The Study of Population Gene based on hierarchy tree Algorithm in Case Product for Innovative Design

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Abstract: Based on biological engineering ideas and methods, for product innovation design, research and discuss on gene of case product. Defining and dividing the population of case product, building a model of population of case produce and describing the gene of product, to establish the hierarchy tree of decompose and the gene tree of population on case product, and express the gene of the population of case product. This method of product gene acquisition and expression contribute to specify, accumulate and reuse of design knowledge, finally, combination lock handle product as instance, to describe the acquisition and expression of product gene for details.

Introduction

Recently, with the development of smart technology and computer-aided technologies, product innovation and design research get into whole new field. Innovation design which have intelligent gene has become a new direction[1],especially with the development of computer-aided technologies, inference with case-based[2]and the reuse of design example or design knowledge become an important research direction and content of intelligent CAD technology. In previous, acquire the knowledge[3] and reuse the knowledge[4]become the main bottleneck in product innovation. In recent years, emerging the technology of case-based reference[5], compensate for knowledge acquisition and reuse in certain extent, but this kind of case-based reference technology may search the case, the scheme of design require design expert intervention manually[6].Base on evolutionary algorithm, the gene design methods which consider case-based reference provide a possible for product design innovation with intelligent and automation[7,8].The classification of the product design example, building the population of produce case, draw the population gene of product design example, the condition for evolution is example of gene products to population, combined with the evolution of reference, to innovate design of these product populations.

The definition and expression of product

In biological, the population are congregation which refers to a certain time and space, with a collection of all kinds of biological individuals. This collection is not mechanical together, they mate between each other to inherit gene of population. Population is the basic form of existence of the species, and also the basic unit of the evolution of species. Refer to the biological, the population of case product is a collection of product in the given time and space, has the same basic function and constituent unit, and the same or similar attributes of product feature.

The model of case product is a collection of knowledge of product design, and also is the design model which consist case product element, relation and parameter of characteristic, the model of case product is described as follows:

$$\begin{aligned} &Case(P_c) = Case(E_i) \\ &E_i = (F_i, P_i, R_i) \\ &F_i = (f_1, f_2, ..., f_l) \\ &P_i = (p_1, p_2, ..., p_m) \\ &R_i = (r_1, r_2, ..., r_n) \end{aligned} \tag{1}$$

In the formula, P_c is case product, E_i is the element of case product, $i = 1, 2, ..., k$. F_i is the feature collection of case elements, P_i is the collection of parameters, R_i is the collection of relations.

Innovation of design which start from concept in product engineering, in this stage, function design, structural design and principle design whose constitute main contents of innovation design. According to definition of knowledge of product, we use model of Multi-dimensional view to express the model of case product of population, and built three-dimensional view of the mapping model of case product in function, principle, structural, shown in fig1.

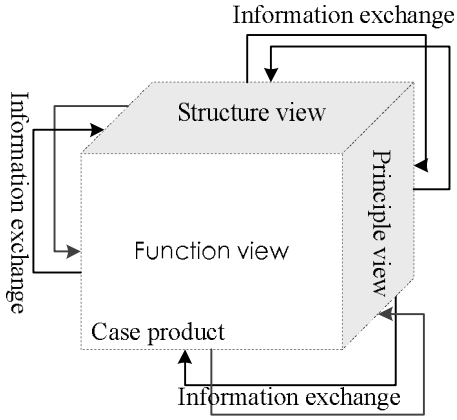

Fig. 1 The model of case product in three-dimensional view

The three-dimensional model of case product express as follows:

$$M_C = M_F \cup M_P \cup M_S \tag{2}$$

In the formula, M_C is the model of case product, M_F is the view model of functional, M_P is the view model of principle, M_S is the view model of structure.

The express model of tree of case product are shown in fig 2, the juncture node between function tree and principle tree are effect of principle in leaf nodes, S, G nodes express the nodes of structure tree and principle tree.

