Preliminary Study on the Innovative Design of Original Bamboo Furniture Based on the Coordination Evolution Rules of Subsystems of TRIZ Theory

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Abstract: The original bamboo furniture is green and environmentally friendly and is a good substitute for wood. But at present, the design of original bamboo furniture develops slowly and its added value is not very high. By applying the coordinated evolution principle of subsystems in TRIZ technology evolution theory, this research makes a preliminary exploration on the innovative design methods of original bamboo furniture in form and structure in the purpose of bringing inspiration and new thinking to the innovative design of original bamboo furniture. In this way, promoting the development of original bamboo furniture design faster and better.

1. Introduction
Today, when we strongly advocate sustainable development, bamboo plays an important role in the sustainable development of the environment. Green furniture is a trend in furniture design and development. Green furniture design attaches importance on the environmental attributes of products (removability, recyclability, maintainability, reusability, etc.) and takes them as design objectives. While meeting the requirements of environmental objectives, it also ensures the proper functions, service life, quality and other requirements of furniture. Raw bamboo furniture is mainly made of bamboo because bamboo has the advantages of fast growth speed, high yield and good wood properties. The use of bamboo can effectively relieve the environmental pressure caused by wood shortage. In addition, the original bamboo furniture is recyclable, and the materials can be reused after recycling. However, at present, the original bamboo furniture in China is simple in shape, single in product category and lack of innovation in design. By using the TRIZ theory coordinated evolution rule, it provides innovative ideas for the design of original bamboo furniture, which can promote the development and utilization of it, increase the added value of original bamboo furniture design, enrich the variety of bamboo furniture products, and at the same time alleviate the shortage of wood resources pressure.

2. The Overview of the TRIZ System Coordination Evolution Rules
The evolution of technology systems is moving in a more coordinated direction with each other. That is, the various components of the system fully utilize their respective functions while maintaining coordination, which is also a necessary condition for the entire technical system to perform its functions.
The manifestation of coordinated evolution is: shape coordination; structural coordination; coordination of performance parameters; coordination of work rhythm, frequency; coordination of location, etc. The coordination between each subsystem of the technical system, the parameters, and the parameters of the system and the parameters of the super system are the basic conditions for the system to realize its functions.

In the field of furniture design, product improvement, appearance design, structure and function all follow the same biological systems process of production, growth, maturity and aging, which has its intrinsic rule to follow. The coordinated evolutionary rule of TRIZ system is one of the core contents of TRIZ theory, and it is also the main theory to reveal the laws of various components in the technical system. The technological system has always been in evolving situation. Most of the new furniture products in the world are developed on the basis of the old products. So, it is practical to analyze the existing furniture market and make a prediction of the future design direction for the purpose of promoting the development and design of a new generation of furniture products. This paper not only makes a correlation analysis of the original bamboo furniture design cases, but also summarizes the innovative methods in shape and structure coordination based on the the coordinated evolutionary rule of TRIZ system.

3. Application Analysis of Original Bamboo Furniture Innovative Design

With the improvement of quality of life, people's aesthetic requirements for furniture are getting higher and higher. More and more designers have endowed original bamboo furniture with different connotations through their understanding of the design. They have brought new vitality to the innovative design of the original bamboo furniture. In the design of existing original bamboo furniture, there are some innovative design cases at home and abroad in many aspects. Most of these cases have carried out innovative design from the combination and application of the structure, form, culture and materials of the original bamboo furniture. For example, the bamboo stool named "Ching" (Figure 1, 2 and 3) designed by Taiwan designers Lin Ta-Chih and Hsieh Yi-Fan integrates the two most common materials of bamboo and cement. Taking the toughness and structure of bamboo as the breakthrough point, a new configuration was designed. The knot inside the bamboo is also applied to the small structure of strengthening the stool, which not only innovate the shape of the stool, but also guarantees the stool's function of carrying weight. The curve on the bamboo stool is natural and graceful, and the bamboo parts are also very suitable which gives people a very comfortable visual feeling. In addition, regarding the original bamboo furniture design form, Taiwan designer Chengzong Fan and master craftsman Gaoming Chen designed a bamboo chair named "Flow" (Figure.4). The designer made use of the bending characteristics of bamboo to create a natural flowing feeling of the furniture, making it look more vital and dynamic.
Through the analysis of the above original bamboo furniture cases, it is found that the original bamboo furniture design attaches importance to the use of the cultural meaning of bamboo and the original form of bamboo, while considering the characteristics of the bamboo itself, such as exploring the internal composition and structural form of the original bamboo for the purpose of seeking the possibility of developing and utilizing the different parts of bamboo under their different physical states. Therefore, we should recognize the basic characteristics of bamboo as a furniture material, and at the same time make use of the aesthetic characteristics of bamboo’s elegance and grace to design furniture products conforming to modern life.

