The Visualization Patterns of Uniformly Formatted Parametric Designs on Lotus Pattern

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Received January 22, 2024; **Revised** March 29, 2024; **Accepted** April 22, 2024

Abstract

This article aims to propose a method for generating parametric design images with regular patterns. In recent years, the burgeoning interest in parametric design has been palpable, driven by its transformative potential within the design sphere through the utilization of advanced computer modeling techniques. However, despite the proliferation of avant-garde parametric designs, there exists a noticeable void concerning the representation of images imbued with regularity and specific patterns. The lotus pattern, deeply entrenched in millennia of traditional Chinese culture, serves as a potent symbol of purity and resilience, permeating various facets of artistic expression and design aesthetics. Its cultural significance and versatile applicability underscore the importance of exploring methodologies that can effectively capture and reproduce its essence. Recognizing the significance of the lotus motif and the broader potential of parametric design. This paper aimed to bridge this gap by presenting a meticulously crafted methodology. By drawing on precise geometric feature extraction, meticulous parametric line drawing generation, and intricate parametric image generation, this approach seeks to empower designers to create imagery that embodies the beauty and symmetry of regular patterns. This academic study not only aims to fill a crucial void in the representation of regular patterns but also to foster a culture of design innovation. By shedding light on the untapped potential of parametric design in capturing cultural motifs and fostering creativity, this method contributes to the broader evolution of design practices within contemporary discourse. Through exploration and refinement, designers are poised to unlock new realms of creativity and make meaningful contributions to the dynamic landscape of design aesthetics and functionality.

Keywords: visualization patterns; uniformly formatted; parametric designs; lotus pattern

Introduction

In recent years, there has been an increasing interest in parametric design in the design field, a method that brings new possibilities to the design process by automatically generating design solutions through computer modeling techniques (Micheletti, Bruckner & Giannetti, 2023). The adoption of parametric design in the design field has shown a significant growth trend, and many parametric design works have relevant application cases in various design projects (Serani & Diez, 2023; Ye & Zhai, 2023). Parametric design methodologies have gained increasing prominence in the design field, offering designers innovative tools for automated design generation. This paradigm shift has introduced novel possibilities for creating complex and intricate designs through computational techniques. Parametric design, characterized by its reliance on mathematical algorithms and parameters, allows for the systematic exploration of design variations. While parametric design has been extensively studied in various contexts, there remains a gap in research regarding its application to conventional patterns, such as the lotus pattern. Past research results also provide useful experiences for the application of parametric design in the design field. Taking Zou's research as an example (Zou, Wang & Luh, 2023), they found that by introducing parametric design, designers are able to adjust and optimize their designs more freely, improving the adjustability and controllability of their designs. Meanwhile, the recently published book 'Computational Design and Digital Manufacturing.' demonstrates the critical role of current parametric design in unconventional, abstract avant-garde, and irregular design innovations (Kyratsis, Manavis & Davim, 2023). Current parametric design work often employs unconventional geometries such as curves, curved surfaces, or irregular structures (AKAZAF, 2023; Hollberg & Ruth, 2016; Ko, Ajibefun & Yan, 2023; Na, 2021; Serani & Diez, 2023). These studies have provided valuable insights. However, we still find that a systematic understanding of parametric design in the design field has yet to be thoroughly researched, and in particular, the methods for generating parametric design images of conventional, reference-specific patterns have not yet been elaborated.

This study focused within the design field and addresses the problem of conventional, parametric designs that possess a specific pattern (e.g., the lotus flower) and methods for generating the image. The lotus pattern holds significant cultural symbolism and aesthetic value, making it a compelling subject for parametric design exploration. However, existing literature primarily focuses on unconventional geometries and abstract forms, neglecting the potential for parametric design to generate uniformly formatted designs on traditional patterns like the lotus. The need for this study stems from the growing interest in parametric design in the design field (Monedero, 2000), especially in the conversion of specific patterns into parametric design images. The researchers involved in this study have conducted a number of related design practices to explore design methods in this field. The study aims to provide practical insights and methods for designers, architects and other professionals in the design field.

The main objective of this research is to demonstrate a parametric design generation methodology for a specific regular pattern and to fill the existing knowledge gap in the understanding of parametric design. This research paper presents a method for generating a parametric design for a specific pattern, the lotus flower, in order to provide designers with a replicable and actionable design generation process for their design practice.

