

Design Strategy for Outdoor Leisure Chairs Based on Parametric Plant Patterns Using Biobased Materials

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To address the growing demand for sustainable, functional, and culturally aesthetic outdoor leisure chairs while enhancing their emotional and cultural significance, this study proposes a design strategy that integrates Kansei engineering with parametric derivation. Plant patterns derived from traditional Chinese artifacts were selected as the research subject, and their types and structural characteristics were systematically classified to construct a representative pattern library. The semantic differential method was employed to evaluate perceptual images and identify patterns consistent with the aesthetic values of outdoor furniture. By using parametric software, the shape of the pattern is simplified into functional holes, achieving lightweight and heat dissipation functions. Two conceptual designs for outdoor leisure chairs were realized using bio-based materials, resulting in reduced material use. The proposed designs were assessed using fuzzy evaluation methods, which yielded high satisfaction scores and validated the feasibility and effectiveness of the approach.

DOI: 10.15376/biores.20.4.9817-9832

Keywords: Outdoor leisure chair; Parametric design; Plant pattern; Kansei engineering; Sustainability; Design strategy

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INTRODUCTION

As living standards continue to rise, tourism and leisure have gradually become an integral part of people's lives. Since 1992, tourism has ranked among the world's largest industries, contributing to both global and national economic development (Yao 2023). As iconic products for leisure vacations and coastal lifestyles, outdoor leisure chairs are seeing growing market demand. However, while meeting basic functional needs, current mainstream market products also present two pressing issues that require urgent resolution. (i) There are prominent issues with material sustainability. This is particularly critical for outdoor furniture, which faces relentless environmental stressors that accelerate degradation. Traditional materials such as wood are susceptible to cracking, coating failure, and rot under prolonged exposure to moisture and ultraviolet (UV) radiation. Similarly, conventional plastics suffer from UV-induced brittleness and color fading, while metals are prone to corrosion. These failure modes not only shorten product lifespans but also exacerbate waste and resource consumption, conflicting with the urgent global demand for sustainable development (Singer and Özşahin 2023). (ii) There is a widespread lack of cultural depth.

Product designs suffer from severe homogenization, rarely incorporating regional or ethnic cultural elements. Thus, many items fail to satisfy consumers' growing demands for emotional connection and personalized aesthetic experiences. Against the backdrop of increasingly intense competition in the global outdoor products market, integrating users' emotional perceptions, cultural connotations, and sustainable development concepts has emerged as the core development direction for outdoor leisure chair design. This enhances product competitiveness while effectively preserving and promoting traditional Chinese culture.

In recent years, many scholars have conducted various studies on the translational design and innovative application of traditional elements in furniture design. Qiao *et al.* (2025) clarified and analyzed its historical inheritance, traditional aesthetics, and pattern composition of carved lacquer craftsmanship, combining modern design concepts and 3D printing technology in furniture design, providing new ideas and methods for the innovative development of carved lacquer furniture. Zheng *et al.* (2022) analyzed the artistic form and cultural connotation of Chu lacquerware from the perspective of cultural inheritance, extracted its pattern elements for innovative design combined with extension transformation, and applied them to urban furniture design. Xue and Chen (2024) applied biological DNA genetic information to furniture products, combined with shape grammar for decorative pattern innovation, designing new forms of wooden furniture that maintain the original genes. Although the above research had expanded the research methods of traditional element translation design, there are still some problems: (i) When analyzing and clarifying traditional patterns, there is a lack of consideration for the Kansei imagery of traditional pattern elements, ignoring the synergistic effect between cultural gene inheritance and consumer Kansei adaptation; (ii) Shape grammar and other element deduction methods require multiple iterations to produce derivative patterns, which often differ only slightly from the original designs; (iii) In practical applications of furniture design, the focus is often limited to the reconstruction of pattern elements, without incorporating structural innovation in alignment with functional requirements.

