Application of Regional Culture in Wooden Furniture Styling Design Based on Extension Semantics and Shape Grammar: Taking Su-Style Stool as an Example

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In view of the current problems of insufficient furniture innovation and uniform styling, this article introduces regional culture to conduct innovative strategic research on existing wooden furniture styling, trying to explore the connection between furniture and culture. Based on the methods of extension semantics and shape grammar, the traditional Chinese furniture Su-style stool is used as an example to demonstrate its feasibility. This work mainly applies extension semantics to illustrate regional culture and combines shape grammar to integrate the cultural elements and furniture shapes, thereby creating new wooden furniture forms with regional cultural characteristics. The article not only draws a genealogy chart of Suzhou's regional culture, but it also extracts a number of semantics and graphics to describe Suzhou cultural characteristics. It expands the graphics into relevant elements as a replacement library to replace some of the DNA genes of the stool by shape grammar, allowing the new stool to carry the cultural memories of Suzhou. Finally, the work generated three design practices, which were evaluated by excellence evaluation method. In conclusion, the article demonstrated that the combination of extension semantics and shape grammar can effectively guide the design of wooden furniture with regional cultural characteristics.

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INTRODUCTION

Regional culture is the essence of a city. It embodies the historical evolution and cultural accumulation of a city for thousands of years, and carries the cultural ideas, symbols, and practices of countless regional activities (Yu 2023). The integration of regional culture and furniture design can effectively increase the added value of furniture and improve the status quo of monotonous styles of works. However, the application of regional culture in wooden furniture is minimal. The main difficulty lies in the fact that regional culture is a type of implicit, complex, and virtual object, which is difficult to quantify and has no standardized expression and clear boundaries. Wooden furniture is a type of explicit and concrete object that can be characterized and quantified. It has a clear shape and outline, a touchable material, and a clear function. Among the furniture, the explicit furniture styling and the implicit regional cultural characteristics are a pair of contradictory issues. How to make furniture a carrier of culture? What kind of culture is

this? To what extent can wooden furniture styling reflect regional culture? Does the wooden furniture have cultural value? These issues are the focus of this article.

Based on the extendibility and conjugation of things (Yang and Cai 2016), extension semantics integrates semantic and graphical thinking into expanding or transforming contradictory issues in an orderly manner, allowing contradictory things to have the possibility of coexistence. Wu *et al.* (2023) used extension semantics to illustrate the semantics of Chengcheng embroidery culture and to obtain the maximum extension interval of the semantic graphics, thereby guiding the innovative design of embroidery patterns. Feng *et al.* (2024) combined extension semantics with Miao clothing patterns, extracted the cultural aesthetic characteristics, and built an extension semantic representation model to guide the innovative patterns of Miao embroidery. Sun and Ma (2024) applied extension semantics to extract the intentional words of the Han Dynasty bronze mirror patterns and to convert them into semantic graphics to generate new pattern factors with recognition and value. The above research has inspired new ideas for integrating regional culture into product styling using extension semantics. For example, Chen and Yang (2020) and Duan *et al.* (2021) separately studied the styling design of smart speakers and injection molding machines based on extension semantics. Both showed that extension semantics can quantify the characteristics and connotation of regional culture through rational data forms and transform them into graphic elements.

However, there is still a lack of in-depth research on how the cultural graphical elements are integrated with product styling. Far from storing biological genetic information, DNA (deoxyribonucleic acid) has now been extended to the field of industrial design for the inheritance of product design genes. With product family DNA and styling algorithms, shape grammar is able to create new shapes that maintain the original DNA gene after many graphics transformations and iterations (Lu *et al.* 2010). Many scholars have applied shape grammar to product styling design. For example, Chen *et al.* (2018) analyzed modern tram modeling from three aspects: modeling lines, geometric shapes, and shape combination relationships, and used shape grammar to extract typical features and deduce new shapes. Wang and Han (2024) used shape grammar to construct a group of line drawings for the shape scheme of the cloud-patterned health pot. Through eye tracking technology and the Likert scale method, they selected the final shape plan of the health pot. Zhang *et al.* (2022) was inspired from the form, color, and culture of the Tang Dynasty architecture, and applied shape grammar to the styling design of Xi'an bus station.

It can be seen from the above research that wooden furniture can also be integrated with the graphical elements of regional culture under the guidance of shape grammar. Therefore, the article explores a hybrid fusion method of extension semantics and shape grammar, which jointly promote the modern development and design of wooden furniture with regional cultural characteristics. Among them, extension semantics is used to illustrate Suzhou regional culture, and shape grammar is used to deduce the shape of Su-style furniture. Finally, the article demonstrates its feasibility by taking the Su-style stool as an example. Since the middle of the Ming Dynasty, skilled craftsmen in Suzhou area have used hardwoods, such as rosewood, wolfberry, and huanghuali, to make furniture. Although traditional furniture is produced in many places across the country, Suzhou, with its rich culture and developed economy, has higher requirements for furniture quality and has produced many classics. Regional and cultural characteristics give Su-style furniture a strong literati flavor, and it also became the origin of Ming-style furniture (Lan and Lan 2018). Therefore, it is recognized that the furniture produced in Suzhou is the authentic version of traditional furniture and is also called “Su-style” furniture.

EXPERIMENTAL

Data Research

Overview and analysis of Suzhou regional culture

As an ancient historical city, Suzhou has a strong historical heritage and inherent cultural genes. Whether it is the old sites, humanities, old streets, history, and culture, or the natural landscape integrated into the city, they all reflect Suzhou's unique urban temperament and cultural characteristics. These precious natural environments and cultural landscapes can not only enable people to appreciate the beauty of nature, but also gain a high degree of spiritual enjoyment and edification. This article sorts out the regional cultural characteristics of Suzhou from two levels: material culture and intangible culture, and then constructs a genealogy map of Suzhou regional culture (Table 1).