This academic artical presents an operational method for generating a parametric design image of a specific pattern. First, we introduce the concept of parametric design and its modeling platform. Then, using the lotus flower pattern as an example, we demonstrate the three key steps of geometric feature extraction, parametric line drawing generation, and parametric image generation. The proposed method may be of interest to designers seeking to implement relatively regular, pattern-specific practices in parametric design. Moreover, it can fill the current knowledge gap in the field of parametric design to a certain extent and promote the development of parametric design in a wider range of design fields.

Literature Review

Parametric design is a common form of computer-aided design methodology (Ko et al., 2023). Parameter, a concept in mathematics, describes the relationship between variables and explains the form of variable that exists in the relationship between the dependent and independent variables. The principle of parametric design is mainly that the important factors are turned into a particular function module in the design, and the result of the function variable is changed by altering one of the factors of its module to obtain a variety of different design solutions (Yu & Gero, 2016). By changing functions or algorithms to generate design solutions, transforming design problems into logical reasoning problems, and replacing subjective imagination with rational thinking, the process of parametric design can better help designers carry out and grasp the complete design process in a rational and efficient way.

Parametric modeling is a kind of working method to deal with the objective problems in reality by using the powerful data computing ability of computer; its core is to write the boundary conditions and constraints in the real problems as mathematical algorithms or functions and get the results through computer operations, thus allowing workers to modify the above conditions or "parameters" and quickly generate different programs, reducing the workload of program modification and reducing the time required for designers to modify the program. Different programs, reduce the program modification workload, to a certain extent, can realize the program output "automation".

At present, parametric design ideas are used in all kinds of design fields. Through the introduction of parameters, designers can easily modify and optimize their designs to adapt to different requirements and conditions (Abo Ganema & Abdelmoneim, 2023; Hollberg & Ruth, 2016; Schumacher, 2015; Ye & Zhai, 2023; Yu, Gero & Gu, 2015). Parametric design is not only about superficial aesthetics, but also the pursuit of design efficiency, logical controllability and repeatability, which is also the reason why parametric design has been developed in all kinds of design fields.

Modeling platforms for parametric design are software or tools used to implement parametric design. These software tools provide designers with a user-friendly environment to create, manipulate, and visualize parametric models, streamlining the design process and enhancing productivity. Among the various modeling platforms available, Rhino Grasshopper stands out as a widely utilized tool for parametric design.

Rhino Grasshopper combines the capabilities of Rhino, a powerful 3D modeling software, with Grasshopper, a visual programming editor. This integration allows designers to seamlessly transition between creating geometric forms in Rhino and developing parametric relationships in Grasshopper. The visual nature of Grasshopper enables designers to intuitively define parametric relationships using nodes and connectors, facilitating the creation of complex designs.

As the complexity of parametric design visualization increases, so does the need for sophisticated functions to define the relationships between parameters and outputs. This complexity often requires extensive data manipulation and analysis to ensure accurate modeling outcomes. Designers must carefully consider factors such as data storage, editing, and management to effectively handle the large volumes of data generated during parametric modeling.

Furthermore, the success of parametric modeling relies heavily on the accuracy and compatibility of the data used in the algorithms. Matching the data inputs with the intended design parameters is critical for achieving the desired design outcomes. Any discrepancies or inconsistencies in the data can significantly impact the final result, highlighting the importance of meticulous data handling in the parametric modeling process.

In summary, modeling platforms like Rhino Grasshopper provide designers with powerful tools to implement parametric design methodologies effectively. By offering intuitive interfaces, advanced functions, and seamless integration with 3 D modeling software, these platforms empower designers to explore complex design possibilities and streamline the design iteration process. However, careful consideration of data management and algorithmic accuracy is essential to ensure the success of parametric modeling projects.

Processes and procedures of parametric designs on lotus pattern

1. Geometric Feature Extraction of Lotus Pattern. Lotus pattern is a pattern with strong cultural heritage, which is one of the common patterns in traditional Chinese culture and has a wide application base in the field of culture and art (Chen et al., 2021; Jung, 2011; Latała-Matysiak & Marciniak, 2023). Lotus pattern has rich symbolic meaning and aesthetic value. Therefore, this paper will take the lotus pattern as an example to illustrate the parametric design generation method of the rule pattern.