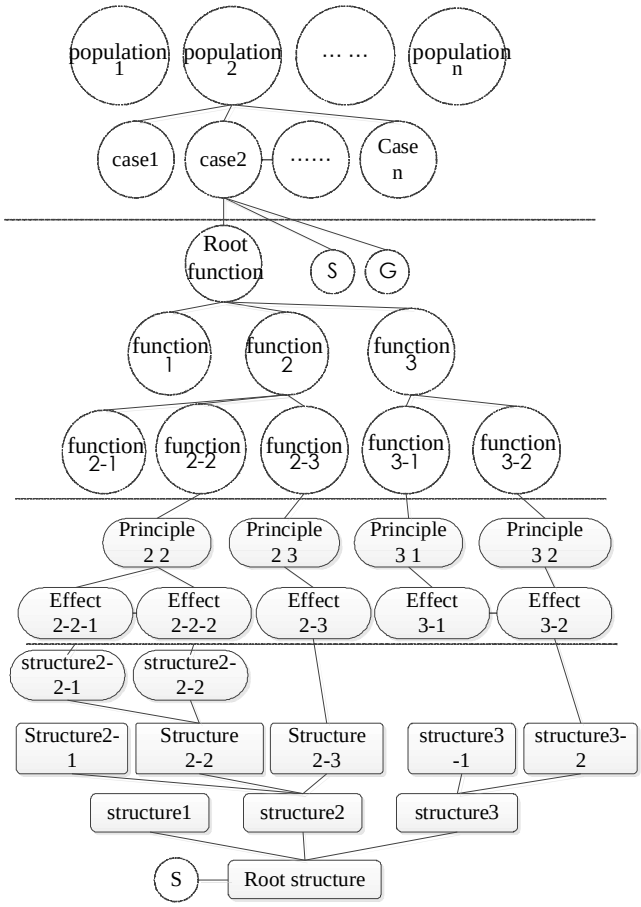

Fig.2 the level express model of population of case product

The tree of case product express as follow:

$$P_C = Tree(N_{C,i}) \tag{3}$$

In the formula, P_C is a case product, $N_{C,i}$ is the i node of case tree, $i = 1, 2, ..., n$, n is the amount of node in the tree.

$$N_{C,i} = f(N_{F,i}, N_{P,i}, N_{S,i}, G_{N,i}) \tag{4}$$

$N_{F,i}$ is the function node of case node, $N_{P,i}$ is the principle node, $N_{S,i}$ is the structure node, $G_{N,i}$ is the gene of node, f is the relation of map in the nodes, express as follows:

$$\begin{aligned} N_{F,i} &= (A_{NF}, C_{NF}, M_{NF}, I_{NF}) \\ N_{P,i} &= (A_{NP}, C_{NP}, M_{NP}, I_{NP}) \\ N_{S,i} &= (A_{NS}, C_{NS}, M_{NS}, I_{NS}) \end{aligned} \tag{5}$$

A_{NF}, A_{NP}, A_{NS} are the feature attribute of node in function, principle, structure, C_{NF}, C_{NP}, C_{NS} are feature constraint of relevant node， M_{NF}, M_{NP}, M_{NS} are operational method of relevant node， I_{NF}, I_{NP}, I_{NS} are connector of relevant node.

The gene of case product and population

Innovative design and genetic evolution have the similar characteristic, most innovative design is what reuse the existing principle and other design knowledge. The gene of product present in the product itself which is the key node in product design of evolution, general process of design which

can't get the product gene, but from the population of case product in reverse thinking, will get the gene of product and reuse in the design of innovative design.

The definition of gene of product

In biology, the carrier of genetic information is Deoxyribonucleic Acid (DNA), the different part of gene which deter the different function[9,10]. In DNA, A, G, C, T four codes constitute gene of life[11].

According biological, the feature of function, the effect of principle and the sample of structure can be defined as the genetic elements of product, definition as follow:

Genes of Function are the basic information unit which describes the features and characteristics of product.

Genes of principle are the basic information unit which describes the theory and physical effects of product.

Genes of Structure are the basic information unit which describes the structure and material properties of product.

The condition of exist of product is identify the gene of function ,genes of principle and genes of structure at the same time, the single gene can't constitute and describe the product.