Table 1. Suzhou Regional Cultural Genealogy Map

Material Culture	Garden Culture	Landscape	Humble Administrator's Garden, Lion Grove, Lingering Garden, Master of the Nets Garden, Canglang Pavilion
	Architectural Culture	Ancient Town	Tongli Ancient Town, Shantang Street, Guanqian Street, Pingjiang Road
		Temple	Tiger Hill, Hanshan Temple, Chongyuan Temple, Beisi Pagoda, Baoen Temple, Lingyanshan Temple
		Landmark	Suzhou Museum
	Natural Landscape	Flowers	Peach Blossom, Wisteria, Crabapple, Lotus, Rose, Jasmine, Osmanthus, Plum Blossom
		Trees	Ginkgo Tree, Magnolia Tree, Loquat Tree, Poplar Tree
		Plants	Pine Leaves, Bamboo Leaves, Banana Leaves, Maple Leaves
	Cultural Attractions	Elements	Rockery, Flowing Water, Bonsai, Leaky Windows, Door Frames, Brick Carvings, Stone Bridges, Corridors
Intangible Culture	Diet Culture	Tea Culture	Order Tea, Boil Tea, Pour Tea, Sprinkle Tea
	Art Culture	Drama	Kunqu Opera, Pingtan
	Craft Culture	Apparel	Kesi, Suzhou embroidery, Hanfu, Cheongsam, Tie-dye, Batik, Valerian Dye
		Furniture	Su-style Furniture
		Manual	Velvet flowers, Entangled Flowers, Paper Cutting, Lacquer Fans, Feather Inlays, Filigree Inlays, Rubbings

Based on the cultural genealogy map, the article unearths five cultural beauties of Suzhou. (i) Suzhou has a diverse beautiful landscape, with flowers blooming all year round. In spring, cherry blossoms bloom and peach blossoms shine brightly; in summer, lotus flowers and dragonflies whisper in the pond; in autumn, the faint scent of osmanthus under the fallen leaves intoxicates the heart with refreshing sweetness; in winter, the plum blossoms bloom proudly in the snow, drawing thoughts back to the brilliant literary of Tang

and Song Dynasty. They give people an ever-changing scenery. Therefore, the first characteristic of Suzhou is the beauty of flowers.

(ii) Suzhou is world-famous for its ingenious garden art, among which the Humble Administrator's Garden, the Lion Grove, and the Liuyuan Garden are considered representatives of Chinese classical gardens. The overall design of the garden pursues the idea of "harmony between man and nature". Although most of the gardens are artificially created, they strive to remove the traces of artificial carvings and make them appear as if they were created by nature. Thus, the second characteristic is natural beauty.

(iii) Suzhou is a typical Jiangnan water town. Whether it is the well-preserved old streets, such as Shantang Street and Pingjiang Road, or the ancient temples and towers, such as Huqiu and Hanshan Temple, these traditional buildings are typical Jiangnan buildings, and the raised angles of the eaves create a unique Chinese classical architectural aesthetics, reflecting the unique classical beauty of Suzhou.

(iv) The swimming clouds are the softness of the blue sky, the well-proportioned houses are the freedom and tranquility among the green water and green mountains, the small bridges and flowing water are swaying with the mottled tree shadows, and the green brick and curved eaves tell the quiet beauty of the years. Most of the ink paintings are inspired from the scenery of Suzhou. Outlined with ink lines and filled with water rhyme, it is full of nature without embellishment. The scenery and objects in Suzhou are laid out in an almost line drawing technique. Therefore, the fourth characteristic of Suzhou is its beautiful artistic atmosphere.

(v) The narrow alleys and uneven green bricks illustrate the slow life of old Suzhou. The aroma of rice noodles from plum blossom cakes fills the streets and alleys. The tricycle drivers start chatting about their new day's work. The grandmothers at the bridgehead talk about summer and weave jasmine into bracelets. Tourists holding lotus flowers are intoxicated by the sound of heavy and light oars. Listen to a Pingtan song by the river as the night rises and be enchanted by Wu Nong's soft words in silence. Therefore, the fifth characteristic is the beauty of slowness.

Overview and analysis of traditional Chinese stool

The traditional Chinese furniture system can be roughly divided into five categories: chairs and stools, desks, beds, cabinets, and other categories. Among them, stools belong to the chairs and stools category (Wang 2008). A stool mainly refers to a seat without a backrest or armrests. The seemingly simple stool is meticulous in structure and decoration, covering almost all the structural and decorative features of traditional furniture, which can be divided into two categories: waisted stools and waistless stools (Fig. 1). The most significant feature of waisted stools is the inward retracted part between the seat surface and the legs and feet. This part is the "girdle". The legs do not land straight, but in an inverted or everted horseshoe shape. The legs and feet of the furniture are directly connected to the surface without any indentation, which is called waistless structure. The ends of legs do not rotate but fall directly to the ground (Niu and Zhao 2022).

The shape of a traditional stool is closely related to its structure, which can be deconstructed into multiple parts, such as the stool surface, the "yazi" (in Chinese), the legs and feet, and auxiliary components. The stool surface adopts the method of "assembling a mortised-and-tenoned frame with the central panel". The specific process is as follows: the frame is composed of four pieces of wood to form a rectangular frame. The long pieces of wood are tenoned at both ends, called "tenon-bearing frame member"; the short pieces are cut with mortises, called "mortise-bearing frame member". There is a groove all around

the inner edge of the wooden frame and the tongue of the panel is inserted into it (Wadum 1998). To strengthen the board, one or more wooden strips will be added underneath, called "penetrating transverse brace" (Fig. 2). Yazi is the component at the intersection of the vertical wood and the horizontal wood of traditional furniture. Not only does it reinforce the load bearing, but it also has the function of beautiful decoration. The patterns usually reflect the characteristics of traditional culture, so the "yazi" part is the core of the design plan.