4. The Application of Coordination Evolution Rule in Original Bamboo Furniture Innovation

In the above-mentioned original bamboo furniture cases, the shape design of furniture cases not only takes into consideration the characteristics of the bamboo itself, but also combines points, lines and surfaces to form a harmonious relationship between the shape, material, function and structure of the furniture shape design, which is in line with the coordinated evolution rule of the TRIZ system. In the analysis of furniture design cases and the coordination rules, we should pay attention to how to achieve such a systematic coordination relationship, so that we can design the better original wood furniture. TRIZ system coordinated evolution method is a universal tool for leading innovation. In the design process of the original bamboo furniture, according to the essential requirements of the original bamboo furniture design, it can be classified into two aspects as showed below.

4.1 The Coordination of original bamboo furniture design

The elements of the original bamboo furniture form include points, lines and surfaces. In geometry, the position of a point can be determined as long as coordinates are given, so the point can exist in any shape and size. Line is the basic element of furniture outline in the original bamboo furniture design. Different expressions of line will compose different shapes; lines make up the surface. In the design of original bamboo furniture, there are many forms of surface, such as bamboo woven chair back, chair seat made of strips of bamboo board ... By using certain design methods, the design of original bamboo furniture applies these design elements to achieve coordination. After the summary of innovative design methods, we can carry out innovative design thinking from the aspects of line-surface mutual transformation, curved surface transformation, mix and match of materials, asymmetry, change of texture, etc. so as to achieve the coordination of original bamboo furniture design. The following is a detailed analysis of line-surface mutual transformation.

Line-surface mutual transformation: line-surface mutual transformation is to use the material of bamboo to transform the shape of the furniture to achieve the aim of enhancing the beauty of the furniture. By using regular or irregular methods, Lines and surfaces follow a certain rule to create new beauty form, presenting a novel, peculiar visual perceptions and regular fluctuating, rhythmic rhythms and organized dynamics feeling for people. For example, bamboo is processed into bamboo chips and strips after following the characteristics of bamboo, and the strips are regularly arranged and combined...
to form different patterns (Figure 5). At the same time, the innovative design work can be achieved by giving the bamboo a sense of volume (Figure 6).

Curve surface: Furniture form may consist of various facets. In the design of original bamboo furniture, curve parts are used instead of straight parts. The curve parts are connected, staggered and overlapped to form a surface, so that the position, combination relationship and size ratio of the surface meet the design requirements. Furniture made of curve surface is simple and light. (Figure 7).

Mix and match materials: On the basis of compliance with wood properties, bamboo and other materials are mixed to show materials and techniques to enhance the artistic quality of products. In the appearance design of original bamboo furniture, furniture materials can be mixed and matched. By using bamboo as the main material and combining wood, fabric, metal and other materials, a contrast or relatively coordinated visual effect can be produced. Bamboo is relatively easy to coordinate with other materials. Local ornament can be made of metal, cloth, etc. (Figure 8).

Change texture: Different treatments were used to change the surface texture of bamboo to achieve the desired performance. For example, natural rhythm can be expressed by using natural bamboo knots (Figure 9). Through the smooth treatment of the bamboo epidermis, it can have a refreshing and clean texture. Processing bamboo into different strips and adopting different knitting techniques or combination rules can make different texture effects of bamboo pattern.

Asymmetry: By combining with its functions, we can design products of different shapes. As people pursue the differentiation and individualization of furniture products, the inspiration and space tension of furniture asymmetric design are loved by more and more people. In the design of original bamboo furniture, simple and flexible lines can be used to stagger all sides of the furniture.
4.2 The Coordination in Design Structure of Original Bamboo Furniture

The original bamboo furniture has different designs, but its basic structure is similar and can be divided into two types: one is frame structure; The second is the plate-like component structure. The coordination of the original bamboo furniture design structure is mainly presented in the rationality, aesthetics and technical feasibility of the structure. In the design of the original bamboo furniture structure, in order to ensure the coordination of the structural design, the following methods can also be used to auxiliary design.

Bamboo-wood socket joint: original bamboo and wood are used as an intermediary to realize the effective connection between them. In the structural design of the original bamboo furniture, the frame of the bamboo furniture should not only consider the appearance of the furniture, but also consider the main force-bearing components of the frame. The frame structure has two major types: bending combination and straight material combination. The bending combination methods are divided into heating bending and slotting bending. After bending, the bamboo is combined with other components to form the frame structure. Generally, the commonly used connection methods are rod-shaped docking, T-joint, cross-joint, L-joint, parallel joint, embedded joint, seam joint, etc. In order to ensure the firmness of the connection, auxiliary materials such as glue, iron nails, bamboo nails and the like are also used. This connection method has good load-bearing performance but poor stability and is easy to fall off at the joint. However, the method of bamboo-wood socket joint not only maintains the advantages of good load-bearing performance, but also effectively solves the shortcomings of poor stability, greatly improving the coordination of the structural design of the original bamboo furniture.