The computer generation of lotus pattern, graphic style elements extraction, are based on basic geometric patterns, such as circles, arcs, straight lines. Complex geometrical forms of lotus patterns are formed by combining operations such as copying, crossing, and trimming of these basic geometrical patterns. How to improve the efficiency and model accuracy being physically realized these lotus pattern processes, using mathematical models or modeling languages to parametrically encode the lotus pattern shape features, construction rules, or programmed layouts, to form lotus pattern entities of specific design styles through aesthetic conventions and spatial constraints, and to generate new visual art forms of lotus patterns with specific styles. How to modularize the lotus pattern through a programmed approach, generate a modeling language for combining to form a natural lotus configuration, automatically simulate a specific art style, and utilize deep neural networks for technical parametric modeling and generation. And then through the specific parameterized features of different combinations together, that is, re-rendering to produce a specific with the diversity of the lotus flower decorative patterns, is a very forward-looking and challenging field.

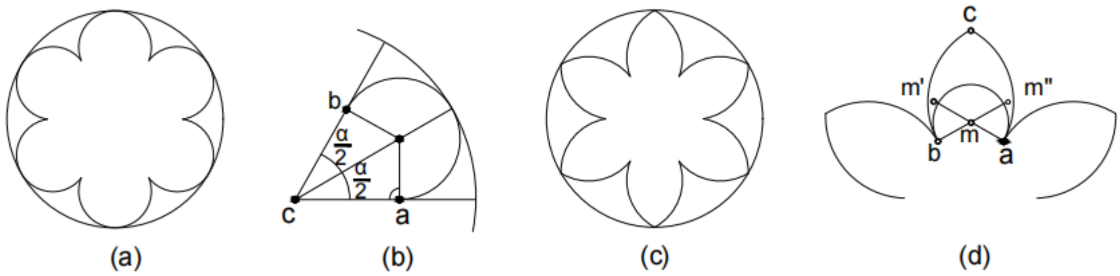

Fig 1. Basic Lotus Pattern Algorithm

As shown in Fig 1, the basic shape of a lotus flower petal is one of the important building blocks for the formation of a lotus flower pattern. In the course of the study, data experiments were carried out with two lotus defense variation forms. One is the round shape and the other is the pointed shape. Trigonometrization of one or more sin function experiments with two sets of geometric shapes is relatively simple to draw a circle with point c as the center of the circle, the distance c to m of the algorithm is 1-r, α =, the length of the plumb line m to the circle tangent line is (1-r) sin, the equation is r = sin / (1 + sin). The perpendicular angles a and b combine to form a modular group, and by performing a rotation and copying the endpoints of the arc n times, the petal group of the lotus pattern is formed. Symmetric displacements of the midpoint m along the line give the cusp-shaped points (a,m) and (b,m), which, combined with the point C at the center of the circle, form the graphic group. The displacement determines the cuspiness.

2. Parametric Line Drawing Generation of Lotus Flower Pattern. Parametric lotus-like models are constructed based on the geometric characteristics of the lotus shape. Using a computer platform for parametric modeling aspects such as the parametric tool Grasshopper, stylized lotus patterns with arbitrary shapes and colors are flexibly generated by setting the parameters and colors of the lotus patterns and arranging them in different rings.