Fig. 1. The waisted stool and waistless stool

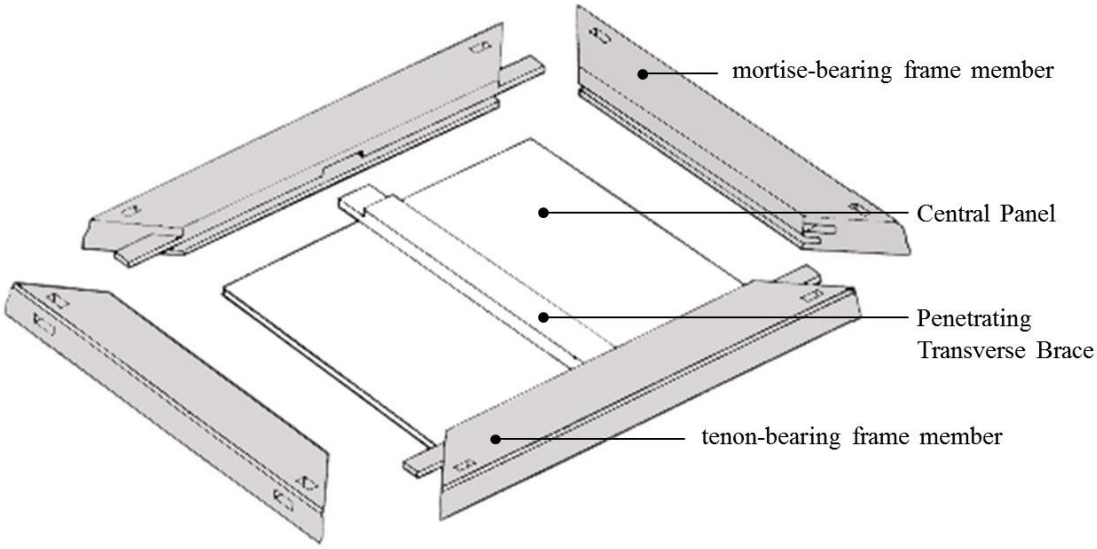


Fig. 2. The structure diagram of stool surface

The legs and feet are the important load-bearing part of the stool and have little decoration. In terms of shape, there are straight legs, inverted horseshoes, everted horseshoes, *etc.* The foot's connection with the stool surface is usually achieved using a mortise and tenon structure. The protruding part is called the tenon, the recessed part is called the mortise, and the engagement of them plays a role in connecting two wooden components (Liang *et al.* 2021). Taking the waisted stool as an example, the embracing-shoulder tenon is the most common one. It is to cut out 45° sloping shoulders from the legs

and feet below the waist, and chisel mortises to combine with the 45° sloping shoulders and tenons of the "yazi". There is also "hanger tenon" on the oblique shoulders with a small top and a large bottom, and it is inserted into the notches on the back of the "yazi", thereby making the junction structure strong and stable (Fig. 3) (Wang *et al.* 2014). The long and short tenons on the end are designed to be combined with the stool surface. The long tenons are installed on the "tenon-bearing frame member", and the short tenons are installed on the "mortise-bearing frame member".

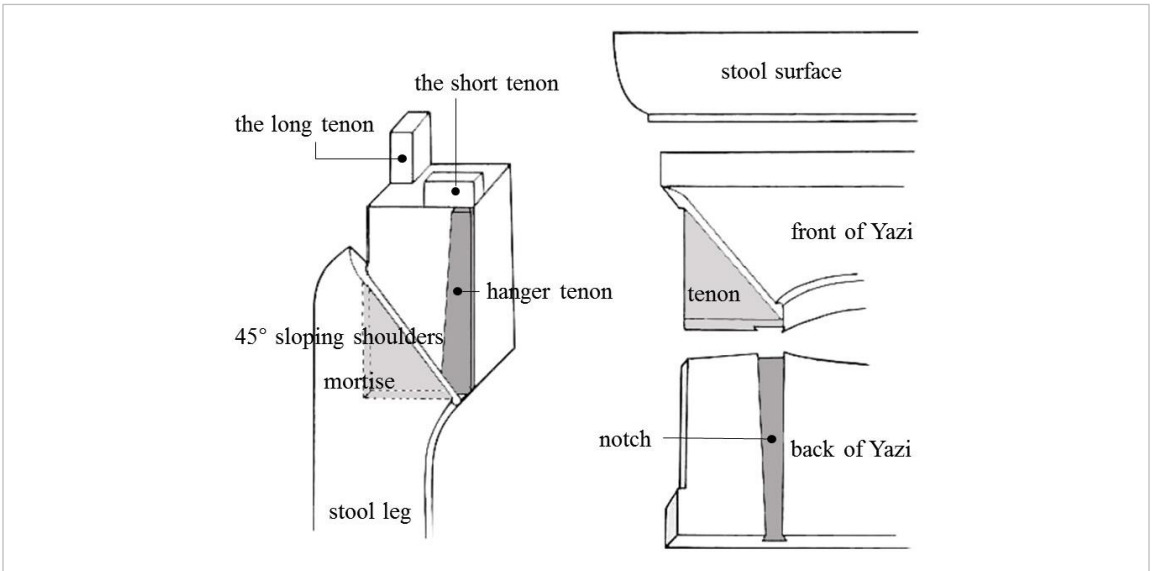


Fig. 3. The structure diagram of embracing shoulder tenon

In addition, there are some auxiliary components, such as stretcher, giant's arm braces, leg-encircling stretchers, pillar-shaped strut, "kazi hua", the base, *etc.* (Fig. 1). Stretcher, giant's arm braces, leg-encircling stretchers, *etc.*, are small structural parts that enhance the stability of the legs and feet. A pillar-shaped strut assists in pressure distribution and increases the stiffness of the stretchers. "Kazi hua" is the special decorative component carved from wooden blocks and embedded in the middle of two horizontal pieces, which is also called "knot decoration". The base can provide a horizontal fulcrum at the bottom of the stool legs.

Methods

Introduction and expressions of extension semantics

Extenics is a new discipline founded by Chinese scholars led by researchers Cai Wen and Yang Chunyan of Guangdong University of Technology (Yang *et al.* 2016). The basic idea of this discipline is to use formal models to study the possibilities of things expansion and the methods of innovation, and to use them to solve contradictory problems and turn incompatibilities into compatibility. Based on extenics, extension semantics integrates semantic thinking and graphic thinking in the expansion process (Duan *et al.* 2019). According to the theory in extenics, triples (object, feature, and magnitude) can be used to quantitatively describe the expanded thinking process of Suzhou regional culture. Its basic element expression is:

$$R = (O, C, V) = \begin{bmatrix} O & C_1 & V_1 \\ & C_2 & V_2 \\ & \cdots & \cdots \\ & C_n & V_n \end{bmatrix} \quad (1)$$

where "R" is the extension primitive, "O" is the Suzhou regional culture, "C" is the cultural characteristics, and "V" is the magnitude obtained by evaluation. "C1, C2, ... Cn" represent "n" characteristics of regional culture, "V1, V2, ... Vn" represent the magnitude corresponding to each cultural characteristic. In the extension theory, "V" is defined as an extension interval, which is the main analysis target. "V" consists of two values "Vx" and "Vy", where "Vx" represents the degree of association between characteristic "C" and object "O", $Vx \in (0,1]$, $Vx1 + Vx2 + \cdots + Vxn = 1 (n \geq 1)$. "Vy" indicates the social value of characteristic "C". The calculation method of "Vx" and "Vy" draws on the research results of many scholars (Qin *et al.* 2021; Gao and Ma 2022; Nie and Wang 2023; Miu *et al.* 2024). The specific formulas are as follows:

1. Assume that the scoring interval used for the correlation between each characteristic and the object is [1,t], the number of people participating in the scoring is α, and the frequency of obtaining score b is $\int b$, then:

$$\overline{V_x} = \frac{\sum_{b=1}^{t} b \int b}{\alpha \frac{t(t+1)}{2}},\ b \in [1, t],\ \int b \in [1, \alpha] \quad (2)$$

2. Assume that the social value of each characteristic adopts a scoring interval of [1, r], the number of people participating in the rating is β, and the score of the nth volunteer is k_n, then:

$$\overline{V_y} = \frac{\sum_{n=1}^{\beta} k_n}{\beta},\ k_n \in [1, r],\ \ n \in [1, \beta] \quad (3)$$

3. The relevance degree "Vx" and the social value "Vy" are important factors in the evaluation of the extension interval "V". "V" reflects the design value of the characteristic. Its expression is shown in Eq. 4:

$$V = \overline{V_x} \cdot \overline{V_y} \quad (4)$$

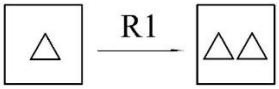
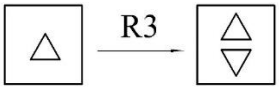
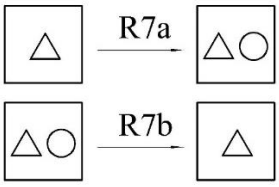
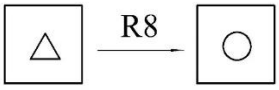
Introduction and rules of shape grammar

In 1972, George Stinney and James Gipps proposed a theory of shape operations - Shape Grammar (SG for short) based on previous research. The formula of shape grammar is SG = <S, L, R, I>, where "S" represents a finite set of initial shapes, "L" represents a labeled finite set of shapes, "R" represents a finite set of derivation rules, "I" represents the initial shape, while SG represents the finite shape set derived after the derivation rule operation (Yue *et al.* 2023). The shape grammar system is one of the earliest algorithm analysis systems in the field of modeling design mathematics (Liu 2020). In terms of product innovation and evolution, the deduction of shape grammar plays an important role in design (Braida 2019).

According to the derivation method, the rules of shape grammar can be divided into derivatives and generatives (Table 2). Derivative deduction generates new shapes by mutating and changing parts of the original shape. It includes 6 basic commands: Copy (*R1*), Rotate (*R2*), Mirror (*R3*), Scale (*R4*), Move (*R5*), and Bezier Curve (*R6*). Generative deduction generates new shapes by changing and replacing the local content of the original shape. It includes 2 basic commands: Add and Delete (*R7*) and Replace (*R8*). It is worth

noting that in the generative rules, whether it is an Add Command or a Replace Command, new graphics need to be incorporated or used as a replacement. The original shape in the article is the DNA of traditional Chinese stools, while the new graphics are derived from elemental symbols derived from Suzhou culture through graphic semantics.

Table 2. Derivative and Generative Inference Rules of Shape Grammar

Category	Command	Number	Illustration
Derivative Deduction	Copy	R1	
	Rotate	R2	
	Mirror	R3	
	Scale	R4	
	Move	R5	
	Bezier Curve	R6	
Generative Deduction	Add and Delete	R7a R7b	
	Replace	R8	

Extension Semantics to Illustrate Suzhou Regional Culture

Characteristic semantics and evaluation of Suzhou regional culture

Digging into the material and intangible culture underlying the city, the authors concluded that Suzhou's regional culture has unique flower beauty, natural beauty, classical beauty, artistic beauty, and slow beauty. It has been flowing with elegance for thousands of years, traveling through ancient and modern times. Through investigating Suzhou's development history and experiencing Suzhou's living customs, five top feature semantics were selected that can represent Suzhou's cultural characteristics: fragrant, natural, classical, picturesque, and leisurely. A formal extension model was constructed based on the semantics, see formula (5). These rich semantics are the representative characteristics of Suzhou's regional culture and the source of motivation for the innovative

design of Su-style stool, laying a preliminary research foundation for the development of products with regional characteristics.

$$R = \begin{bmatrix} \text{Suzhou Culture} & \text{Fragrant} & V1 \\ & \text{Natural} & V2 \\ & \text{Classical} & V3 \\ & \text{Picturesque} & V4 \\ & \text{Leisurely} & V5 \end{bmatrix} \quad (5)$$

The authors selected 14 people (7 men and 7 women) who have a certain understanding of Suzhou culture in Suzhou and other areas to conduct a 5-level Likert scale questionnaire survey, asking each respondent to evaluate the relevance degree of the above 5 feature semantics and Suzhou culture. The score that best reflects the cultural characteristics of Suzhou is 5 points, gradually decreasing, and the score that least reflects it is 1 score. According to formula (2), the average value of the correlation between different semantics and Suzhou culture can be obtained, as shown in Table 3.

Table 3. Relevance Degree Assessment of Semantics and Suzhou Culture

Characteristic Semantics	Number of People					$\overline{V_x}$
	5 points	4 points	3 points	2 points	1 point	
Fragrant	3	2	1	3	5	0.176
Natural	5	3	2	2	2	0.233
Classical	7	4	2	0	1	0.276
Picturesque	2	0	5	4	3	0.171
Leisurely	0	2	6	2	4	0.162

Another 5 product designers (numbered a1, a2, a3, a4, a5) with a certain understanding of traditional Chinese furniture were selected to score the above five semantics. The survey used a 7-point Likert scale. The feature semantic that best reflects the cultural value of the Suzhou area is scored 7 points, gradually decreasing, and the semantic that least reflects the cultural value is scored 1 point. According to formula (3), the average cultural value of different semantics can be obtained, as shown in Table 4.

