

Innovative Design of Hakka Civil Furniture Product Modeling Based on Shape Grammar

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Abstract

The development of Hakka household has a long history and profound cultural heritage, and these material and cultural wealth are the advantages of our modern furniture design innovation. However, since the moderns of furniture in Ming and Qing Dynasties, it has not formed its own characteristics. In order to endow products with special shapes and style images to create unique brands, and to quickly produce a series of design schemes in a short period of time, this paper puts forward an innovative design method of Hakka household products modeling based on shape grammar. After analyzing the typical features of traditional patterns, the core primitive is extracted as the initial shape, and combined with popular elements, a new pattern design scheme is generated by using shape grammar. According to the deduction rules and design constraints, and taking the results as the design basis, the scheme group is designed, screened and evaluated, and the optimal solution is obtained, and the scheme refinement and effect display are carried out. In the end, taking the design of kitchenware as an example, the functionality of kitchenware products is unified with the meaning of traditional culture, and the modeling style and cultural connotation of kitchenware products are enriched.

Keywords

Shape grammar; Hakka civil furniture; Make product type; Innovative design.

1. Introduction

Hakka is one of the Han ethnic groups. Hakka culture is based on the Central Plains culture, inherits the cultural foundation of the Han nationality in the Central Plains, absorbs and integrates the local cultural characteristics in the course of hard work and reproduction after migrating to Fujian, Guangdong and Jiangxi, and gradually forms and develops, and becomes a new quality culture after the variation of Chinese culture. In order to meet people's different aesthetic needs, modern furniture design will use different patterns and other elements to design and decorate, and Hakka decorative elements with unique aesthetic characteristics also provide absorption and application of elements for furniture design, and become an important path for innovative furniture design.

At present, the focus of furniture design is mostly on modeling, technology, craft, etc., lacking the excavation of history, culture, and spirit [2-3], which leads to the duplication of existing products and lack of new ideas. In the field of design, shape grammar is often used for product innovation and evolution. Literature [4] puts forward the concept of product family DNA, which provides some methodological guidance for the rapid design of continuing product style from the perspective of industrial design; Literature [5] puts forward a DNA reasoning method of product design based on shape grammar, which can generate a series of design schemes while maintaining the inheritance of brand style; Literature [6] combined with orthogonal analysis method to design the fitness function of interactive genetic algorithm for product modeling

design; Porcelain is used as input in reference [7]. The limitations of this kind of research and application are: due to the limitation of the initial products, the degree of freedom of obtaining products by grammar deduction is not high, and the semantic control of products is insufficient, so the applicability to furniture industry is low. Therefore, a deduction model is constructed, which takes shape grammar as the main evolution tool and combines product semantics and user research related knowledge. Based on specific morphological prototype input, the model constructs the path of morphological prototype evolution, and provides guidance for innovative design and prototype evolution of Hakka household products.

2. Brief Introduction of Shape Grammar

"Shape Grammar" was first proposed by George Steiny, a professor of computer design in the Department of Architecture, Massachusetts Institute of Technology, in 1972. His article "Introduction to Shape and Shape Grammar", published in Environment and Planning B magazine, completely described the concept and structure system of shape grammar, and laid the theoretical foundation of shape grammar.

Specifically, shape grammar is a computer aided design method, which can automatically generate new shapes according to certain rules according to people's design ideas and requirements. Shape grammar is a quadruple, namely:

$$SG = (S, L, R, I) \quad (1)$$

Where S is a finite set of shapes; L is a finite set of symbols; R is a finite set of rules, and the form of rules is: $\alpha \rightarrow \beta$; I is the initial shape, and all shapes produced by shape grammar should be derived from the initial shape through shape rules. The basic situation is shown in Figure 1.