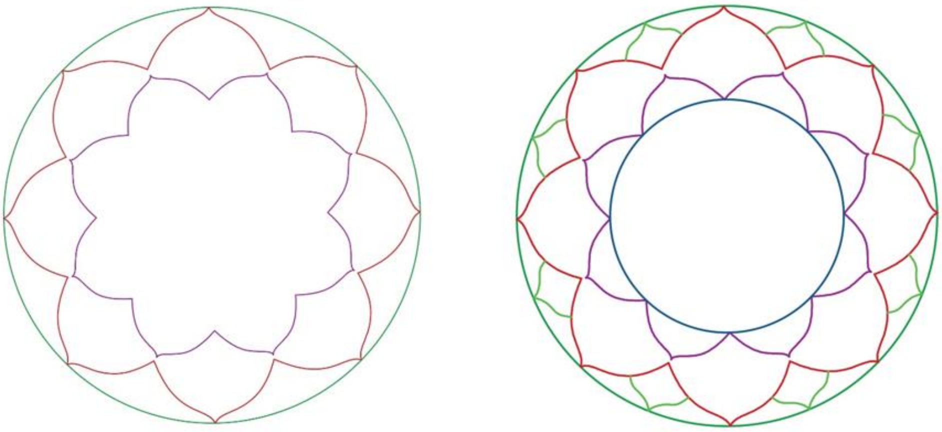

Fig 2. Structure and decorative shapes of the lotus pattern

The traditional lotus patterns each differ in geometry and compositional structure. Parameterized patterns are constructed based on geometric features in each pattern on demand and placed in the same hierarchical structure to generate different lotus patterns. The petals of the lotus pattern may contain 4, 8, 10 or 16 equal petal patterns from the outer ring to the inner core. In this study, 8 petal patterns are used as an example to describe the parametric modeling and generation of lotus patterns. As shown in Fig 2, the model is divided into two parts: skeleton and decorative shape. The main body of the skeleton is the whole petal structure and petal outline, and the center part is the decorative shape. Combining these two parts forms the construction of the skeletal pattern and the decorative shape.

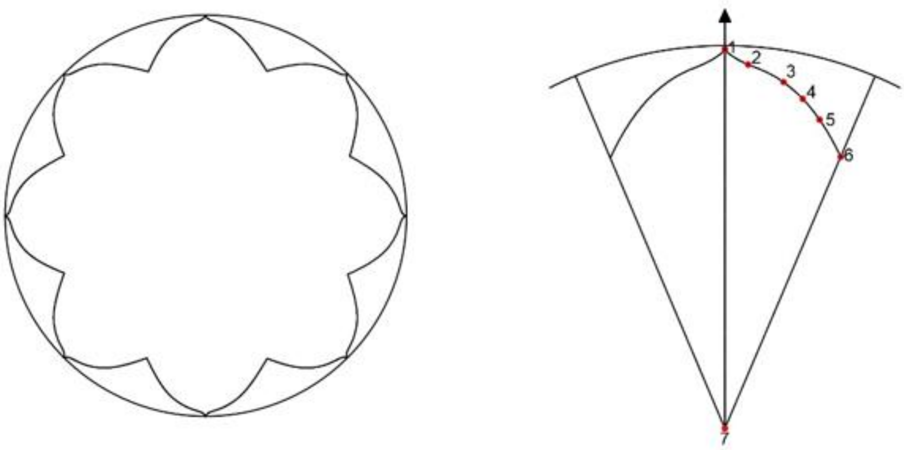

Fig 3. Construction of the skeleton of the eight-petaled lotus flower

As shown in Fig 3, by dividing the lotus flower into 8 petals, which are confined to one-eighth of a unit circle, and the petals are shaped symmetrically around a central axis, the other half of the petal can be modeled by specifying 7 control points as the original set of control points, which are then used to model the other half of the petal. The positions of these 7 control points are represented in polar coordinates. We use a 3D array to store the radius r_i, the angle θ_i, and the relative angle $\Delta_i = |\theta_{ref} - \theta_i|$, where i = 1,2, ... , 7, and θ_{ref} are the angular coordinates of the reference control point taken from the given control point.