The expression of gene of product

The code expression of gene is foundation what is evolving design and genetic computing in the later stage[12,13]. According to the tree model of product in decomposition which established on previously, using tree of gene of product to express the gene of case product shown as follows:

$$G_C = tree(G_{N,i}) \tag{6}$$

In the formula, G_C is the tree genome of product, $G_{N,i}$ is the i code gene on the tree genome, i=1,2,3,…,n。

$$G_{N,i} = f(F_{GB,i}, S_{GB,i}, P_{GB,i}) \tag{7}$$

$F_{GB,i}$ is the gene of functional of code, $S_{GB,i}$ is the gene of structure of code, $P_{GB,i}$ is the gene of principle of code, f is the relation between code which shown as follows:

$$\begin{cases} F_{GB,i} = (A_{gf}, C_{gf}, M_{gf}, I_{gf}) \\ S_{GB,i} = (A_{gs}, C_{gs}, M_{gs}, I_{gs}) \\ P_{GB,i} = (A_{gp}, C_{gp}, M_{gp}, I_{gp}) \end{cases} \tag{8}$$

A_{gf} , A_{gs} and A_{gp} are the characteristic properties of gene, C_{gf} , C_{gs} and C_{gp} are feature constraint, M_{gf} , M_{gs} and M_{gp} are method of operation, I_{gf} , I_{gs} and I_{gp} are interface of gene, and express the relationship between structure, function and principle.

The tree of gene of product built shown as fig3, the code of leaf is the original gene on the tree, other code is composition gene. The tree of gene of product shown as fig3 is correspond G of fig2.

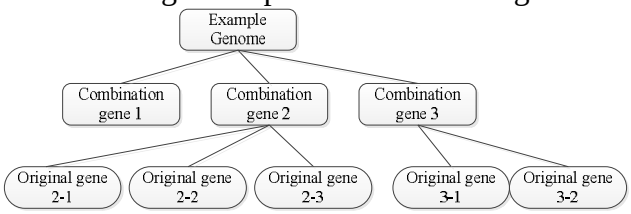

Fig.3 The tree of gene of product

The example of gene on handle product

To illustrate the above method of acquisition and expression on gene of product, the article described the latch handle product for examples. First, analysis the example of product on structure, principle and function, and decompose until the least unit on structure, principle and function. Second,

analysis the effect of principle detail on handle, and get the resolving theories of handle. At last, drawing the analysis figure of tree of gene on handle shown as fig4.

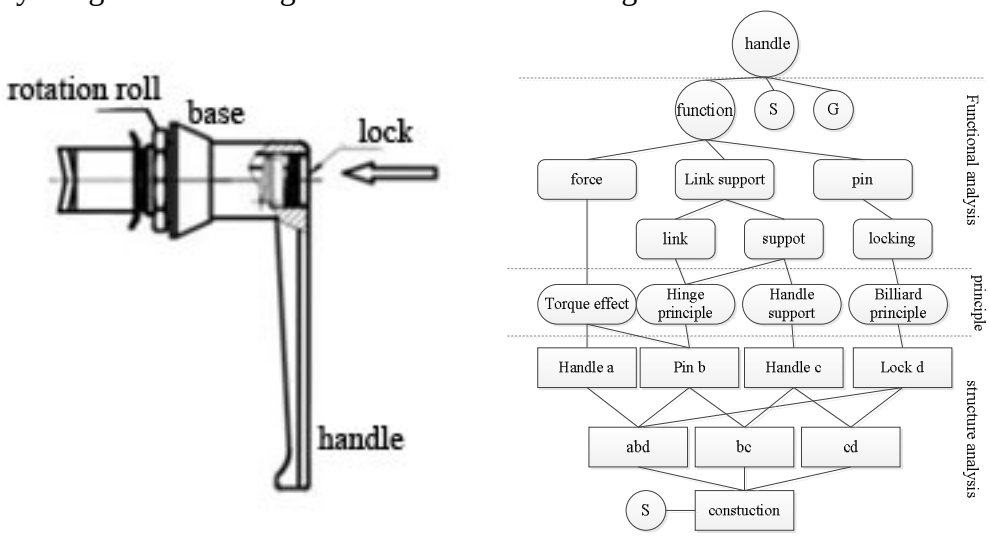

Fig.4 The figure of handle and the tree of gene

According to the analysis figure of tree of gene on handle, we can get the case tree of gene on handle shown as fig5, the G code on fig5 is correspond to G code on fig4.

