to see that patterns are always in an ordered and balanced visual state. These characteristics are used in this experiment.

The combination of changes in tetragonal continuous and bidirectional continuous patterns is more efficient in the application of parametric patterns. By adjusting the color, size, bones, and other pattern structural elements by parameters, the deconstruction and reconstruction of the pattern can be completed quickly, which greatly improves the application possibility of complex patterns. “Beauty lies in numbers and harmony, and the beauty of fractal graphics is the mystery of mathematics [19].”For designers, this is not only an innovation in technical means, but also an innovation in thinking.

2.2 Systematic and structural beauty

Compared with traditional patterns, systematic parametric patterns have more novelty and vitality. The integrity of the parametric pattern is based on the dynamic interpretation of the individual elements. The parametric operational logic relationship generates pattern prototypes, which are reproduced and combined with pattern bones. These prototypes will become an aesthetic whole. The patterns generated under the systematic operational logic rules of the parametric patterns show the consistency of visual style and have the ability to update quickly. Each adjustment of parameters under the same logical framework can randomly generate pattern prototypes with different forms and internal connections. Such flexibility cannot be achieved by traditional pattern design methods. The modularization of the parametric operational logic strengthens the systematicity of the pattern, that is, by changing or duplicating the modular units, the resulting unit terms generate systematic patterns [20]. In a constant system, due to the different arrangement and change of the modulus units, a rich combination of forms is produced, and the resulting information connotation develops to multi-dimensional with the increase of the level of the modulus change [21]. A rich combination of forms is produced in a constant system due to the different arrangement and change of the modulus units, and the resulting information connotation develops to multi-dimensionality as the level of the modulus change increases

The superimposed application of parametric variables and generation rules makes the pattern structure present a unique visual beauty, and the parametric topology structure brings the pattern a unique form and rational beauty. By depicting the method of expressing the relationship between “point” and “line” in the form of a graph [22], the connection between points and lines is strengthened, and these modeling relationships have constructive value in exploring the spatial morphological representation of patterns.

2.3 Vitality and dynamic beauty

The parameters endow the pattern with a personalized growth trajectory, and the visual presentation of the parameterized pattern generated by the algorithm is a changeable evolution process. Small changes in algorithmic logic can be reflected in the pattern shape, and the pattern evolves into a complex pattern that spreads with neuron patterns as a trajectory, with the beauty of contingent life dynamics. The parametric pattern thus forms a set of “growth systems”. Constantly mutating into new styles.

Different from traditional patterns, the topological and abstract nature of parametric patterns makes them have multi-dimensional derivative forms, that is, morphological styles in different dimensions of patterns are obtained based on parameter changes and logical organization [23]. Vital signs determine the dynamic beauty of parametric patterns. Ramazo proposed: “The most beautiful and most vital part of the work is that it can express movement. ” Patterns with dynamic aesthetics can attract people's attention and stimulate visual perception. This is because the dynamic form is more likely to arouse the excitability of the human cerebral cortex, mobilize the sensory response, and cause a pleasant physiological-psychological resonance. Parametric patterns are based on the beauty of life dynamics based on mathematical regularity and are destined to have stronger visual communication value.

3. METHOD CONSTRUCTION OF CULTURAL AND CREATIVE PATTERN DESIGN

This experiment uses Rhino and Grasshopper as the operating platforms, and builds the design experiment platform through plug-ins. The purpose is to explore the Bird-and-Insect Script conformal pattern design method with preliminary intelligence. The algorithm logic is divided into two parts: first, to construct the logical framework of the pattern generation form of Bird-and-Insect Script; second, to conform the pattern on the basis of the generated pattern; and finally, tpcomplete the conversion process from font to conformal pattern . The Yuewangzhou sentence sword is now in the Zhejiang Provincial Museum (Figure 1). This experiment is carried out with the eight-character Bird-and-Insect Script of the sword body “Yuewangzhou sentence, self-acting sword”. The morphological logic path of this experiment mainly includes the following four ways: 1, multi-line offset form; 2, variable form of line length and angle; 3, contour line form obtained by gray value interference; 4, point form. Due to the complexity of the experiment and the highly approximate process, this paper only shows the specific experimental process of the multi-line migration pattern. The specific processes are as follows:

Figure 1. Sword of Goujian, and the Bird-and-Insect script of "Sword of Goujian, Self-acting Sword".