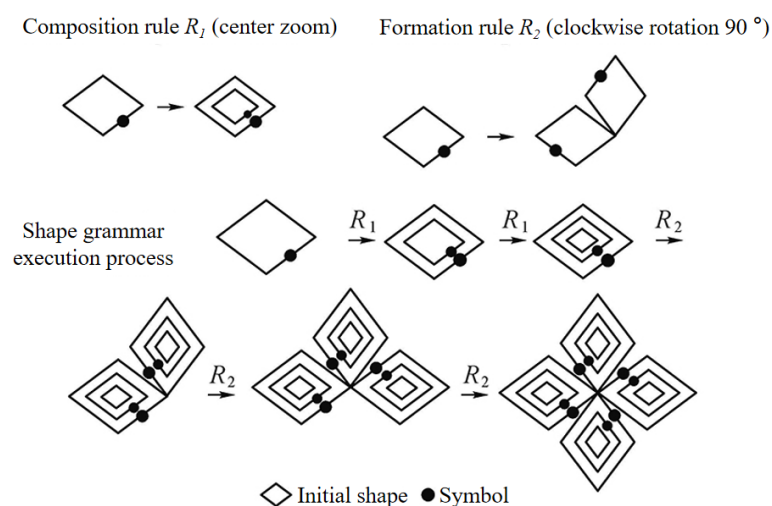


Figure 1. Execution process of shape grammar

In the process of executing shape grammar, we should pay special attention to the following three points [8-9]:

- (1) Different initial shapes, shape rules and the order of executing shape rules are the same, but the shapes produced are different.
- (2) The same initial shape, but different shape rules, will result in different shapes after executing shape grammar.

(3) The same initial shape and shape rules, but the order of executing shape rules is different, the shapes produced after executing shape grammar are also different.

3. Aesthetic Principles of Household Product Modeling Design

The reasonable construction of the basic elements of an excellent product design is very important. How can we construct the basic elements? This is a problem that product designers have been discussing for a long time. Form creation of household products should not only focus on appearance, but also organically integrate practicality and form, technology and art, material function and aesthetic function into the whole product, so that people can not only meet functional needs, but also enjoy aesthetics.

3.1. Rhythm and Rhythm

Rhythm and rhythm are the expression of dynamic formal beauty, and are a rhythmic form with regularity, repeatability and continuity. Rhythm refers to regular repeated movement, and in this repeated movement, there are strong and weak changes, time changes and regular changes, which show the law of things' own movement.

Static rhythm and rhythm mainly use regular morphological changes to express a sense of movement, which is soft and orderly, and gives people a lively feeling at the same time. Static rhythm and rhythm are more rational, and this rational beauty will make household products have a sense of order and rhythm, forming the overall effect of proper relaxation and quietness in motion. In the process of repeated appearance, the elements of household product form design show organized rhythm of increasing, decreasing, weakening and strengthening, which has a sense of movement, vivid and harmonious effect, and is easy to attract people's attention visually. The elements restrict each other, showing a variety [10]. This diversity exists in the change of shape, line, direction, position, hue or texture, and has vivid effect of live wave.

3.2. Contrast Harmonic

Contrast and harmony is a common rule of formal beauty in the form design of household products. Contrast refers to juxtaposing the forms with obvious morphological characteristics, with one side setting off the other; Harmony refers to emphasizing the commonness between its constituent elements in the form, so that the two sides of the contrast weaken the differences and tend to be coordinated.

Material is the material basis in the shape design of household products, and the texture and characteristics of different materials can produce different finishing effects. The rational use of these materials not only enriches the formal aesthetic feeling of products, but also shows the connotation of products and brings people different psychological feelings. For example, the natural simplicity of wood, the hardness and heaviness of steel, the ethereal psychedelic of glass and so on. The contrast and harmony of materials are mainly manifested in the contrast of texture changes, hardness and transparency of materials, etc.

The role of color in household product design should not be underestimated. Color has a direct impact on people's senses and emotions. Consumers generally choose their favorite colors when their functions, prices and appearance are roughly the same. Color contrast is mainly carried out from the aspects of purity, warmth and warmth, lightness and darkness, saturation, etc. Color can not only strengthen the final effect of product form, and make the product and environment achieve harmony and unity, but also has great aesthetic feeling.

3.3. Unified Change

Among aesthetic rules, unity and change are the most flexible and versatile aesthetic forms with the most expressive force of various performance arts. Any product design is composed of points, lines, surfaces, colors and textures.

In the form design of household products, the unification of lines gives people a neat aesthetic feeling, but excessive unification makes people feel monotonous and boring. If these lines are properly changed according to aesthetic rules, such as changing the direction of lines according to certain rules, changing the length of lines according to certain standards, changing the distance between lines according to certain intervals, changing the width of the lower line according to a certain proportion, and turning straight lines into curves, etc., all these will have unexpected effects.

In the form design of household products, the unity of body is to comprehensively use elements such as point, line and surface, and make use of differences in shape, color and quality to obtain vivid effects of products from the perspective of three-dimensional space. According to the design orientation of the household product form, a certain component element of the form is used to unify it to all parts of the product form. In the form design of a series of complete sets of products, special attention should be paid to the changes and unification between each product, between each part of the product and between the part and the whole.