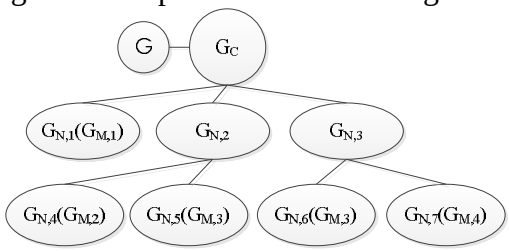

Fig.5 The case tree of gene on handle

In fig5, the tree of gene is consist by 7 code, $G_C = Tree(G_{N,1}, G_{N,2}, G_{N,3}, G_{N,4}, G_{N,5}, G_{N,6}, G_{N,7})$, and $G_{N,1}, G_{N,4}, G_{N,5}, G_{N,6}, G_{N,7}$ are nodes of leaf, according to fig4, those five nodes are constitution by four gene of original: $G_{N,1} = G_{M,1}, G_{N,4} = G_{M,2}, G_{N,5} = G_{N,6} = G_{M,3}, G_{N,7} = G_{M,4}$, $G_{N,2}, G_{N,3}$ are genes of combination, $G_{N,2} = (G_{N,4}, G_{N,5}), G_{N,3} = (G_{N,6}, G_{N,7})$, and the genes of original shown as follow:

$$
\begin{aligned}
&G_{M,1}(\text{force})=(F_{GB,1}(\text{force}), P_{GB,1}(\text{torque effect}), S_{GB,1}(\textit{abd}\ \text{combination}))\\
&S_{GB,1}(\textit{abd}\ \text{combination})=(S_{GB,1,1}(\text{handle}), S_{GB,1,2}(\text{pin}), S_{GB,1,3}(\text{lock}))\\
&G_{M,2}(\text{connect})=(F_{GB,2}(\text{connect}), P_{GB,2}(\text{hinge principle}), S_{GB,2}(\text{pin}))\\
&G_{M,3}(\text{support})=(F_{GB,3}(\text{support}), P_{GB,3}(\text{handle support}), S_{GB,3}(\text{handle}))\\
&G_{M,4}(\text{lock})=(F_{GB,4}(\text{lock}), P_{GB,4}(\text{billiard principal}), S_{GB,4}(\text{lock}))
\end{aligned}
\tag{9}
$$

Describing the gene of original by $G_{M,1}$ for example to elaborate the gene of function(force), principle(torque effect) and structure(abd combination) shown as table1.

table 1. the original gene of GM1

Name:force		Code ID：G001
Gene of function: $F_{GB,1}$	Gene of principle: $P_{GB,1}$	Gene of structure: $S_{GB,1}$
Code ID：FB001	Code ID：PB001	Code ID：SB001
content	content	content
Characteristic Properties Verb: exert Modifiers: hand Noun: force Modifiers: Gene category: energy input: F_A constraint Properties constraint : F_A<20kg connecter inside principle gene: PB001 structure gene: SB001 connecter outside case code: C001	Characteristic Properties Principle: torque formula: $M=F_A.L$ properties: properties 1：F_A properties 2：L constraint Properties constraint: $L>0$ connecter inside function gene: FB001 structure gene: SB001 connecter outside case code: C001	Characteristic Properties Structure: combination structure: torque pin structure：*abd* combination substructure: handle（a）: S1-1 handle pin (ab): S1-2 hand lock (ad): S1-3 constraint Properties constraint 1: hand and lock together constraint 2：handle easy use connecter inside function gene: FB001 principle gene:PB001 connecter outside case code: C001

Conclusions

Defining the population of case product, we proposed the gene of product and built the tree of gene and the tree of case, at last, get the gene of product and express the gene of product. To illustrate method of acquisition and expression on gene of product, the article described the latch handle product for examples. The extracting of gene help to regulate, heritage and reuse knowledge of product design, and development of design intelligent, integrated and automated are mutually reinforcing. The article focuses on the gene of case product technologies, the evolution design is the next research points.

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