3.1 Morphological experiment of multi-line offset

Multi-line offset is divided into equidistant broken line offset and non-equidistant multi-line offset. These two forms use lines as the main elements to generate patterns. Linear patterns have distinct personality and are full of changes, and are the best means to express patterns such as curved, straight, thick, thin, long, and short. The linear composition of the Bird-and-Insect Script is highly compatible with the multi-line offset form, which is very suitable for experiments on this intelligent pattern generation method. The specific process is as follows:

Experimental steps of equidistant disconnection offset

a. Create an interpolation curve operator <Curve>, perform equidistant offset through <polyline offset>, set <Distance> and <Divisions>, adjust the line offset distance and refine the segmentation parameters.

b. Create a construction domain <Construct Domain> to set the parameter range of the line thickness range, connect to the <Distance> in step 1, and control the distance value and layer value range of the offset.

c. Set <Split List> for line interval selection, which is divided into two parts: list A and list B. The lines of List A are not cut, and the peripheral control is performed through <index> to cut the lines of List B.

d. On the basis of the line in step c list B, set <Divide Cure> to take several points according to the line length, link <Division> to set the segment value of the line, and set the minimum value of the <Maximum> division to ensure the length division of the short line. The smaller the input List B value is, the more segments are divided.

e. Based on the points obtained in step d, cut the lines through <Shatter> and link them to <Cull Pattern>, so as to filter the cut lines through False and True intervals (False means not preserved, True means preserved), In this way, the basic pattern of disconnection is obtained, and the filtered values are sorted through <Reverse List>, and the values are combined through <Group>.

f. Use the combined values in step e to filter out invalid data through <Clean Tree>, create a construction domain <Construct Domain> to set the range of the start and end parameters of the offset thickness, and connect it to the remap value <Remap Numbers>, make the line spacing gradient offset according to the value from thin to thick.

g. Create the interpolation curve operator <Curve> and set it to the gradient offset line in step 6. Set the <Divide Curve> to divide the line into equal-length segments, that is, take several points on the line through the length of the line. And link with <Division>, obtain A and B values through division operation, in order to control the smoothness of the line.

When the value of the denominator B is larger, the resulting value is smaller and the line is smoother. Then re-string the split points into a nurbs curve through <Nurbs Curve>.

h. Create <Boundary Surfaces> Group the curves obtained in step g to create a smooth surface, and convert the surface to create a breps geometric mesh through <Mesh Brep>, which is convenient for coloring.

i. Create a color value gradient <Gradlient>, and link it with the thickness gradient offset value of the curve in step f, and control the line color to gradually gradient from the inside to the outside through a nonlinear function, that is, the color gradient value is affected by the thickness value of the line. Create a <Jitter> link to a <Gradlient> to make the line color jump randomly and change the gradient coloring order.

The Bird-and-Insect Script pattern generated by the experiment can be adjusted and controlled for the shape elements such as the thickness, number of layers, range, precision, segment value, peripheral curve value, thickness, smoothness, gradient coloring order, etc. of the disconnection offset, so as to achieve the optimal shape (Figure 2, Figure 3) .These linear pattern prototypes have strong dynamic vitality, showing good applicability in later cultural and creative product design.