4. Innovative Design of Hakka Civil Furniture Product Modeling

4.1. Pattern Generation Based on Hierarchical Shape Grammar

Layer is a common structured function in CAD tools. Combining this function can reduce the complexity of shape grammar in the process of computer pattern generation. Specifically, after analyzing the complex graphics in a single layer, it is decomposed into simple graphics in several different layers, thereby reducing the time requirement of sub-shape generation and greatly reducing the number of derivation layers of shape derivative tree.

Formally, based on the original shape grammar, a layered shape grammar is defined as a function with five components [11], which is written as:

$$LSG = (S, L, R, I, La) \quad (2)$$

In which S, L, R, I is the same as the definition in traditional shape grammar SG ; And La is a finite set of n layers.

The layered shape is a group of n marked shapes $(\delta_{La_0}, \delta_{La_1}, \dots, \delta_{La_{(n-1)}})$, that is, each layer has a marked shape. The layered shape is shown in Figure 2, in which the plum blossom in the lower left corner represents the mark of rule application.

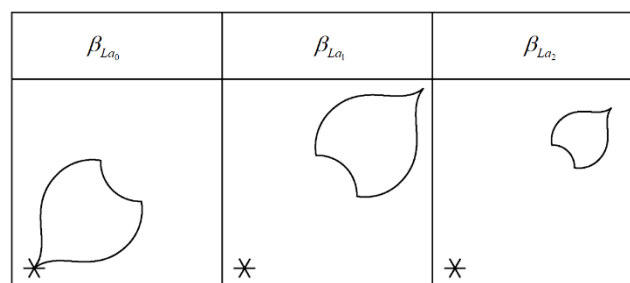


Figure 2. Layered shape

The layered shape γ when the transformation rule τ exists makes $\tau(\alpha_{La_i})$ a sub-shape of γ_{La_i} , i.e. q , for each layer La_i . The applied transformation rule τ must be the same in each layer. The remaining algorithms of marking shapes expand the layered marking shapes in a similar way, and apply the arithmetic in parallel to the shapes of each layer.

4.2. Construction of Product Form Deduction Model

Shape grammar provides a form deduction idea, but in practical product design, it still relies mainly on the designer's personal experience to transform the design scheme. In order to improve the design efficiency and intelligence, and give full play to the specialty of machine learning, this paper combines genetic algorithm with shape grammar. Genetic algorithm (GA) is an adaptive and global probability search algorithm which simulates the genetic and evolutionary process of survival of the fittest and survival of the fittest in the natural environment [12]. It has been successfully applied in different fields such as industry, economic management, transportation and so on.

The whole deduction process is divided into three stages.

(1) Morphological feature analysis

Starting from the target products, the similar products under the brand are investigated, and the experienced designers summarize the appearance elements of products from historical product samples, and design eye tracking experiments based on them, and then extract the dominant features of products based on the brand.

(2) Execute shape grammar

According to the dominant features of the product extracted in the morphological analysis stage, the shape grammar of the target product is formulated, the initial shape is determined and the inference rules of the shape grammar are specified. After the prototype of the product form is completed, the parameters affecting the product form characteristics are coded, and as individuals in the next genetic algorithm, the form deduction is carried out in the interactive evolution system.

(3) Innovative scheme generation based on interactive genetic algorithm

According to the shape grammar, the feature parameters are encoded to generate the initial population. The strategy of combining fitness function with score of every generation is adopted. Designers score every fixed algebra, and the interval algebra is set together with other genetic operation parameters before the interactive genetic algorithm starts. In the genetic operation cycle of non-designer scoring, the fitness value is evaluated by the fitness function aiming at the functional requirements of the target product, which can meet the functional constraints of the design scheme while carrying out morphological innovation design.

4.3. Example Verification Design

In addition to giving priority to the target use in the design of kitchenware products, modeling design is the second most important step to be considered. It is more convenient to use traditional cultural elements for reference in the design of kitchenware products. The reason why traditional culture is difficult to be applied to modern products in a practical way is that there is a big time gap between history and modernity. The design process involved in this paper is as follows: firstly, the functional structure of the product is analyzed; secondly, the traditional cultural prototype in the database is analyzed and the elements are extracted based on the analysis results of the product; secondly, the shape grammar is applied to the extracted element modeling features; finally, the color material is applied to the newly combined product; finally, the final scheme is selected through evaluation. This time, the target is a Hakka style kitchen ware.