Bending curved: Bamboo has a simple structure, vascular bundles and bamboo rafts are arranged in parallel, the fibers are straight, and have a good property of bending. Under the action of external force, the bamboo can be permanently deformed without destroying its integrity, and it is easy to manufacture bending and peculiar works. By using this property of bamboo, it is possible to design unique and special works of various combinations of bending shapes. (As showed in Figure 7).

When designing a piece of original bamboo furniture, by combining the above several design methods, it can provide different ideas for product design and add creativity. The following table is an analysis and summary of the original bamboo furniture design method.

| Table 1. Analysis and summary of original bamboo furniture design method |
|-----------------------------------------------|
| **Coordinated evolutionary rules** | **Corresponding Elements of Original Bamboo Furniture Design** | **Innovative Design Method of Original Bamboo Furniture** | **Explanation** |
|-----------------------------------------------|--------------------------------------------------|-------------------------------------------------|-----------------|

Figure 8, Bamboo frame cloth screen  
Figure 9, “The Question of Bamboo”  
Figure 10, Interlaced bending of table top
Original bamboo diameter; length; different forms; color; volume; texture; bamboo wall thickness; flexibility

Curved surface

According to the bending characteristics of bamboo, the curved surface can be processed into different arcs, which can be used in the turning point of the original bamboo furniture. The application of curved surface design method in the design of the original bamboo furniture should consider the bamboo joint length (and the position of bamboo joint), bamboo flexibility, bamboo wall thickness and other factors.

Material mix and match

The combination of bamboo with another different materials will make the best use of each advantages

Asymmetry

When the original bamboo furniture is designed asymmetrically, the left and right sides present different shapes, which can be changed differently through bamboo volume or texture.

Texture Change

The texture of bamboo can be shown as delicate and smooth skin, vertical and smooth cross-section, delicate and fine bamboo weaving, etc. The texture of bamboo, thickness of bamboo wall, flexibility and other factors need to be considered in the design of changing texture.

Structural coordination

Compressive strength; Tensile strength; Torsional strength; Bamboo hardness; Bamboo density; Shear strength; Glue curing; bending

Bending curved

By conforming to the bamboo lines and bending it into different shapes, it can enhance the innovation of the product. The most important thing to pay attention to when designing the curved design is the torsional strength of bamboo.

5. Conclusion

In the process of furniture design, designers need to face many kinds of problems and different objects. Through the analysis of existing furniture cases and the coordination evolution rule of TRIZ system, designers can be helped to fully understand the existing technology, improve the design efficiency and increase the added value of product design. The TRIZ theory system coordination evolution rule is applied to guide furniture design, systematize and smooth furniture design process, which help designers shorten design cycle and save cost.

Original bamboo furniture is endowed by nature with unique aesthetic feeling and superior material characteristics, which plays an important role in improving the quality of human living environment. In the study of original bamboo furniture, many innovative methods of original bamboo furniture are summarized, which provides help for the original bamboo furniture design based on TRIZ system coordination evolution rule. It is hoped that more designers can pay attention to the innovative manufacture of original bamboo furniture and carry out value added innovative design in line with the material characteristics, regional characteristics, national resources, development trends and other factors, so as to promote the development of original bamboo furniture design in China.

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References
[1] Xia Yu. Study on Manufacturing Technology of Original Bamboo Furniture [J], Journal of Bamboo, 2017, 36(5): 64-67,43.
[2] Zhang Buyong, Liu Zuhua. Study on the Connection Mode of Bamboo and Wood in the Original Bamboo Building[J], Journal of Jiamusi University (Natural Science Edition) [J], 2013.31 (41).
[3] Lin Yihuang. Analysis of Traditional Round Bamboo Furniture and New Material of Bamboo Furniture [J], Journal of longyan university, 2009.29(5).
[4] Xiao Jun. Application of Resource Conception in TRIZ Theory to Furniture Design[J], journal of Northeast Forestry University, 2010,38(4): 117-118.
[5] LI Junwei. Features and Production Technology of Bamboo Glued Furniture[J]. Wood Processing Machinery, 2011(4): 47-49.
[6] Chen Mengyao, Zhang Zhongfeng. Application of material characteristics in furniture design[J]. Packaging Engineering, 2017, 38(2): 141-145.
[7] Lei Da, Chen Doudou. Analysis of the form of bamboo furniture [J], Journal of bamboo research, 2004, 23(3): 31-33
[8] Xu Minxiao. Design and manufacture of bamboo ecological furniture[J]. Furniture of bamboo, 2008, 6(6): 37-41.
[9] Wu Zaixing, Tu Yongning. Relying on bamboo resources to develop bamboo-based furniture[J]. World bamboo and rattan, 2005, 3(4): 43-44
[10] Wang Lianjun. The critical analysis of bamboo product design[J]. Journal of bamboo research, 1996, 15(4): 43-51.
[11] Liu Xiaoxu. Material mix and match in furniture design[J]. Furniture, 2016, 37(1): 57-60.