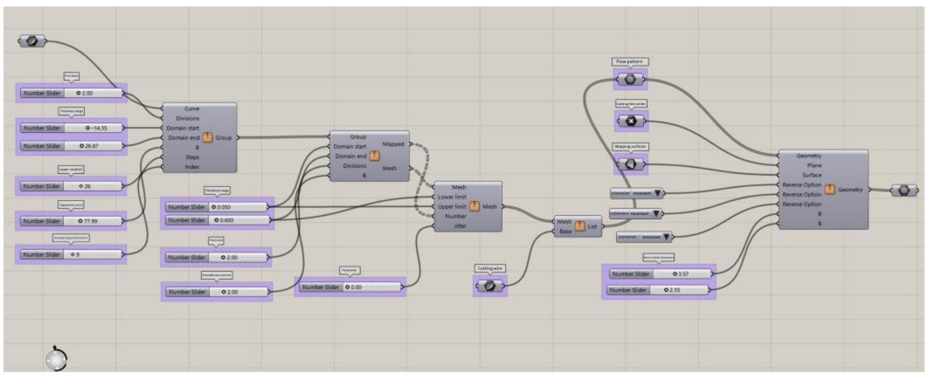

Figure 2. Isometric break offset logic build frame.

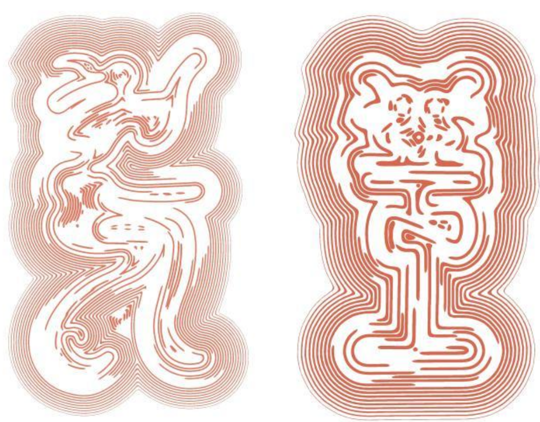

Figure 3. Bird-and-Insect script pattern for isometric break offset patterns.

Non-equidistant multi-line migration experimental steps

a. Create an interpolation curve operator <Curve>, create a set of arithmetic progressions through <Range>, set the <Graph Mapper> graphic mapper to set the numerical operation range of the function, affect the arithmetic progression values, and use <Remap Numbers> to convert the sequence values Scale to fit size.

b. Link the value to <Polyline offset>, distinguish the inner and outer offsets of the difference curve, and perform unequal offsets respectively. Sort the internal and external offset values in step 1 through <Reverse List>, and combine the two groups of values through <Group>.

c. Filter the invalid data from the combined values in step b through <Clean Tree>, create a construction domain <Construct Domain> to set the range of the start and end parameters of the offset thickness, and connect it to the remapping value <Remap Numbers>, make the line spacing gradient offset according to the value from thin to thick.

d. Create an interpolation curve operator <Curve> and set it to the gradient offset line in step c, and set <Divide Curve> to divide the line into equal-length segments, that is, take several points on the line through the length of the line. And link with <Division>, obtain A and B values through division operation, in order to control the smoothness of the line. When the value of the denominator B is larger, the resulting value is smaller and the line is smoother. Then re-string the split points into a nurbs curve through <Nurbs Curve>.

e. Create <Boundary Surfaces> Group the curves obtained in step e to create smooth surfaces, and convert the surfaces to create breps geometric meshes through <Mesh Brep>, which is convenient for coloring.

f. Create a color value gradient <Gradlient>, and link it with the thickness gradient offset value of the curve in step c, and control the line color to gradually gradient from the inside to the outside through a nonlinear function, that is, the color gradient value is affected by the thickness value of the line. . Create a <Jitter> link to a <Gradlient> to make the line color jump randomly and change the gradient coloring order.

The *Bird-and-Insect Script* pattern generated by the experiment can be adjusted and controlled for the multi-line offset layers, range, precision, thickness, smoothness, gradient coloring order and other shape factors, so as to achieve the optimal shape (Figure 4, Figure 5). The linear pattern prototype has a strong sense of order, and good visual aesthetics.