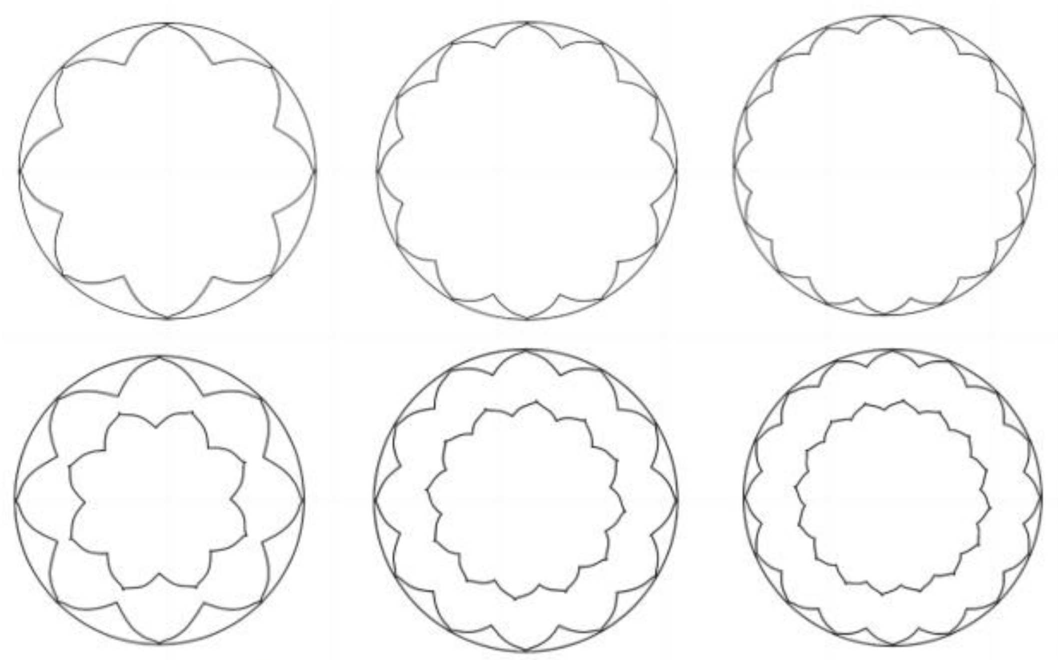

Fig 4. Lotus skeleton pattern with different number of petals

We can modify the relative angle Δ_i set at the original control point. The shape of the petals is narrower than the shape of the original control points. As shown in Fig 4, a pattern of n petals can be generated in a similar way with the new control points. It can be a skeletal pattern with 8, 12, 16, etc. petals.

The construction of different pattern models in the lotus pattern can be parametrically modeled and generated by the following steps. As shown in Fig 5, the first step is to formulate np as the number of petals in the pattern and then divide the unit circle into n p-points. Generate skeletal patterns for the external and internal patterns in the lotus petals and add decorative shapes in order to obtain a complete lotus petal pattern. Perform grouping to obtain unit one, and generate the petal lotus pattern for the rest of the unit circle by rotating the petal pattern of unit one by $2\pi/np$ around the center of the circle. Thereby, lotus patterns with different petals can be generated. Since the lotus pattern is confined to a unit circle, a confined in-circle lotus pattern can be obtained by expanding or reducing the radius r to coordinate the entire control point.

Fig 5. Adjust the radius of the inner and outer rings to obtain a more complex lotus pattern.

3.Iterative Exploration of Lotus Pattern Elements. Parametric design enables designers to iteratively explore various design variations inspired by the lotus pattern. During this phase, designers systematically adjust parameters, observe changes in the lotus pattern, and refine the design iteratively to achieve desired aesthetic and functional objectives.

4.Visualization and Rendering of Lotus Pattern. Upon achieving a satisfactory parametric design variation of the lotus pattern, visualization and rendering become crucial for presentation and analysis. Parametric design software tools offer advanced rendering capabilities, allowing designers to create realistic and visually compelling representations of the lotus pattern in different environments and lighting conditions.

5.Validation and Testing of Lotus Pattern. Finally, validation and testing of the parametric design of the lotus pattern are conducted to ensure feasibility and effectiveness. This may involve physical prototyping, computational analysis, or user feedback sessions focused specifically on the integration of the lotus pattern. The assessment evaluates the pattern's performance, structural integrity, and visual appeal, ensuring it resonates with the cultural significance and artistic expression associated with the lotus." After the above experiments and data analysis, with the model of the lotus pattern, it is possible to add the corresponding pattern to each link to generate the lotus pattern with a hierarchical structure of concentric circles. Parametric modeling and generation tools Grasshopper computing platform provides data visualization, use of functions and data mapping, implementation of algorithms, user interface display and so on.