Based on the above research and existing problems, a design method is proposed, which combines function-oriented parametric traditional pattern design with perceptual factors. To bridge the gap between user emotions and design elements, this study uses a user-centered approach from Kansei engineering to systematically translate consumer feelings into design parameters. The core of this method is the semantic difference (SD) method, which uses pairs of opposite adjectives to measure emotional responses through a structured questionnaire (Guo *et al.* 2020). Firstly, the emotional elements in traditional Chinese artificial plant patterns were analyzed, and the appropriate patterns were selected by semantic difference method. Then, combined with function-oriented parametric design, the contour of the pattern was dynamically adjusted through the heat map to generate organic hole textures. This not only goes beyond visual aesthetics, but it also improves the structure and function to make the application of patterns lightweight and heat dissipation. To achieve sustainability and functionality goals, the proposed design used bio-based composites to verify its feasibility. The goals included excellent moisture protection, UV degradation resistance, and corrosion resistance compared to conventional materials. With the integration of interdisciplinary, this design method makes the design of outdoor leisure chairs achieve coordinated improvement in terms of functionality, aesthetics, cultural heritage and resource sustainability.

EXPERIMENTAL

Research Data

As carriers of history and culture, traditional Chinese bronze mirrors not only serve practical purposes, such as reflecting people's faces and as decoration, but they also carry deep symbolic meanings. Across different historical periods, these mirrors display distinct artistic features and cultural significance, following clear developmental logic and evolutionary patterns (Zhao *et al.* 2024). Tang Dynasty bronze mirrors are not only important cultural artifacts in the history of Chinese bronze mirrors but also mark a new high in their development after the Han Dynasty. The integration of diverse cultures and economic prosperity during this period promoted cultural diversity, which was evident in the innovative decorative patterns on these mirrors (Wang and Duan 2022). Tang Dynasty bronze mirror decorations mainly drew themes from nature and social life. These motifs ranged from mythical creatures imagined in folklore to realistic depictions of flowers, birds, fish, and insects, and even extended to narrative scenes of daily life. Together, they reflect the social values and unique characteristics of the Tang Dynasty. The patterns also show the artistic fusion between Eastern and Western cultures along the Silk Road. Moreover, the motifs have been refined through parametric techniques, preserving natural forms while expressing structured beauty. This aesthetic aligns with the idea of 'harmony between human creations and the natural environment,' which is crucial in outdoor furniture design.

Patterns were gathered through fieldwork, literature reviews, and online sources. The plant motifs on the reverse sides of Tang Dynasty bronze mirrors include distinct types such as lotus, grape, cinnamon, and peony. These designs are notable for their clear features and realistic style. Representative sample images were selected for further processing. To reduce interference from bronze mirror materials and lighting during photography, Adobe Illustrator was used to convert selected images into black-and-white line drawings. Adobe Illustrator is a design software based on vector graphics technology. Vector graphics are composed of paths defined by mathematical formulas, which have the core characteristics of 'resolution independent, smooth and accurate lines'.

In order to reduce the interference of copper mirror material reflection and uneven shooting illumination on the image, the selected image is converted into black and white line art and refined by using the software. After the image is selected, the bitmap pixels are analyzed using the 'Image tracing' function. To generate black and white line artwork, the 'black and white logo' preset is often used, or the Threshold parameter is customized, which can accurately control the thickness of the pattern outline and the degree of detail retention.

After completing the image tracing, the instructions are to click 'Expand' to convert the vector object into an editable 'anchor + path segment' structure; Then adjust a single anchor point or path segment through the 'direct selection tool' to further optimize the curvature and length of the line, so that the pattern is more accurate.

These were labeled with names and codes. The sample order was randomized to improve differentiation and enhance the reliability of the subsequent questionnaire. Sample names and codes are listed in Table 1.

Table 1. Naming and Numbering of Copper Mirror Samples

Number	Pattern Naming	Sample Graph	Sample Extraction
A1	Lotus Pattern		
A2	Grape Pattern		
A3	Peony Pattern		
A4	Diamond Pattern		
A5	Floral Pattern		
A6	Laurel Pattern		
A7	Treasure Pattern		
A8	Pomegranate Pattern		
A9	Cluster Pattern		

Methods

Parametric design

Parametric design is a method based on parameters, where new forms are generated by combining different parameter values within a design prototype (Chen and Jia 2024). Currently, it is widely used in architecture and product design and is gradually expanding into graphic design (Huang and Wang 2024). Grasshopper, a widely adopted plug-in for parametric design, generates visual outputs through algorithmic programming. It allows users to develop highly complex and logic-based models, which are automatically executed by computational algorithms within a visual interface (Yao 2023). Designers can further refine the parameter values of these visual elements to produce derivative patterns (Zhang *et al.* 2024). Compared to traditional methods of pattern derivation, parametric design provides distinct advantages, including increased efficiency and more visually striking

outcomes. Through enabling real-time modifications through parameter adjustments, it significantly enhances the effectiveness of the design process (Hu *et al.* 2021).