Table 4. Cultural Value Assessment of Semantics

Characteristic Semantics	Score					$\overline{V_y}$
	a1	a2	a3	a4	a5	
Fragrant	3	3	4	5	6	4.2
Natural	5	5	6	3	4	4.6
Classical	5	7	5	3	4	4.8
Picturesque	4	2	3	6	5	4.0
Leisurely	3	4	3	5	3	3.6

The extension interval of Suzhou cultural semantics was calculated according to Eq. 4, and the calculation results are shown in Table 5. The descending order of semantic extension intervals is as follows: classical, natural, fragrant, picturesque, and leisurely. It can be seen that "Classical" can better reflect the cultural connotation and cultural value of Suzhou's region, has a larger extendable design range, and can provide guidance for the modeling design of Su-style furniture.

Table 5. Extension Interval Evaluation of Semantics

Semantics	Fragrant	Natural	Classical	Picturesque	Leisurely
$\overline{V_x}$	0.176	0.233	0.276	0.171	0.162
$\overline{V_y}$	4.2	4.6	4.8	4.0	3.6
V	0.7392	1.0718	1.3248	0.684	0.5832

Semantic graphics and evaluation of Suzhou regional culture

The Suzhou regional cultural connotation displayed by the stool is mainly based on the shape. Cultural symbols decomposed from graphics that match the semantics are integrated into the design. Use diagrammatic thinking to convert graphic knowledge into visual representations. In the shape design of Su-style stool, it is necessary to combine the visual modeling language, graphic logic, cultural connotation in the art field and rational design thinking. Through graphically decomposing the above five semantics, the article extracted three symbolic graphics (h1, h2, h3) from each semantic (Table 6).

Table 6. Graphics of Each Semantic

Number	Semantics	h1	h2	h3
1	Fragrant			
2	Natural			
3	Classical			
4	Picturesque			
5	Leisurely			

In the process of expanding cultural characteristics into semantic graphics, it is distinguished from the "Vx" and "Vy" of "V" in Eq. 4. Assuming that the semantic graphic

is “h”, then “Vhx” describes the degree of recognition of the graphic and the cultural characteristic semantics. The larger the value, the higher the correlation between the graphic and the semantics; “Vhy” describes the design value of the graphic. The larger the value, the higher the value of the graphics for product styling design. Three designers were invited to evaluate the recognizability and design value of each semantic graphic, with an evaluation range of 1 to 5 points. The average value can be calculated respectively from Eqs. 2 and 3, as shown in Tables 7 and 8. Based on the scores, the extension design interval of each graphic can be calculated according to Eq. 4, as shown in Table 9.

Table 7. Relevance Degree Evaluation of Graphics and Semantics

Designer Number	Illustration Number	Fragrant	Natural	Classical	Picturesque	Leisurely
1	h1	1	3	4	4	4
	h2	4	1	5	2	1
	h3	2	5	5	2	2
2	h1	2	2	4	4	3
	h2	3	3	5	2	2
	h3	1	5	1	3	2
3	h1	3	3	5	4	1
	h2	3	3	4	1	4
	h3	2	5	3	3	3

Table 8. Design Value Evaluation of Semantic Graphics

Designer Number	Illustration Number	Fragrant	Natural	Classical	Picturesque	Leisurely
1	h1	2	4	3	4	4
	h2	4	3	4	4	3
	h3	4	4	5	2	3
2	h1	2	4	4	2	3
	h2	5	4	5	5	3
	h3	1	5	5	5	4
3	h1	1	2	4	3	4
	h2	3	4	5	4	4
	h3	2	4	2	2	3

Table 9. Extension Interval Evaluation of Semantic Graphics

Graphic Number	Semantic Graphics Magnitude				
	Fragrant	Natural	Classical	Picturesque	Leisurely
h1	0.22	0.59	1.06	0.8	0.65
h2	0.89	0.57	1.45	0.48	0.52
h3	0.31	1.44	0.8	0.53	0.44

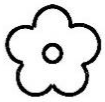
According to the calculation results of the extension interval of the semantic graphics, it can be seen that the extension design interval of the second graphic in "Classical" was the largest. However, the third graphic in "Natural" was also very large. In the process of illustrating features, the article discovered that some feature elements with semantic graphics can be fused. Therefore, assuming that the serial number of the semantics in Table 9 is "*u*" and the serial number of the graphic is "*m*", then "h_{um}" is the "m-th" graphic of the "u-th" semantic in Table 6. The maximum result after fusion is: h23 + h32 = 1.44 + 1.45 = 2.89.

Shape Grammar and Construction of DNA Gene Library

Constructing the replacement library map of Suzhou cultural elements

According to the evaluation of semantic graphics in Table 9, the feature types of the 3rd graphic of the 2nd semantic and the 2nd graphic of the 3rd semantic can be fused. According to the bamboo leaf indicated by h23 and the plum blossom window indicated by h32, their symbols are extracted and abstracted. Finally, each symbol evolved into 3 cultural elements: h23 = {P11, P12, P13}, h33 = {P21, P22, P23}. At the same time, the elements are decolorized to facilitate the simplification of outlines. The replacement library map of Suzhou cultural elements is shown in Table 10.

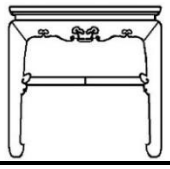
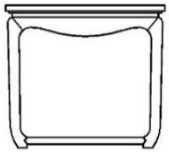
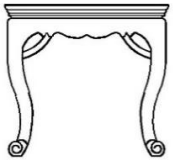
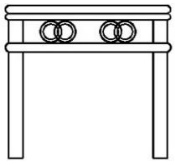
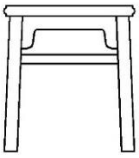
Table 10. Design Value Evaluation of Semantic Graphics

No.	Semantic Graphics	Indication	Symbol	Cultural Elements		
h23		Bamboo Leaf		P11 	P12 	P13 
h32		Plum Blossom Window		P21 	P22 	P23 

Constructing the DNA gene library map of traditional Chinese stools

Because the top views of the stools are basically the same and the side views are almost identical in shape, only the outline lines of the front views that best show the style of the stools are extracted. After sufficient data research in the early stage, the article constructed a DNA gene library map for traditional stools, which is shown in Table 11 (the prototype in the table is taken from "Ming-style Furniture Appreciation"). A batch of typical and graceful traditional Chinese stools were selected to cover as many different types as possible. A total of 10 stools, 7 with the waisted structure and 3 with waistless structure. They were used as gene pool factors and were coded as S, S={S1, S2, S3, S4, S5, S6, S7, S8, S9, S10}.