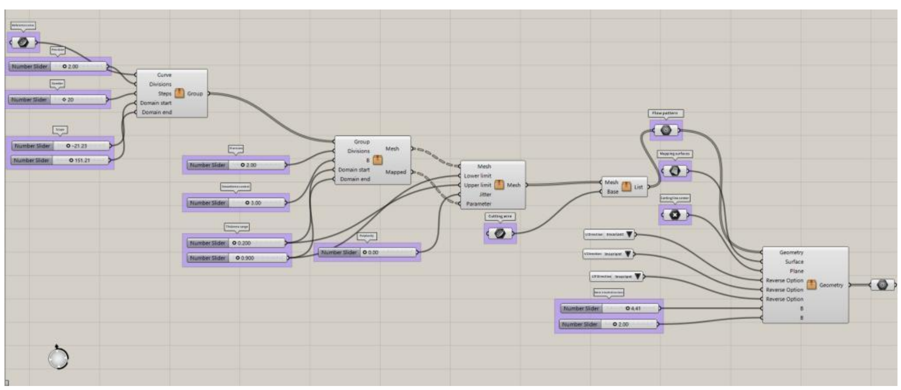

Figure 4. Non-equidistant multi-line offset logic construction framework.

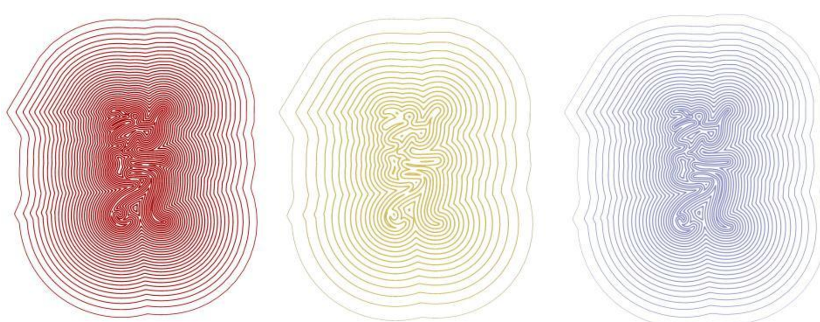

Figure 5. Bird-and-Insect Script pattern for unequally spaced multi-line offset patterns.

3.2 The experiment of obtaining the shape of the variable of line length and rotation value

The Bird-and-Insect Script pattern experiment, which uses line length and rotation as variables to obtain the shape, pursues the beauty of linear divergence. This experimental idea draws on the principle of linear divergence in parametric architectural design to create a sense of space and movement in the font pattern. E.H. Gombrich pointed out that in the process of pattern appreciation, the eyes are forced to move along fixed, redundant repeating lines, and this visual perception mechanism creates a sense of spatial chaos in the pattern. The Bird-and-Insect Script pattern generated by the experiment can be adjusted and controlled for the shape factors such as line length, line rotation angle, line thickness, smoothness, color gradient, etc., so as to achieve the optimal shape (Figure 6, Figure 7). These linear patterns The prototype has a complex sense of space, and the visual effects have a certain sense of technology.

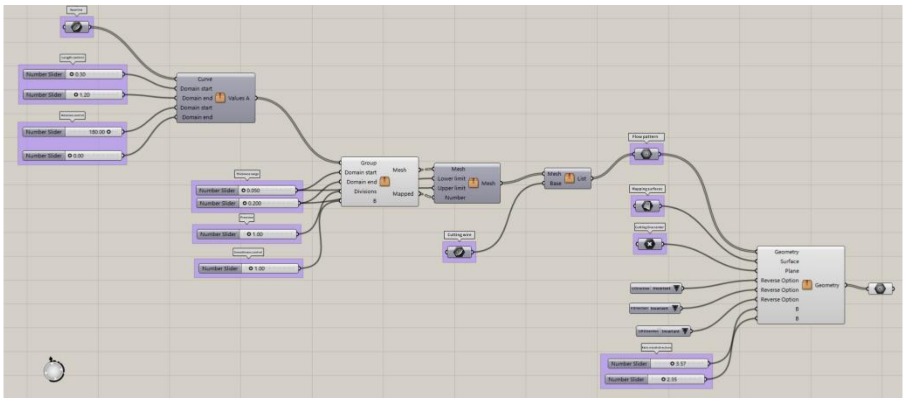

Figure 6. The logical construction principle of obtaining the shape with the line length and rotation value as variables.