Kansei engineering and semantic differential method

The concept of ‘Kansei engineering’ was initially introduced by Japanese researchers in the 1980s. It represents an innovative research methodology that integrates human emotional responses with engineering principles (Chi and Xie 2022). Kansei engineering focuses on quantifying human physiological and psychological responses, thereby fulfilling people’s expectations for sensory evaluation of products through scientifically grounded approaches (Ding *et al.* 2020). Since its inception, Kansei engineering has been extensively adopted in the design domain. Unlike traditional emotional design, it serves as a user-centered design support technique rooted in ergonomics (Wei and Liang 2022).

The Semantic Differential method is a research approach used to measure subjective perceptions by quantitatively analyzing the psychological meanings conveyed by linguistic symbols (Zhao *et al.* 2025). Its core mechanism involves constructing scales composed of pairs of opposing adjectives, such as ‘comfortable–uncomfortable,’ and asking participants to rate target objects along defined dimensions (Zhang and Zhang 2021). This method provides essential technical support for Kansei engineering. Through systematic scale construction, it transforms abstract sensory impressions into quantifiable and specific dimensions, enabling designers to precisely capture users’ emotional reactions to design elements such as color, shape, and material (Zhang 2020). Within the practical framework of Kansei engineering, the Semantic Differential method is commonly employed during the early stages of user research to establish mathematical models linking sensory vocabulary with design attributes (Feng and Jiang 2024). This form of correlation analysis not only uncovers cognitive structures embedded in users’ subconscious but also translates subjective ‘sensory needs’ into objective ‘design language,’ thereby facilitating the scientific realization of emotional value in product design. Consequently, the Semantic Differential method functions not only as a core measurement instrument within the Kansei engineering system, but also as a crucial methodological link between human emotional experiences and engineering technologies.

Data Collection and Questionnaire Distribution

The selection of Kansei imagery word pairs for plant patterns in bronze mirrors was primarily conducted through online resources such as relevant literature, pattern-related websites, and professional books. Offline methods included collecting Kansei evaluations from professors and students in the field of design. Initially, a total of 30 pairs of imagery words were collected. Those with overlapping meanings or a certain degree of ambiguity were excluded, resulting in 8 valid word pairs: Imaginary-Realistic; Diverse-Single; Interesting-Stereotyped; Gorgeous-Minimalist; Mysterious-Ordinary; Delicate-Solid; Classical-Modern; Repulsive-Lovable.

A total of 200 participants aged 20 to 60 years, with a balanced gender ratio (1:1), took part in the questionnaire. This age range reflects adequate aesthetic awareness and purchasing power. The survey used a five-point Likert scale, with each pair of Kansei image words placed at opposite ends. The closer the score is to one end, the stronger the association with that Kansei image. For example, in the pair ‘diverse-single,’ a score of 1 means ‘very diverse,’ 2 means ‘relatively diverse,’ 3 means ‘neutral,’ 4 means ‘relatively single,’ and 5 means ‘very single.’ To ensure data accuracy, logic-check questions were

included to eliminate random responses and filter out invalid questionnaires, improving overall data reliability.

RESULTS

Analysis of Data Results

Analysis of means

The questionnaire data were systematically tabulated and analyzed using SPSS to compute the mean values of Kansei image word pairs for each sample. These values are summarized in Table 2. In the table, scores closer to 5 indicate a stronger association with the corresponding Kansei image. According to the survey findings, among the bronze mirror plant pattern samples, A1, A3, and A6 exhibit imagery and minimalist characteristics; A2, A4, and A7 exhibit diverse and interesting characteristics; and A5, A8, and A9 exhibit dynamic and conventional characteristics. Preference for each sample was assessed using the ‘repulsive–liked’ semantic differential scale. Higher mean scores on this scale reflect greater user preference. Based on the results, the three most preferred patterns are A1, A5, and A8, indicating a high degree of overall user acceptance.