Table 11. The DNA Gene Library Map of the Traditional Stools

Code	S1	S2	S3	S4	S5
Name	Ming dynasty huanghuali rectangular stool with waist and cross braces	Ming dynasty huanghuali rectangular stool with waist and stretchers	Qing Dynasty mahogany square stool with waist and base stretchers	Ming dynasty huanghuali square stool with waist and convex apron and bulging leg	Ming Dynasty rosewood square stool with waist and convex apron and bulging leg
Prototype					
Line Extraction					
Code	**S6**	**S7**	**S8**	**S9**	**S10**
Name	Ming dynasty huanghuali rectangular stool with waist, three curved legs and stretchers	Ming dynasty huanghuali square stool with waist, three curved legs and giant's arm braces	Ming dynasty huanghuali waistless square stool with leg-encircling stretchers and double loops	Ming dynasty huanghuali waistless square stool	Ming dynasty huanghuali waistless square stool with leg-encircling stretchers and pillar-shaped strut
Prototype					
Line Extraction					

RESULTS

S3 was randomly selected as the original shape from the traditional stool DNA gene library map, and then 5 patterns were selected as replacement genes encoding P11, P12, P21, P22, and P23 from the graphical semantic elements replacement library map. The auxiliary software Adobe Illustrator was used for grammatical deduction. The process of deduction and the establishment of the plan do not consider color matching factors to avoid becoming an interference factor in the later evaluation stage. Combined with the structure of stool S3, which is mainly composed of four major structures: stool surface, yazi, legs,

and base stretchers, the yazi is coded as d, d = {d1, d2, d3, d4, d5, d6, d7}, and the legs are coded as e, e = {e1,e2,e3,...,e14,e15, e16}(Fig. 4).

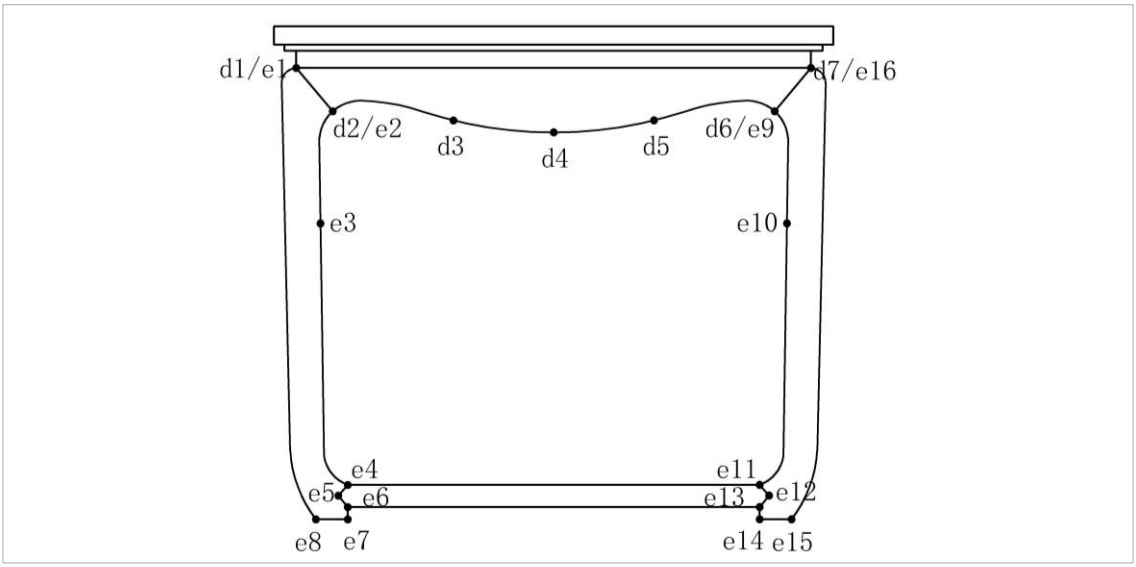


Fig. 4. The deconstruction diagram of the stool. Yazi is coded as d, d = {d1, d2, d3, d4, d5, d6, d7}. The legs of the stool are coded as e, e = {e1, e2, e3, ..., e14, e15, e16}.

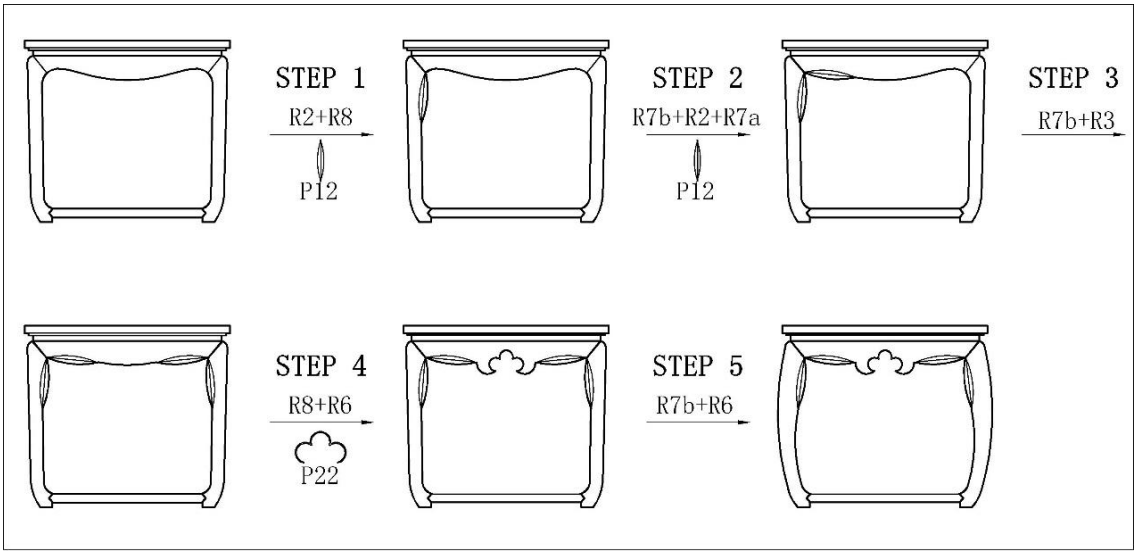


Fig. 5. The derivation steps of Plan A

Plan A

The procedure for development of Plan A can be summarized as follows: Analyze the continuity of the structure and the symmetry of the lines in the original shape of S3, and select P12 and P22 in the replacement library map to generate the deformation process of Plan A. The process of the deduction is shown in Fig. 5.