Figure 7. The pattern of bird and insect book with variable line length and rotation value to obtain the shape.

3.3 Morphological experiment of grayscale interference

The experiment of grayscale interference to obtain the shape mainly pursues the accidental effect of the Bird-and-Insect Script pattern, and the font-based pattern is diffused and extended outwards. The focus of the experiment is to set a curve function <Graph Mapper> to control the density of points on the concave-convex surface so as to control the density of points on both the concave-convex surface and the plane. Use <Contour> to generate different numbers of uneven contour lines, use <Boundary Surfaces> to create a flat shape from a series of edge contour lines, and use <Scale NU> to proportionally scale the flat shape to finally form equal heights Linear forms (Figure 8, Figure 9) ,these linear pattern prototypes have flowing contingency, and the visual effect has a strong anti-counterfeiting function.

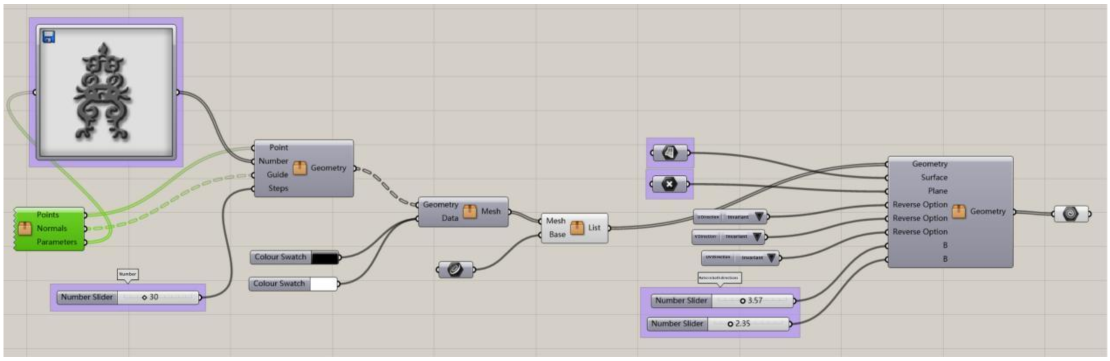

Figure 8. Grayscale interference acquisition morphological logic construction framework.

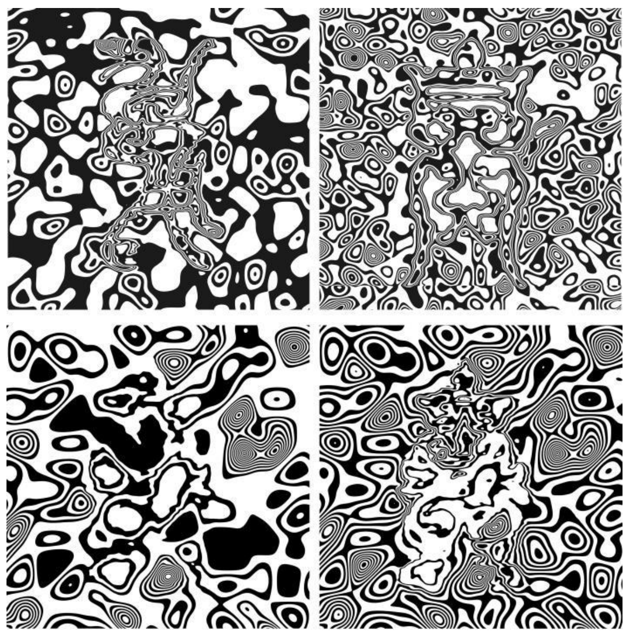

Figure 9. Bird-and-Insect Script Pattern of Grayscale Interference Acquisition Morphology.