Table 2. Mean Table of Kansei Imagery Words

No.	Imagistic– Realistic	Diverse– Single	Interesti ng-Rigid	Exquisite– Minimalist	Mysterious– Normal	Careful - thick muddy	Classical - Modern	Rejection - Love
A1	4.41	4.12	3.21	4.45	3.65	2.65	4.61	4.21
A2	2.63	2.65	1.62	1.82	2.01	3.61	3.66	3.81
A3	4.07	4.21	3.61	3.25	4.4	3.44	3.28	3.29
A4	2.44	2.01	2.83	2.03	2.7	3.62	1.84	3.82
A5	3.81	4.4	3.68	3.8	3.61	4.28	2.83	4.22
A6	4.46	3.42	4.37	3.6	3.82	3.81	2.4	3.4
A7	2.28	1.83	2.61	2.83	1.83	4.46	1.61	3.61
A8	4.81	3.81	3.41	4.41	4.2	3.22	4.44	4.25
A9	4.2	4.41	4.63	4.41	4.02	4.21	1.03	3.92

Factor analysis

The Factor Analysis (FA) was employed specifically to address the core challenge in Kansei engineering: to reduce the dimensionality of the complex perceptual space and to identify the latent, underlying constructs that govern users’ emotional responses to the traditional patterns (Cai *et al.* 2025). This method transcends mere description of means and allows us to uncover the hidden psychological structure behind the eight semantic pairs. The rotation method (*e.g.*, Varimax) was applied to achieve a simpler, more interpretable factor structure, ensuring that the resulting factors are orthogonal and represent distinct perceptual concepts.

To systematically explore user group preferences and extract common Kansei factors, the survey data underwent factor analysis using SPSS, focusing on Tang Dynasty bronze mirror patterns. The Kaiser-Meyer-Olkin (KMO) measure yielded a value of 0.701, exceeding the acceptable threshold of 0.6 (Hu *et al.* 2021). Additionally, Bartlett’s test of sphericity produced a significance (Sig.) value less than 0.05, thereby confirming the appropriateness of the dataset for factor analysis (Huang *et al.* 2024). Principal component analysis was conducted to extract common factor variances, as displayed in Table 3. The

variance explained by the common factors for each original variable exceeds 0.6, indicating a substantial alignment between the variables and the underlying factor structure (Liu *et al.* 2023). A variance ratio closer to 1 reflects a higher degree of explanatory power of the model, thereby enhancing the interpretability and reliability of the dataset.

As presented in Table 3, the first two extracted common factors exhibited eigenvalues of 4.446 and 2.054, with variance contributions of 55.572% and 25.669%, respectively. The cumulative variance contribution was 81.242%, indicating that these two factors jointly accounted for over 81% of the total variance in the original dataset. According to the Kaiser criterion, only these two factors were retained, as the remaining factors demonstrated negligible explanatory power, despite the high cumulative variance (Wang and Wang 2025). Further analysis was conducted using component matrix analysis to assess the initial correlations between original variables and unrotated factors, facilitating the preliminary identification of variable-factor associations. Adjustments to factor directions were made to enhance interpretability and enable more precise semantic labeling (Zhan *et al.* 2024). Factor 1 comprises the Kansei imagery word pairs ‘Imagistic–Realistic,’ ‘Diversified–Single,’ and ‘Interesting–Rigid,’ which capture users’ perception of artistic expressiveness in the patterns. Accordingly, it is designated as the Visual Perception Factor. Factor 2 comprises the word pairs ‘Exquisite–Minimalist,’ ‘Classical–Modern,’ and ‘Rejection–Love,’ reflecting users’ preferences for modern interpretations of traditional design elements. Hence, it is labeled the Cultural Connotation Factor. The two extracted factors—‘Visual Perception’ and ‘Cultural Connotation’—not only provide a quantitative model for user perception but also resonate deeply with established design theories. The first factor aligns with Berlyne’s theory of aesthetic perception, which emphasizes complexity and novelty as key drivers of interest (Margarit *et al.* 2022). The second factor reflects the ‘Genetic Model of Cultural Symbols’, suggesting that successful traditional pattern derivation must balance historical continuity with contemporary relevance (Zhang *et al.* 2020).

Pattern A8 achieved an average score of 4.51 on the ‘Rejection – Love’ word pair—substantially higher than other samples—demonstrating the strongest emotional preference among users. Additionally, it performed prominently in the ‘Exquisite–Minimalist’ and ‘Classical–Modern’ pairs under Factor 2. This demonstrates that the pattern not only retains the classical charm and intricacy of traditional designs but also incorporates the simplicity and balance favored by modern aesthetics. Therefore, Pattern A8 is considered to be an ideal candidate for subsequent parametric pattern derivation design experiments.

