Mass Customized Furniture Product Design

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Abstract: With the improvement of people’s living standard, mass customization production model has been the trend of the furniture industry. A model of furniture product design and assembly for customization is proposed. It can decompose customers’ needs and transform them into homologous modules set in the structure tree. This process will not only save manpower and resources, but also improve enterprise efficiency. In this article, an instance was given in order to verify the correctness of product design and assembly processes based on product family of mass customization.

Keywords: mass customization; module; function-structure

1 Introduction

As customer needs change faster and faster, lags in the traditional mode of production make furniture companies cannot be good to keep up with changes of customer demands. Developing a new product model is crucial for furniture companies to make success in the increasingly fierce market competition.

Furniture design model based on mass customization is intended to provide personalized products and services meeting customer demands using the cost and time of mass production [1]. This model can significantly improve the design efficiency. A collection of product parts will be created by the production configuration model based on function-structure mapping. This process will meet the needs of individual customers to produce differentiated products that enable companies to have a lasting competitive advantage of differentiation. This paper will take an example of the design of TV cabinet.

2 Build product model based on function-structure mapping

In mass customization, product platform and product family architecture are constituted of functional view, technical view and structural view. Functional view describes the functional requirements and its decomposition of product family; technical view describes the technical solutions to satisfy the functional requirements; structural view describes the physical structure of product family. Proposed axiomatic
design theory divides design into four domains: customer domain, functional domain, physical domain and process domain [5]. The relationship between these domains is sequence mapping. From theories above, a product configuration model is created based on mapping from functional domain to structural domain.

2.1. The composition of functional module and structural module

Functional module: TV cabinet features are divided into three sub-functions: appearance, placement and convenience. Appearance includes style and vein; placement includes basic placement function, horizontal separation and vertical separation; convenience includes movable space, grip, support, touch ground, close and other sub-functions.

Structural module: according to the function-structure mapping principle above, the sub-functions of TV cabinet, such as appearance, placement and convenience, are mapped into decoration, main structure and accessory [2]. Main structure can be broken down into frame, clapboard and vertical board, respectively, to achieve the functions of basic placement, horizontal and vertical separation. Accessory can be subdivided into a drawer, handle, cabinet leg, kick plate and glass door panels and other modules, to achieve the corresponding sub-functions of the functional domain.

2.2. Function-structure mapping principle

According to set theory, when functional domain and structural domain have a mapping from functional expression space to structural expression space, it is demonstrated that two spaces have some function. Functions within the functional domain are decomposed into sub functions to make up a functional tree. These sub functions can be mapped into different structural units. The structural units can be used as a modular, need to be considered in function, structure and other sides.

2.3. Generalized module matrix planning for product family

According to the modular design principle, the product design transforms user’s needs into product functional model. With the decomposition of the functional tree, the total product FR (Functional Requirement, FR) can be made up of multiple functional modules called FRi:

\[
\text{FR} = [\text{FR}_1, \text{FR}_2, \ldots, \text{FR}_i, \ldots, \text{FR}_n] (i \in N)
\]

In Equation above: \( \text{FR}_i \rightarrow \text{PC}_i \)

PC (Product Component, PC) is the set of generalized structural modules; each functional module can be mapped to multiple generalized structural modules. According to product modular matrix planning method, generalized modular product family planning matrix is shown in Figure 2. Each column, there is a family of model-based products which main parameter changes from small to large [4]. Each row, modules make up a product module chain [3].
3 Functional decomposition and define the structural modules

Through the functional tree of TV cabinet, the customer’s needs are finally decomposed as follow:

\[ FR = \begin{bmatrix} [\text{Modern Style}] & [\text{Bamboo Texture}] & [\text{Basic Placement Function}] & [\text{Horizontal Separation} \times 2] & [\text{Horizontal Separation}] & [\text{Moveable Space}] & [\text{Grip}] & [\text{Support}] & [\text{Close}] \end{bmatrix} \]

According to the set of sub-function above, the TV cabinet’s assembly components collection is \( PC = [PC_1, PC_2, PC_3] \), where PC1 is decoration modules, PC2 is pattern modules, and PC3 is accessory modules. PC1 and PC3 will be added after the completion of PC2. The set of PC2 is shown as follow:

\[ PC_2 = \begin{bmatrix} \begin{bmatrix} \text{apical board, bottom board, back board, left side plate, right side plate} \end{bmatrix} & \begin{bmatrix} \text{left vertical board, right vertical board, clapboard} \end{bmatrix} \end{bmatrix} \]

In PC2, the side plates and vertical boards are the same height.

4 Build assembly relationship graph and assembly relationship matrix

An assembly relationship graph can be drawn based on the relationship between the components of PC2. It is an undirected graph, forming with nodes and edges of connected nodes, in which nodes represent components and edges mean the correlation between these components, which is the assembly relationship between two different components. According to the assembly relationship of the parts in PC2, the TV cabinet’s assembly relationship graph is shown in Figure 3.
In Figure 3, number 1-8 represents apical board, left side plate, left vertical board, right vertical board, right side plate, bottom board, back board and clapboard. According to the assembly relationship graph, a matrix of N rows and N columns expresses the relationship of assembly process can be created, shown as follow:

\[
R_{n \times n} = \begin{bmatrix}
\eta_{11} & \cdots & \eta_{1n} \\
\vdots & \ddots & \vdots \\
\eta_{n1} & \cdots & \eta_{nn}
\end{bmatrix}
\]

In this matrix, \( \eta_{ij} = 1 \) shows there is a related surface or edge between node i and j, otherwise, \( \eta_{ij} = 0 \) shows that there is no related surface or edge between node i and j. If \( i = j \), in order to facilitate the calculation, that it is completely unrelated, and its value is 0. It can be seen that this matrix is a symmetric matrix. According to the TV cabinet assembly relationship graph, an assembly relationship matrix in which 8 rows and 8 columns shown as Figure 4:

5 Conclusion

Through the product model of function-structure mapping, layers of functional modules are decomposed from users’ needs. This process combines the design and assembly process together, saving manpower and resources so as to improve enterprise manufacturer efficiency. However, this article did not involve the technology areas, much further researches still to be done.

References