Step 1. First, enter P12, execute command number R2, and rotate P12 15° clockwise with the top as the center. Then, execute command number R8 to replace a section of lines e2-e3;

Step 2. First, execute command number R7b to delete a section of line d2-d3. Then, enter P12, execute command number R2, and rotate P12 80° counterclockwise with the top as the center. Execute command number R7a to add P12 to the line segment just deleted;

Step 3. First, execute command number R7b to delete the two lines d5-d6 and e9-e10. Then, execute command number R3 to mirror the two line segments d2-d3 and e2-e3 with the center line of the original graphic as the axis of symmetry, and fall on the previously deleted line segment;

Step 4. First, enter P22, execute command number R8, and replace the two lines d3-d4-d5. Then, execute command number R6, and use the Bezier curve to connect the nodes at both ends of P22 with the d3 and d5 nodes.

Step 5. First, execute command number R7b to delete the two lines e1-e8 and e3-e4. Then, execute command number R6 to use Bezier curves to expand the curvature of the leg and foot lines while fitting the original line segments.

Plan B

Likewise, Plan B involves the following procedures: Analyze the continuity of the structure and the symmetry of the lines in the original shape of S3, and select P12 and P23 in the replacement library map to generate the deformation process of Plan B. The process of the deduction is shown in Fig. 6.

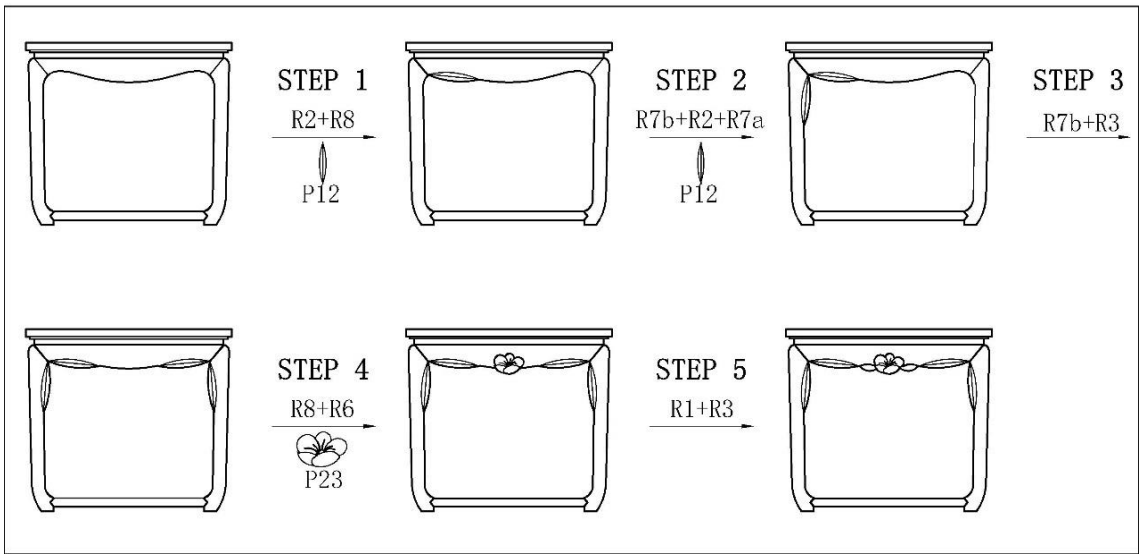


Fig. 6. The derivation steps of Plan B

Step 1. First, enter P12, execute command number R2, and rotate P12 80° counterclockwise with the top as the center. Then, execute command number R8 to replace a section of line d2-d3;

Step 2. First, execute command number R7b to delete a section of lines e2-e3. Then, enter P12, execute command number R2, and rotate P12 15° clockwise with the top as the center. Execute command number R7a to add P12 to the line segment just deleted;

Step 3. First, execute command number R7b to delete the two lines d5-d6 and e9-e10. Then, execute command number R3 to mirror the two line segments d2-d3 and e2-e3 with the center line of the original graphic as the axis of symmetry, and fall on the previously deleted line segment;

Step 4. First, enter P23, execute command number R8, and replace the two lines d3-d4-d5. Then, execute command number R6, and use the Bezier curve to connect the nodes at both ends of P23 with the d3 and d5 nodes;

Step 5. First execute command number R1 to copy the Bezier curve generated in the previous step. Then execute command number R3 to mirror it around the horizontal line.

Plan C

The development of Plan C involved the following steps: Analyze the continuity of the structure and the symmetry of the lines in the original shape of S3, and select P11, P21, and P22 in the replacement library map to generate the deformation process of Plan C. The process of the deduction is shown in Fig. 7.