Table 3. Table of Common Variance

Kansei Imagery Words	Original Value	Extracted Value
Imagistic–Realistic	1.000	0.949
Diverse–Single	1.000	0.842
Interesting–Rigid	1.000	0.960
Exquisite–Minimalist	1.000	0.838
Mysterious–Normal	1.000	0.892
Careful - Thick, Muddy	1.000	0.775
Classical - Modern	1.000	0.916
Rejection - Love	1.000	0.927

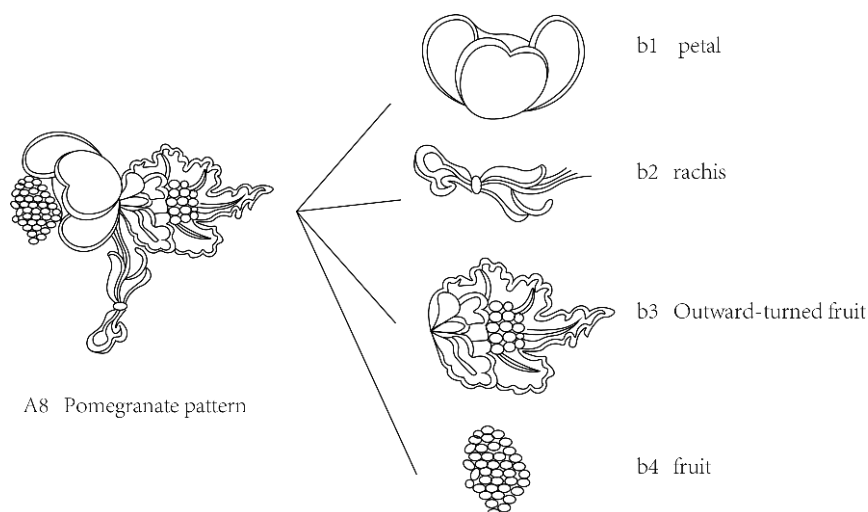
Table 4. Table of Total Variance Explained

Ingredient	Initial Eigenvalue			Extract the Sum of Squares of the Loads		
	Total	Variance Percentage (%)	Grand Total (%)	Total	Variance Percentage (%)	Grand Total (%)
1	4.446	55.572	55.572	4.446	55.572	55.572
2	2.054	25.669	81.242	2.054	25.669	81.242
3	0.923	11.531	92.773	/		
4	0.272	3.406	96.179			
5	0.175	2.188	98.367			
6	0.085	1.059	99.426			
7	0.035	0.432	99.858			
8	0.011	0.142	100.000			

Parametric Deduction Design of Decorative Patterns

Pattern A8 exhibited superior performance across multiple evaluation indicators, achieving the highest user preference ranking and demonstrating strong alignment with the aesthetic principles of outdoor equipment design, as evidenced by prior Kansei image experiments.

Therefore, a parameterized deduction design was carried out for the A8-Pomegranate Pattern. The A8 pattern is composed of four structural elements: petals, flower stems, everted fruits, and fruit bodies, all of which incorporate traditional Chinese cultural symbols. The fruit component symbolizes reproductive worship, conveying the desire for abundant offspring and blessings; the petals signify yang, while the fruits signify yin, illustrating the philosophical concept of yin-yang duality; the circular bronze mirror represents heaven, the pomegranate motif symbolizes earth, and the intertwining branches and vines signify the continuity of life. From a cultural connotation perspective during the Tang Dynasty, the pattern embodies auspiciousness and joy, conveying people's aspirations for a better life through its graceful form and dynamic posture. To support further design innovation, the primitive elements of the pomegranate pattern are disassembled and encoded for derivative design, as illustrated in Fig. 1.

**Fig. 1.** Pomegranate pattern structure diagram

A ‘battery pack’ module was created in Grasshopper to generate the A8 pattern’s shape and structure using parametric modeling. The vector graphics of the pattern’s four basic components were imported into Rhinoceros 3D. Key parameters—such as points, lines, angles, and quantities—were defined within the module. Through adjusting angle and quantity parameters systematically, multiple derivative graphic schemes were generated. As shown in Fig. 2, the Count parameter was set to 4, and the Angle ranged between 18 and 316°. In Grasshopper, input a rectangular battery pack, double-click the ‘X dimension’ and ‘Y dimension’ parameters of the battery, set the seat surface size, add ‘rounded curve’ batteries to smooth the corners of the rectangle, making it more in line with the shape of the seat cushion. Connect the output end of the ‘rectangular’ battery (the rectangular contour curve) to the input end of the ‘rounded curve’, double-click the ‘radius’ parameter of the ‘rounded curve’ to set the radius of the rounded corner. The battery generates gradient data-driven aperture size based on the ‘heat zone map’ of the seat surface (assuming the center of the buttocks contact is the high-temperature zone). The aperture size is larger in the central area and smaller in the edge area, as shown in Fig. 3. The organic hole pattern generated based on the lotus pattern can effectively guide air convection, significantly improve thermal comfort, and reduce weight. And in this process, the formal beauty of the pattern is unified with the functional benefits.