3.4 Morphological experiment of point form

The different arrangements and combinations of dots produce the laws of beauty. The size, quantity, position, movement, light and shade of dots and other modeling elements have derived the ever-changing visual forms. The point-shape Bird-and-Insect Script parameterized pattern experiment starts from three-dimensional space, combines the curvature changes of each point and the surface, and controls the size value of the point shape through the numerical field. In addition, through the color value gradient, the color change of the line is controlled by a nonlinear function, that is, the color gradient value is affected by the thickness value of the line. Finally, point patterns with different angles, colors, virtual and real, and density are obtained through calculation (Figure 10, Figure 11). These linear pattern prototypes have rich color changes, and the visual effect is similar to the "pointillism" school of painting[24].

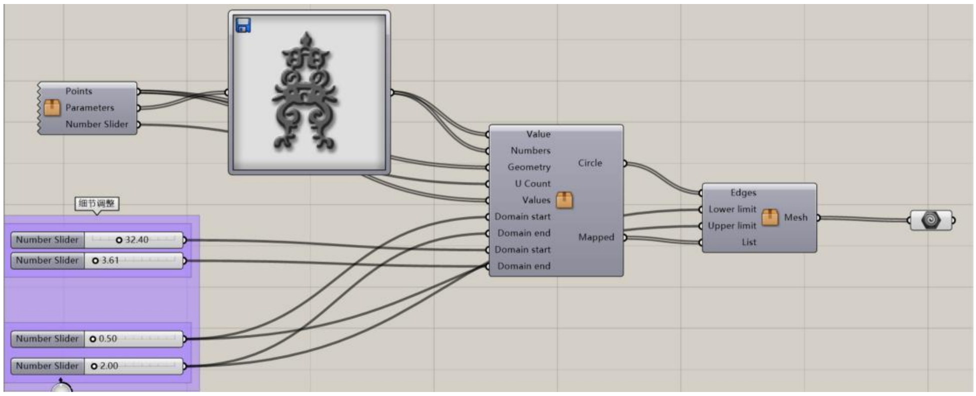

Figure 10. Morphological logic construction framework.

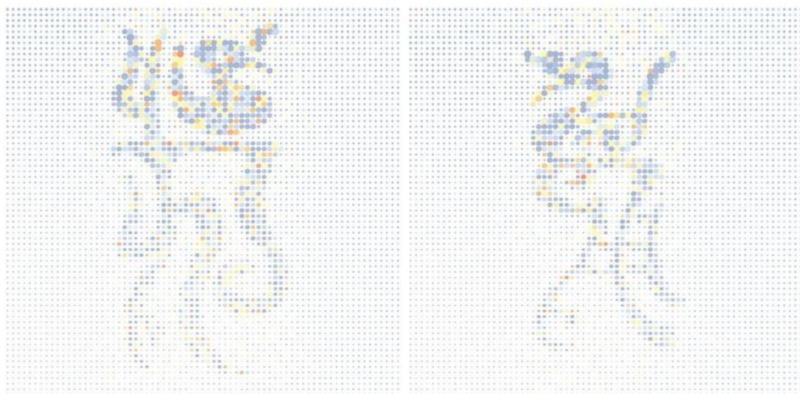

Figure 11. Bird-and-Insect script pattern of dot pattern.