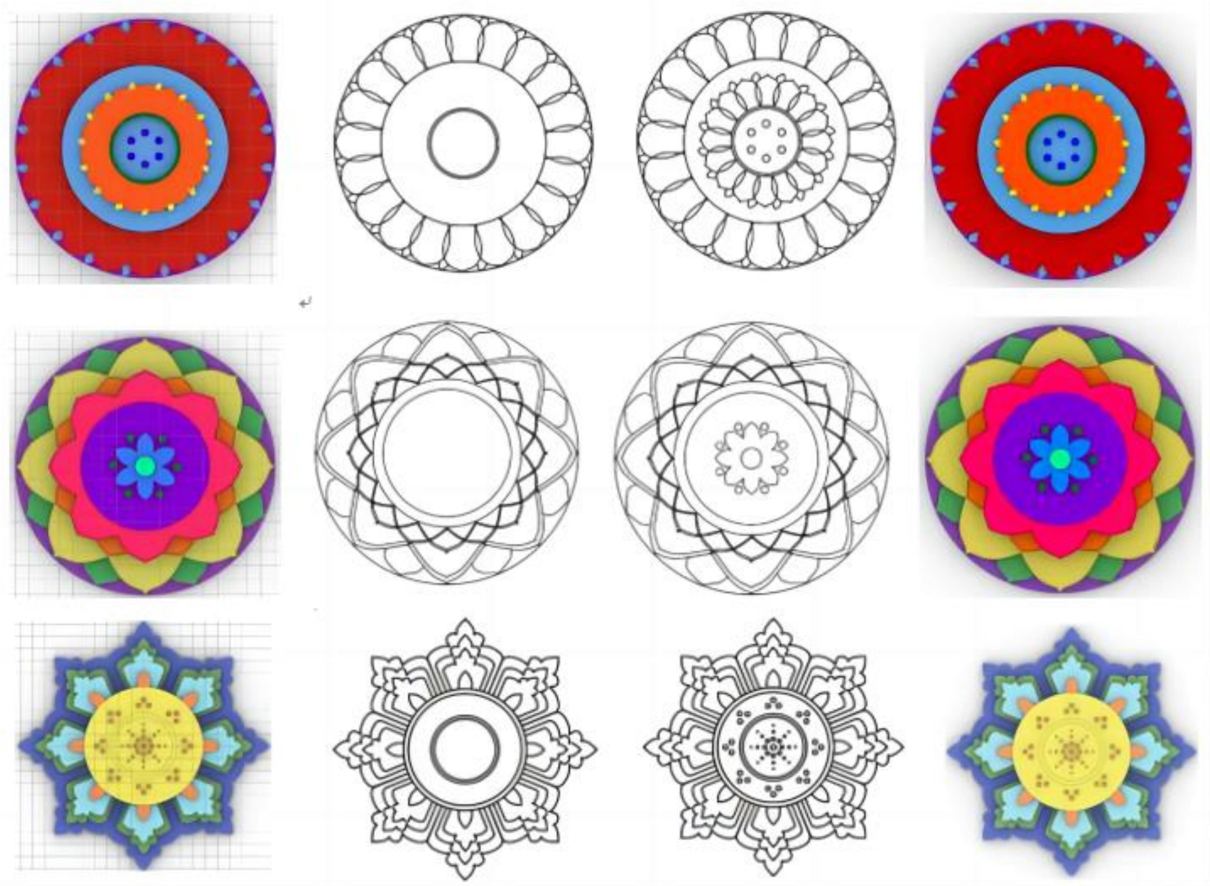

Fig 6. Adding color to the final Lotus pattern parametric design image.

As shown in Fig 6, the geometric features of the lotus pattern were used as a basis for exploring the possibilities and diversity of the design space of the lotus pattern with the different parameters and colors associated with the corresponding pattern. The experimenter specified the total number of rings and the associated radius of each ring in the lotus pattern. Then for each drawing step and select the corresponding color. The parameters and colors associated with the corresponding motifs in each module can be edited by Grasshopper parameters. The user can edit the number of petals of the lotus pattern, add basic content shapes such as circles, rectangles, polygons, sectors, arches, etc. By setting the parameter battery buttons, add skeletons or decorative shapes in the inner large and small petals of the circle, as well as additional fills in the corresponding colors. Lotus pattern on parametric modeling and generation through the computational power of the computer, usually takes longer than other pattern generation visualization because it involves more interactions, adding large or small petals, setting up the bones and filling in the colors and the decorative shapes for each petal and so on.