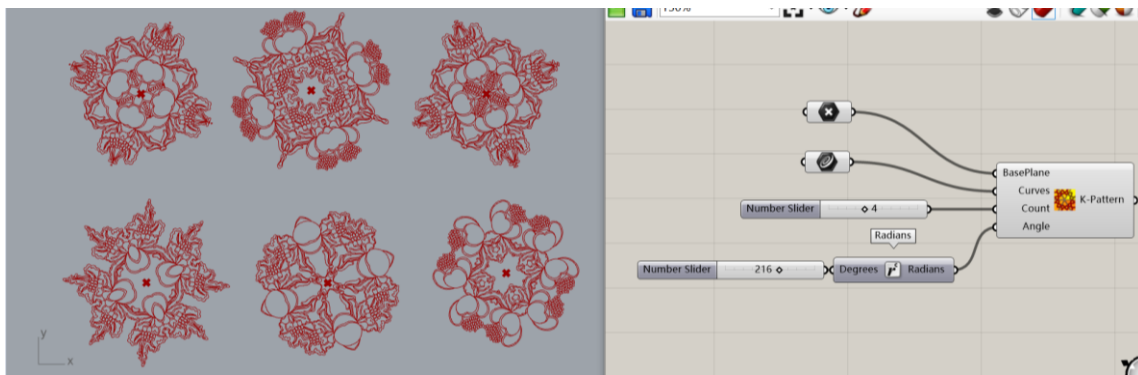


Fig. 2. Parametric deduction design of pomegranate pattern

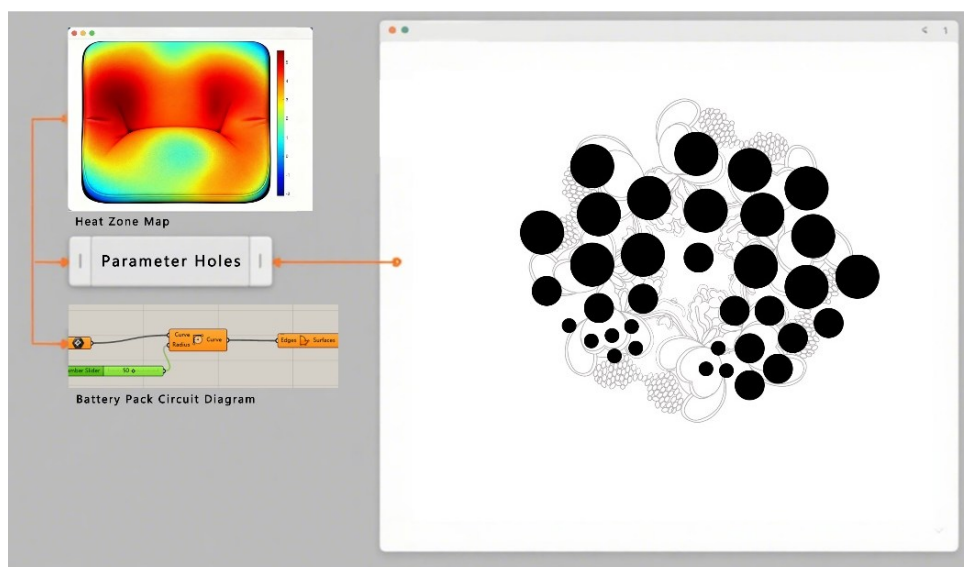


Fig. 3. Hot zone-driven parameter hole distribution map

DISCUSSION

Scheme Design

The vector graphics of the A8 pomegranate pattern, generated through parametric modeling, are imported into Adobe Illustrator for layout design. Based on these graphics, two outdoor leisure chair designs are developed as part of the ‘Vinea Collection’ series. ‘Vinea’ comes from Latin, meaning vine, and symbolizes the interwoven branch structure of the pomegranate pattern, evoking plant growth and natural circulation. ‘Collection’ emphasizes the adaptability and derivability of parametric patterns, aligning with sustainable design principles, as shown in Fig. 4.