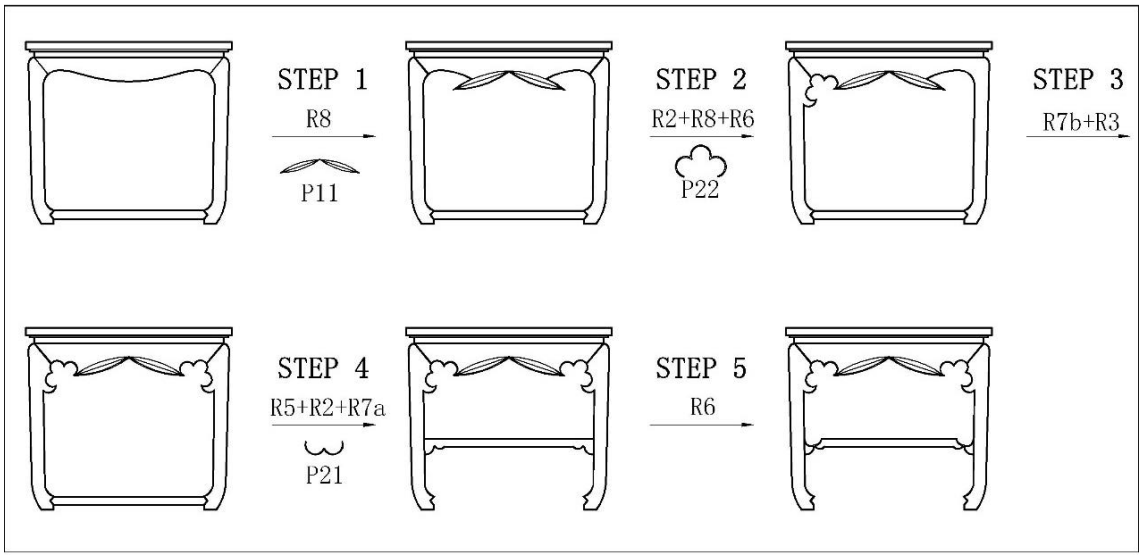


Fig. 7. The derivation steps of Plan C

Step 1. First, enter P11, execute command number R8, and replace the two lines d3-d4-d5;

Step 2. First, enter P22, execute command number R2, and rotate P22 45° counterclockwise with the left end as the center. Then, execute command number R8 to replace the two lines d2-d3 and e2-e3. Execute command number R6, and use the Bezier curve to connect the node at the left end of P22 with the e3 node;

Step 3. First, execute command number R7b to delete the two lines d5-d6 and e9-e10. Then, execute command number R3 to mirror the two line segments d2-d3 and e2-e3 with the center line of the original graphic as the axis of symmetry, and fall on the previously deleted line segment;

Step 4. First, execute command number R5 and move the two lines e4-e11 and e6-e13 to the middle of the leg and foot. Then, enter P21, execute command number R2, and rotate P21 30° counterclockwise and clockwise with the left end as the center of the circle. Then, execute command number R7a to add it to the left and right ends of the stretcher;

Step 5. Execute command number R6, use a circle to connect the top of the stretcher and the legs of the stool, and smooth the nodes.

DISCUSSION

Evaluation and Reflection

The excellence evaluation method is a method for evaluating the advantages and disadvantages of objects, strategies, methods, *etc.* It can quantify the evaluation results and more comprehensively reflect the comprehensive level of the target object, thereby meeting the needs of users (Fu and Che 2023). The excellence evaluation method is used to comprehensively evaluate the above three plans from three indicators of cultural expression (*Q1*), pattern innovation (*Q2*), and visual beauty (*Q3*), to obtain the best solution and optimize the product shape. The scoring value interval of the evaluation is set to [1,g], in which λ individuals rate it on average, and the n^{th} rater scores the plan as "k_n". Calculate the average score of the three design solutions, and the formula is as follows:

$$\overline{Q1} = \frac{\sum_{n=1}^{\lambda} k_n}{\lambda},\ k_n \in [1, g],\quad n \in [1, \lambda] \tag{6}$$

The average value of *Q2* and *Q3* is calculated in the same way as the formula (6). Finally, the comprehensive score Q of the design solution is calculated based on the addition of the three scores. The expression is:

$$Q = \overline{Q1} + \overline{Q2} + \overline{Q3} \tag{7}$$

Ten local residents in Suzhou were invited to conduct a questionnaire survey. The investigators rated the design plan based on their personal feelings, with a score ranging from 1 to 5 points. The higher the average value of the design plan, the higher its recognition. The summary of comprehensive evaluation results is shown in Table 12.

Table 12. Comprehensive Evaluation Results

Object	$\overline{Q1}$	$\overline{Q2}$	$\overline{Q3}$	Q
Plan A	3.5	3.8	3.6	10.9
Plan B	3.8	3.4	4.1	11.3
Plan C	3.9	4.0	3.5	11.4

Modeling and Rendering

Fig. 8. Image rendering of Plan C

The quantitative calculation results show that the comprehensive score of Plan A is 10.9, that of Plan B is 11.3, and that of Plan C is 11.4. In summary, it can be seen that Plan C has the highest score. Therefore, design optimization and modeling rendering are carried out around Plan C.

CONCLUSIONS

1. The first phase of this work involved data research on Suzhou regional culture, traditional Chinese stools, and Su-style furniture. Second, a set of semantic expressions were extracted and a few semantics were evaluated to express the cultural characteristics of the Suzhou area. Third, graphic thinking was incorporated as a way to expand, thereby transforming tacit knowledge into explicit representations of graphics. Then, rational data forms were used to evaluate the relevance degree of multiple semantics and specific graphics, and finally to obtain the graphics with the largest extendable design interval. Fourth, several cultural elements were abstracted and simplified from the graphics as a backup library to replace parts of the DNA genes in the original stool. Fifth, the article used shape grammar to continuously incorporate regional cultural elements in the process of deriving and evolving the styling design of the stool, thereby creating Su-style furniture with regional cultural characteristics.
2. The advantage of extension semantics is that it can mine the regional culture connotation contained in wooden furniture, transform perceptual features with subjective intentions into graphic elements, and present them in the form of rational data. It transforms the explicit furniture shape and implicit regional cultural characteristics into non-contradiction problems and improves the problem of insufficient connection between the wooden furniture and culture. With the help of shape grammar, it can also ensure that the stool can still inherit the DNA genes of the original shape after many iterative evolutions with Suzhou cultural elements.
3. The innovation strategy of wooden furniture design not only relies on breakthroughs in technology and materials, but also relies on the design inheritance of traditional culture. Only when a furniture reflects the regional characteristics of Chinese culture can it stand out internationally. The inheritance of culture is the responsibility of every designer. In addition, regional Su-style furniture is much more than designing a shape, but designing a lifestyle that belongs to that place, just like walking in the gardens or listening a Pingtan song along the river in Suzhou. It advocates an original, natural, and slow rhythm of life, allowing everyone to use furniture with the intention of experiencing the beauty of life and living poetically on the earth.

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