Knowledge from Research

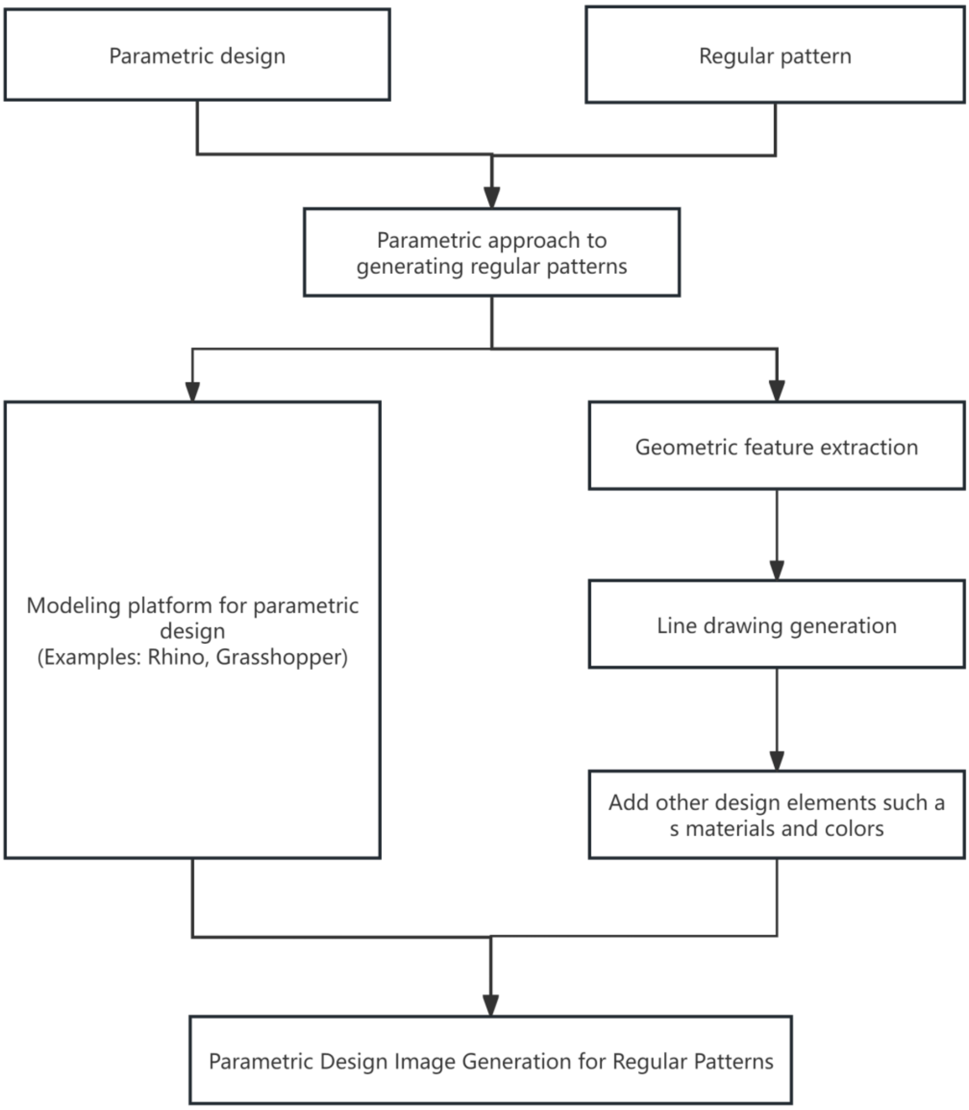

Fig 7. Flowchart of parametric design image generation for regular patterns

As shown in Fig. 7, this study systematically demonstrates the method for generating parametric design images of regular patterns. The whole process is carried out with the help of a parametric design platform. The three main processes of geometric feature extraction, line drawing generation, and addition of other design elements such as materials and colors are carried out successively. Through this method, controlled parametric images of regular patterns are finally generated.

Conclusion

This study has introduced methods related to parametric design into the design process of works similar to the lotus pattern. By analyzing the structure of the lotus pattern, we have successfully converted it into an efficient and controllable parametric model. Through iterative exploration, visualization, and validation processes focused on the lotus pattern, we have provided practical design ideas for professionals in the design field. Parametric design empowers designers to systematically explore design variations inspired by the lotus pattern, allowing for the adjustment of parameters to achieve desired aesthetic and functional objectives. Visualization and rendering tools further augment the presentation and analysis of lotus pattern designs, enabling designers to create lifelike representations across diverse contexts.

Future work can further explore the application of parametric design in other conventional patterns to expand the design space, improve design efficiency, and promote the wider application of parametric design in the design field.

In conclusion, this study underscores the potential of parametric design to drive innovation and creativity in design practice, particularly in the realm of pattern generation. By embracing parametric design principles, designers can unlock new possibilities for crafting intricate, customizable, and visually striking lotus patterns that reflect the beauty and symbolism of this revered cultural icon, while also paving the way for broader applications in design.

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