Fig. 4. Outdoor lounge chair design scheme

Scheme 1 is ‘vine – biohole’, which takes the winding and branching structure of Tang Dynasty bronze mirrors as the core parametric design element. The Grasshopper algorithm is used to create a gradient density curve grid, with the grid diameter ranging from 0.8 to 2.2 mm. By simulating the heat zone map to drive the distribution of hole density and size, the parametric hole pattern design is placed at the bottom of the chair. The higher the temperature, the larger and denser the holes are, and the central area has more and larger pores, while the edge area has fewer and smaller pores. The parametric holes can remove the material to achieve the lightweight of the lounge chair, and it also can serve as a heat dissipation channel.

Scheme 2 is Vinea-EcoType, the deconstructed form of pomegranate seeds was used to create fractal perforated units with aperture sizes gradually changing from 3 mm to 8 mm. A large parametric pattern covers 40% of the chair surface and is placed on the upper right. Laser-etched text with micro-bumps, 0.3 mm in height, was applied on the lower left to improve grip in contact areas. The seed cluster hole pattern is topology-optimized to reduce weight while preserving compressive strength on the seat surface.

Both design schemes use plant-based fibers—such as bamboo, hemp, and soybean fiber—as surface materials. These fibers provide natural breathability and moisture absorption, enhancing comfort, especially in areas with fluctuating climates and varying temperature and humidity. Bio-based fibers improve thermal comfort by eliminating the stuffy feeling of traditional canvas chair surfaces. For the surface materials, the favorable attribute is their sustainable end-of-life option (compostability), after they have provided a

long service life (Zhang 2025). Moreover, they work together with the pomegranate pattern's gradient perforation to improve heat and moisture exchange efficiency. The seat frame can be made from a composite using coffee grounds and recycled polypropylene (PP). For the structural frame, the key sustainable attributes are its use of recycled and bio-based content and its engineered resistance to environmental degradation. The fibers are extracted from waste coffee grounds and processed through calcination and nano-powdering to retain their natural porous structure and active components. These fibers are mixed with bio-based polypropylene (Bio-PP) to create functional composite particles (Zhang 2023), which are synergistically modified such as lignin and UV agents to significantly improve durability, corrosion resistance and UV resistance, ensuring long-term outdoor durability (Li *et al.* 2021). The surface of the leisure chair frame has a unique texture of coffee grounds particles, emitting a light coffee aroma, which can combine aesthetics and functionality.

Design Evaluation

To enhance the practical applicability of the design schemes, the fuzzy comprehensive evaluation method was employed to systematically assess the two design alternatives (Wang *et al.* 2023). This evaluation framework, based on fuzzy set theory, is specifically developed to address complex decision-making problems characterized by ambiguity and uncertainty (Feng and Hu 2022). A total of 50 participants—including design experts and professors, industrial design students, and general consumers—were invited to assess and rate the design schemes, as presented in Table 5 (Wan and Wu 2025).

Three primary evaluation sub-indicators—functionality, sustainability, and cultural relevance—were established to construct the first-level indicator set $M = \{M1, M2, M3\}$, the evaluation scoring set $N = \{N1, N2, N3\}$, and the corresponding weight set W for each indicator, as illustrated in Fig. 6.

Table 5. Design Scheme Scoring Table

Evaluation Indicators	Plan 1			Plan 2		
	N1	N2	N3	N1	N2	N3
M1	38	10	2	28	18	4
M2	35	12	3	22	22	6
M3	33	15	2	20	23	7

Table 6. Description and Weight of Evaluation Indicators

Evaluation Index	Description of Evaluation Indicators	Evaluate and Score	Evaluation Weight
M1	Function	Satisfaction N1	0.4
M2	Culture	Ordinary N2	0.4
M3	Sustainable	Dissatisfaction N3	0.2

The fuzzy comprehensive evaluation model integrates the weighted indicators (W) and the fuzzy relation matrix (R) to calculate the satisfaction value $X = W \times R$. Based on this model and the corresponding mathematical formulation, the overall satisfaction degree was determined, with the results displayed in Table 7 (Bu *et al.* 2024). Each design scheme was evaluated using three qualitative ratings—‘satisfactory,’ ‘average,’ and ‘unsatisfactory’—which were quantitatively assigned values of 1, 0.5, and 0, respectively. Consequently, the evaluation vector is defined as $Y = (1, 0.5, 0)$.

