Innovative Design of Furniture Modeling Based on Tree Structure Genetic Algorithm

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Abstract

The development of furniture design is the same as the whole process of human culture. There are different stages in the development of the whole human culture. The contemporary fashion furniture pays more attention to the semantic and morphological semantics, denies the design principles of functionalism, and shows strong characteristics of the times and personal color. This paper mainly studies the innovative design of furniture modeling based on tree structure genetic algorithm, and proposes an implementation method of interactive innovation evolution system based on evolutionary algorithm. Making full use of the advantages of the evolutionary function of genetic algorithm and taking the tree structure based genetic algorithm as an innovative support, we have developed a prototype innovation evolution system, which can help designers complete the creative styling design. The experiment shows that the genetic algorithm has a good application prospect in the innovative evolutionary system.

Keywords: Furniture Modeling, Innovative Design, Computer Aided Design, Genetic Algorithm, Two Forked Tree Structure.

1. INTRODUCTION

With the changing consumption concept of society, more and more attention has been paid to the factors such as product innovation, artistry, agreeableness, environmental protection and so on. This trend prompted enterprises to develop new products to the product design innovation, appearance, body and other aspects of the project to a new height, which is also an urgent requirement of industrial design can have a further breakthrough, to improve the corporate image, product design level and market competitiveness (Wu et al., 2015). The transmission algorithm is an efficient optimization algorithm developed rapidly in recent years. It is becoming more and more widely used in scientific research and practical problems. At present, the research of binary genetic algorithm is relatively mature. However, some basic theorems which are used to explain the validity of genetic algorithm are not applicable to other codes. Real number coding is mainly suitable for solving high dimensional or complex optimization problems (Dao et al., 2017). The genetic algorithm using real number coding has been proved to be convergent. The natural representation of many problems is the form of a tree or graph, especially the two forked tree. It is more convenient to use the two forked tree to encode this kind of problem (Jian-Ning et al., 2016). In this paper, an interactive innovative evolutionary system based on evolutionary algorithm is proposed. The tree structure based genetic algorithm is used as an innovative support for generating 3D components, and then binary encoding of components in database is performed. By performing standard genetic algorithm, different combination schemes can be generated, which can assist designers to finish creative furniture modeling design.

2. THE FUNCTION AND BASIC ELEMENTS OF FURNITURE DESIGN

2.1 The function of furniture design

There is no fixed pattern in the design of furniture design under the requirements of specific function. Its evolution style and popular trend are mostly abstract and practical modeling. The design is designed in accordance with the principle of formal beauty, the reference of ergonomics, and the bold design of the new technology (Chen et al., 2015). Design of furniture is the furniture the appearance, texture, color, volume and other decorative factors, thus creating a new and peculiar structure form of furniture. Modern furniture design is more humanized and intelligent. More attention should be paid to the concept of furniture modeling, the pursuit
of avant-garde and the times. We should pay attention to various combinations of materials, as well as the formation of lines, more colorful colors and more rich shapes (Tang et al., 2015). We should pay more attention to cultural connotation and cultural information, pay attention to morphological language and emotional symbols, and combine technology with ergonomics, nationalism and internationalization, rationality and sensibility, public and personality.

2.2 Basic elements of furniture design

"Point" is a form of the basic unit, based on the characteristics of the "point", will play an important role. Such as cupboard, drawer, door handle and lock type; clasp, rivet and hardware accessories on soft furniture. In the visual plays a dynamic contrast effect in static.

"Line" is the moving track of "point", which is divided into linear system and curve system. The characteristics of the straight line are strong and forceful, and the characteristics of the curve are flexible, smooth and smooth. In furniture design, linear features can create different styles of furniture modeling. Straight line direction, summarize the modeling space, expressing emotion and aesthetic style, momentum and strength, individuality and commonness.

The "face" is formed by the expansion of the "point" and the movement of the "line". The "surface" is characterized by two degrees of space, which is divided into planes and surfaces. The feeling of the plane is stable, stable and correct; the feeling of the surface is changing, lively and light (Fan et al., 2014). In furniture design, the proper use of different shapes of faces and combinations of faces with different directions can form different styles and different styles of furniture modeling. Usually, square furniture has the feeling of simplicity, clarity and stability, and the surface furniture has the feeling of mild, soft and flowing.

"Body" is a three degree space formed by the dots, lines and bread. It is divided into entity and virtual body. The entity (real space directly composed of block) weight, solid, closed, surrounded by the feeling; virtual body (virtual space is composed of a plurality of wires enclosed) makes people feel light, transparent, ethereal and elegant feeling. In furniture design, "body" is a complex of various shapes of cubes and combinations of several cubes. Generally speaking, the space of the table in the open body is a virtual space, and the space of the closet and the cabinet is the entity space. In addition, the change of body color, light, texture can change people feel about it; the viewpoint changes can also make the "body" depth, simplified in vision changes.

3. GENETIC ALGORITHM FOR TWO FORKED TREE STRUCTURE CODING

The standard genetic algorithm adopts fixed length binary encoding. The advantage of this encoding method is that the gene expression is fine and the problem code is longer, which helps to solve the combinatorial optimization problem. But this coding method is not flexible enough. And you need to map from the coded domain to the problem domain (Kuang et al., 2013). In this paper, we need to use mathematical functions as object to do evolutionary operation, coding mathematical expressions. The coding domain is consistent with the problem domain and the encoding length varies greatly, so the representation method of tree structure is more flexible. A mathematical representation of a two - fork tree is a set of finite nodes composed of a mathematical operand and a two - yuan mathematical operator (Lin, 2013). The set is empty or consists of two disjoint tree roots and called the two fork tree of the left and right subtree. The sequence ergodic sequence of two forked
trees is a legitimate mathematical expression. The node of a tree can be a terminal node (operand) or an intermediate node (operator). Operand variable can also be constant including basic operator: +, -, *, /, ^; the basic mathematical functions: sqrt(), exp(), log() and trigonometric functions. The two forked tree structure representation of the mathematical expression $\sin(8x)/x + x^2 \cdot \cos(x)$ is shown in figure 1.