3.5 Conformal design and application of parameterized cultural and creative patterns

The pattern prototype obtained from the experiment can better participate in the design application through conformalization, and the conformalization will be completed through two steps of pattern cutting and pattern mapping flow (Fig 12). After cutting the pattern prototype, the pattern flows from the source surface to the desired object, so as to complete the conformal application of the parametric pattern in cultural and creative design. Through related operations, the horizontal position, cutting style, mapping direction, and size of the pattern can be adjusted according to the shape of the object. Specific steps are as follows:

a. Create an interpolation curve operator <Curve> to construct a set of curves. The lines required by <Curve> can be drawn in rhino according to the cutting shape requirements to cut the pattern.

b. Create <Extrude>, extrude the curve curve in step a along the vector to form a surface, and solve the volume properties of the closed breps and mesh through <Volume>, and make it uniformly scaled through <Scale>, and finally the curveA curve forms a solid.

c. Divide the entity of the step through <Mesh Split>, and pass the divided surface through <Shap In Brep> to test whether the pattern to be cut is inside the curve divided in step a, so as to filter out the segmented surface. interior pattern.

d. Create a <Plane Surface> plane to create a pattern map reference source surface. And obtain the size value in the uv direction through <Dimensions>, set the scale value in the uv direction, and change the size of the adaptive pattern on the model by adjusting the value.

e. Use the pattern cut in step c as the pattern to map the flow, and set a <Point> as the center of the cutting line to move the position where the pattern needs to be adapted, and create a <Surface> as the surface to be mapped (required Adaptive objects can be modeled in rhino and linked to <Surface> as the target surface to be adapted), and the pattern will flow from the source surface to the target object through <Sporph>.

f. Create <Reverse Surface Direction> to reverse the UV direction, and set the U direction and V direction of <Value List> to change the pattern direction, thereby controlling the relative position of the pattern on the target object.

g. Apply the pattern to the design performance of related products (Figure 13).

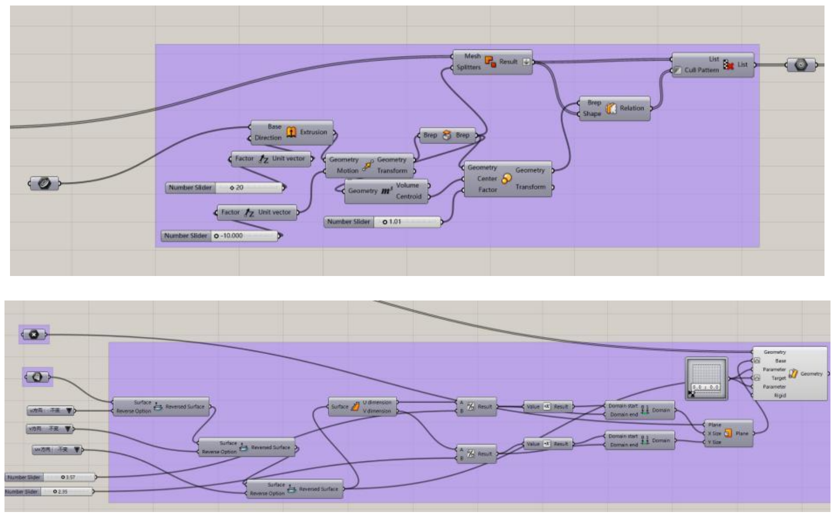

Figure 12. Bird-and-Insect script parametric cultural and creative pattern conformal logic construction framework.

Figure 13. Application of Bird-and-Insect script pattern conformalization.

4. CONCLUSIONS

The experiments in this paper have proved through repeated experiments that it is completely feasible to automatically generate thematic cultural and creative patterns combined with digital technology using Bird-and-Insect Script as the original image to be tested. The parametric Bird-and-Insect Script cultural and creative patterns obtained from the experiment have aesthetic characteristics such as mathematical rationality, systematicness and vitality, and have aesthetic connotations such as orderly beauty, structural beauty and dynamic beauty. Compared with traditional patterns, it reflects the application value of intelligence, efficiency and economy in the design of cultural and creative products. The parametric cultural and creative pattern organically combines rational algorithms and perceptual aesthetics, showing new design possibilities for the cultural and creative industry.