Table 7. Score Survey Data Table

Scheme	Functional Satisfaction (%)	Sustainable Satisfaction (%)	Cultural Satisfaction (%)	Overall Satisfaction (%)
Plan 1	86.0	82.0	81.0	83.2
Plan 2	74.0	66.0	63.0	68.4

Based on the final satisfaction evaluation, Scheme 1 was determined to be the optimal solution, exhibiting superior performance in functionality, sustainability, and cultural relevance. It successfully captures the essential characteristics of traditional Chinese patterns while fulfilling consumers’ diverse expectations regarding functional utility, environmental responsibility, and cultural significance.

Implications for Commercial and Public Application

The findings and methodological framework of this study suggest significant potential across diverse application contexts, moving beyond the initial design concepts. As astutely observed, the parametric design toolkit enables two distinct commercial strategies. The first is the ‘Optimized Mass Appeal’ approach (Fig. 4), where Kansei analysis identifies a single, high-preference pattern for mass production. However, a more transformative paradigm is the ‘Personalized Portfolio’ approach. The present method can efficiently generate a vast array of design variations, catering not only to popular tastes but also to niche aesthetics. This aligns with the Long Tail theory of marketing (Jun and Xiao 2015), where online platforms can profitably offer a large number of unique items. Thus, the present framework provides a means for manufacturers to tap into micro-audiences, where a highly motivated minority might strongly desire a design that the majority dislikes, generating significant collective sales.

Furthermore, the cultural significance of these patterns makes them ideal for the production of cultural places in public spaces such as urban parks, historical monuments, and municipal squares. The developed themes can be incorporated into the overall identity of the public area as a tool for cultural promotion and tourism. For such permanent outdoor applications, the durability of the proposed material is crucial. While the design in Fig. 4 is suitable for domestic use, the coffee shell powder and lignin composites specified in this study are explicitly designed for high outdoor durability. Its mechanical properties, corrosion resistance, and aging resistance make it an excellent candidate for public furniture that can withstand years of harsh weathering and meet the aesthetic and functional requirements of urban use.

CONCLUSIONS

1. In response to the increasing demands for sustainability, functionality and cultural aesthetics in the design of outdoor leisure chairs, this study adopted contemporary design methods to interpret traditional Chinese cultural elements and formulate an overall design plan. In the initial stage, the semantic difference method was used to select the lotus pattern - a plant pattern that is highly suitable for outdoor aesthetics. Combined with parametric design, the aesthetic nature of the pattern was transformed into functionality applied in the product. This was not just simple parameter deformation but also converting the morphological characteristics of the pattern into parameter hole designs that affect physical properties, and applying them to the seat of the leisure chair to achieve lightweight and heat dissipation functions.
2. Bio-based plant fibers, including bamboo, hemp, and soybean fiber, were integrated with coffee grounds-recycled polypropylene (PP)-based materials to enhance overall performance. Parametric hole patterns minimize material consumption while enabling compostable degradation. Furthermore, the natural texture of coffee ground particles, when combined with parametric design elements, contributed to visual harmony and elevated the aesthetic appeal of outdoor leisure chairs.
3. This study has presented a design methodology that integrates cultural elements with parametric functional design and bio-material adaptation. Despite proposing an integrated design strategy that blends cultural aesthetics with functionality, this study has several limitations that also outline directions for future research. This research focused on parametric generation and design, but it did not conduct physical prototype testing or computer simulation verification of the functional benefits of the porous patterns. While the sample size aligns with standards for exploratory Kansei studies, it somewhat limits the generalizability of the findings. Future work will focus on conducting larger-scale cross-cultural user studies to validate and refine the perceptual image model, and to explore the potential of artificial intelligence to drive parametric design, thereby generating more diverse and optimal integrated aesthetic function solutions.

ACKNOWLEDGMENTS

The authors would like to acknowledge Shanxi Provincial Natural Science Foundation Project (2023-JC-YB-820) for providing funds for the first author to work on this project.

The authors utilized [DeepSeek] during the preparation of this manuscript for [improvement of grammatical fluency]. The final content and intellectual conclusions remain the sole responsibility of the authors.

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Article submitted: August 4, 2025; Peer review completed: August 30, 2025; Revised version received: September 9, 2025; Accepted: September 21, 2025; Published: September 26, 2025.

DOI: 10.15376/biores.20.4.9817-9832