The two forked tree is used to represent the following advantages of the mathematical function:

1. The mathematical function of any length can be expressed in theory. Because the length of the mathematical function is not fixed, it is not suitable for the use of fixed length coding scheme, and the two-tree representation rule is relatively flexible.

2. Because the representation is simple and intuitive, the evolutionary operation is simple. Due to the nesting problem of functions in mathematical functions, it is easy to appear the phenomenon of function illegality in the process of crossover and mutation if other coding methods are adopted. The two way tree method can solve this problem well.

3. Because of the use of basic mathematical elements as the objects of cross and variation the progeny changes greatly and can produce more abundant offspring.

3.1 Cross operation

In genetic algorithms, the role of cross operation is very important. On the one hand, it preserves the characteristics of the good individuals in the original group to some extent; on the other hand, it crosses the good genes of the parents, and produces new excellent individuals (Li and Yang, 2014). The cross operation in this paper is based on two successful parent trees, which produce two new trees, randomly select one intersection point on every parent tree, and then exchange two sub trees with crossing points as root, generating two offspring. This operation is shown in figure 2.

![Cross operation of tree structure genetic algorithm](image1)

3.2 Mutation operation

Mutation operation is used to enhance the diversity of future generations, thus extending the solution space. This operation selects a node randomly on a single parent tree, and then uses a new subtree to replace the subtree of the parent tree with the selected node as the root. This operation is shown in figure 3.

![Mutation operation of tree structure genetic algorithm](image2)
3.2 Selection operator

The selection mechanism adopted by the genetic algorithm of the two forked tree structure is similar to the mechanism of roulette in the binary algorithm, so there are:

\[ S_n = \prod_{i=1}^{n} f(\lambda_i(i)) > 0, \quad \forall i \in K \]  

So the matrix S is allowed to be included in the column.

4. DESIGN OF FURNITURE MODELING BASED ON TREE STRUCTURE BASED ON GENETIC ALGORITHM

The standard genetic algorithm adopts the fixed length binary coding. The advantage of this method is that the gene expression is delicate and the problem coding is long, which is helpful to solve the combinatorial optimization problem. But the method is not flexible enough and needs to be mapped from the encoding domain to the problem domain. The representation of the tree structure is more flexible for the problem that the coding domain is consistent with the problem domain and the coding length is changed greatly (Cong, 2014). A mathematical representation of a two - fork tree is a set of finite nodes composed of a mathematical operand and a two - yuan mathematical operator. The set is empty or consists of two disjoint tree roots and called the two fork tree of the left and right subtree. In order traversal sequence two binary tree is a valid mathematical expression. A mathematical representation of a two - fork tree corresponds to a rule, and the rule eventually generates a two-dimensional graph. The overall structure of the system is shown in figure 4.

![Figure 4. Innovative design system overall your structure](image)

The steps of the genetic algorithm are as follows:

Step 1. Initialization population

The initialization of a population mainly takes two ways: the first method is to manually input the expression through the designer or the user. The system provides a floating panel for manual parameter input for the designer. This method is suitable for designers and users with a certain mathematical basis. It requires a general understanding of the properties of the manipulated functions and the second way is random combination. No matter how complex the mathematical function is, it is formed by combining some mathematical operators, operands and mathematical functions. The generation of initial population can be generated by random selection in the set of effective operators and operands. Then the validity of the generated expression is detected. Then the expression is constructed as a two forked tree of mathematical representation.

Step 2. Setting of fitness
By manually setting the fitness value method, the designer can set the fitness value for the rules according to the generated two-dimensional graphics. A three-dimensional figure is generated on the basis of a two-dimensional graph. The designer can also set the fitness degree for the generated 3D modeling, and the three-dimensional modeling with high fitness can be directly saved to the component library, or modify or reset the fitness of two-dimensional graphics according to the generated 3D graphics.

Step 3. A new population is formed according to the fitness value.

Step 4. Crossover and mutation operations are performed on the population, and each stage of the operation can interactively assign the fitness values to the generated components for other operations.

Step 5. If the user does not terminate the process, turn (2); otherwise end.

The function module of the plan generation is to assemble and assemble the generated components and render them after rendering. There are mainly two ways to generate programs in the system. The components in the database are binary coded to generate different combinations of combinations; the generated components are manually combined. The final result is shown in figure 5.

![Figure 5. The drawing of the furniture](image)

5. CONCLUSIONS

To give full play to the unique personality of the material and the rich creative design of imagination in the design of furniture, a new art life can be given to the material. At the same time, the organic integration of furniture's shape, color and material can bring a lot of unexpected visual effects and enhance the quality of creativity. This paper introduces the tree structure based component generation module in the innovation design system, and proposes an interactive creative evolutionary design method based on evolutionary algorithm. A genetic algorithm based on tree structure is used as an innovation for generating components. Taking product modeling innovation design as the research object, this paper analyzes the necessity and development status of product innovation design, and makes in-depth research on product innovation design theory and existing product innovation design methods. On this basis, a new product innovation design method based on evolutionary algorithm is proposed, and the key technology of product modeling innovation design based on evolutionary algorithm is studied, and the prototype system is developed.

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REFERENCES

Expert Systems with Applications, 90, 196-208.