REFERENCES

[1] Oxman, R., MFD: Material-based design informed by digital fabrication. Materia Arquitectura, (13), 105-109 (2016).
[2] Lu, X., Yang, Y., Wang, L., Wang, H., Cultural and Creative Design of Dunhuang Murals in Xixia Period Based on Deep Learning. Wireless Communications and Mobile Computing (2022).
[3] Shi, H. Y., The evolution of the meaning of “pattern”: A perspective on the theory of Chinese design in the 20th century , China Academy of Arts (2019).
[4] Ji, C., Li, Y. N., Digital creative design of Pingyang new year wood-block prints based on scene theory, Packaging Engineering, vol.42, pp.388-395 (2021).
[5] Wu, S., Application and analysis of traditional cultural elements in cultural and creative products, Art Education Research., vol.08, pp.70-71 (2021).
[6] Ding, L., Wan, X., A study on the modernity turn of Shu brocade pattern in cultural and creative products , Design, vol.35, pp.20-23 (2022).
[7] Yue, Y., Extraction and application of pattern modeling factors of Nanjing Brocade, Art and Design (Theory), vol.2, pp.101-103 (2022).
[8] Dang, L. J., Research on the application of facial mask patterns in Jin opera in cultural and creative design, China National Expo, vol.24, pp.118-120 (2020).
[9] Tesařová, K., In the pixel zone: Perception of digital design ,Architecture Papers of the Faculty of Architecture and Design STU (2022).
[10] Fang, J., Deng, W., Design of lingnan cultural gene implantation cultural and creative products based on virtual reality technology. Mathematical Problems in Engineering, pp.1-9 (2021).
[11] Li, X., Lin, B., The development and design of artificial intelligence in cultural and creative products. Mathematical Problems in Engineering, pp.1-10 (2021).
[12] Zhao, Y. P., Inheritance and Transcendence: typeface design in the background of new technology and digital media , Decoration, vol.05, pp.69-77 (2022).
[13] Baldwin, C. Y., Clark, K. B., Modularity in the design of complex engineering systems (pp. 175-205). Springer Berlin Heidelberg (2007).
[14] Oxman, R., Thinking difference:Theories and models of parametric design thinking, Design Studies, vol.52, pp.4-39 (2017).
[15] Yin, X. C., Wang, N., Wu, S. W., Research on parametric innovation design of traditional connected foursquare continuous pattern, Design, vol. 35, pp.128-131 (2022).
[16] Hillmayr, D., Ziernwald, L., Reinhold, F., Hofer, S. I., Reiss, K. M., The potential of digital tools to enhance mathematics and science learning in secondary schools: A context-specific meta-analysis. Computers & Education, 153, 103897 (2020).
[17] Peterson, E., Mathematics and Art - Infinite Fragments, Translated by Yuan Zhendong and Lin Lei, Shanghai: Shanghai Education Press (2018).
[18] Gombrich, E. H., Sense of Order: A psychological study of decorative Art, Nanning: Guangxi Fine Arts Publishing House (2015).

[19] Gao, Q., Numbers and principles of form, Central Academy of Fine Arts (2016).
[20] Yin, X. C., Wu, S. W., Research on geometric pattern design method based on parametric method, Design Art Research, vol.12, pp.13-17 (2022).
[21] Zhang, Z. T., Research on the practice and application of parametric font design, Nanjing University of the Arts (2017).
[22] Yu, J. Y., Lines and meanings: The rhythm and orderly beauty of decorative art lines, Shanghai Normal University (2017).
[23] Ru, T., The inspiration of parametric design to visual graphics, Xi'an Academy of Fine Arts (2013).
[24] Pereira, J., Wijaya, T. T., Zhou, Y., Purnama, A., Learning points, lines, and plane geometry with Hawgent dynamic mathematics software. In Journal of Physics: Conference Series (Vol. 1882, No. 1, p. 012057). IOP Publishing (2021).