According to the result of modeling deduction, the principle of scheme formation and evaluation. After comprehensive consideration and re-refining of elements, some changes can be added to the handle shape in combination with the extension of the phoenix head element in Chinese traditional culture. Therefore, the raised dragon head and phoenix head are initially used as handrails at both ends of the casserole. The advantage of this design is that traditional cultural elements are used in it, and certain practical value is played in the use process.

(1) Color and texture design

Color and pattern texture can be extracted and used in the new design according to Chinese traditional cultural habits and elements list. However, it is necessary to pay attention to the fact that green and coffee color may have some uncomfortable effects in kitchen utensils, and it is necessary to fine-tune the approaching color. Using the main colors, patterns and materials extracted from the traditional element prototype corresponding to the initial shape, several schemes are obtained, as shown in Figure 3.

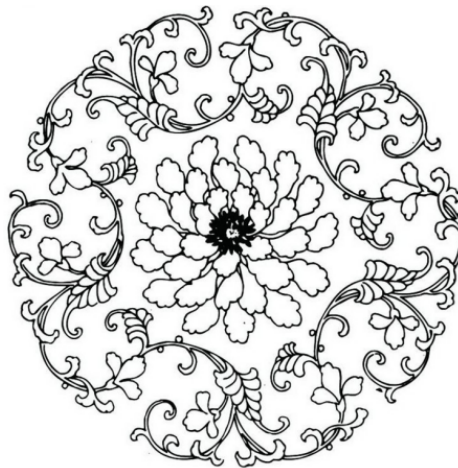


Figure 3. Group flower texture map

(2) Size refinement

For casserole, when used, it is mainly liquid food such as water, while solid food is much less than wok. The capacity of casserole used by 1-2 people is about 2600ml. According to the size of the casserole in the market, the main dimensions of the designed casserole are 24cm in diameter and 15cm in height (Figure 4).

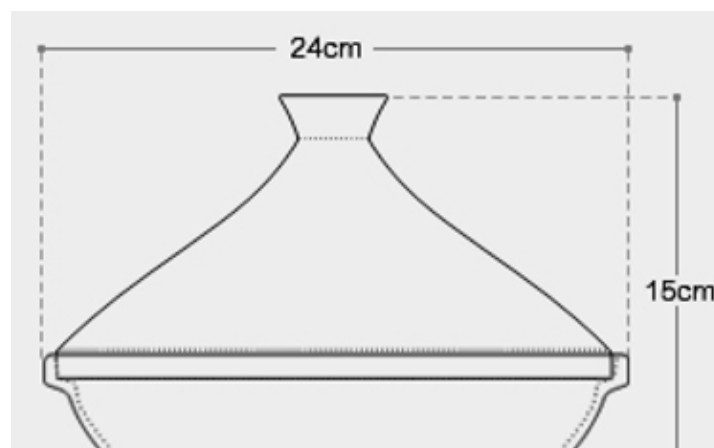


Figure 4. Size refinement diagram

According to the screening results of renderings, combined with the characteristics of simplicity, miniaturization and semantic clarity of kitchen products in investigation and analysis. Figure 4 shows the final scheme of refining the size details.



Figure 4. Final scheme diagram

(3) Programme evaluation

The functions of stewing in casserole, placing, heat preservation and handling can be satisfied. The design of the size can be held conveniently, and the shape of the handle has a downward bending curve at the outer end, which has more suitable stress. Ceramic materials can be integrally molded or metal materials can be welded and molded. The handle can be formed by metal casting or ceramic bonding.

5. Summary

Hakka traditional furniture is the carrier of Hakka culture, which has a long history, rich connotation, exquisite craftsmanship, beautiful patterns and rich characteristics. The development and production of Hakka traditional style furniture plays an important role in developing furniture with Chinese local characteristics, building Hakka household brands, rallying Hakka people's hearts and carrying forward Hakka excellent cultural traditions. Furniture product design based on morphological prototype evolution path can be clearly expressed by the deduction model described in this paper. Through shape grammar deduction, semantic analysis and user research, the model designs furniture products based on a certain shape prototype. Through this model, we can get products with certain style images and accord with users' cognition. On the basis of satisfying the use demand of furniture products, it also endows them with symbolic meanings related to prototype.

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