An Improved model of product design case reuse based on extension theory

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Abstract

This article studies the question of product design case reuse based on extension theory for complex product with various information, categories and attributes. It also proposes to use case space elementary system and case subject index elementary model based on elementary model of product design case research to describe complex design case. Besides, it also builds design case research and reuse model based on extension correlation function to acquire the most similar design result. The application of this method can acquire the design case closest to the design objective rapidly, thus improving the efficiency of product configuration, and shortening design period of complex product. Finally, it testifies the effectiveness of the model with application cases.

Keywords: Product Design, CBR, Design Reuse, Extension Theory, Artificial Intelligence

1 Introduction

Case based research (CBR) technology is an important design method for the rapid intelligent design of large complex products. It is an analogical reasoning method by simulating human beings' thoughts to seek intelligent and rapid solution and decision of the design question, search for similar design case according to design requirements, and adapting to the new design configuration by adjusting to related design parameters. [1-4] CBR technology is a rapidly developing research method in the field of artificial intelligent research. But traditional CBR technology has its own limitations that influence its deeper application in large complex product designs. For example, the attributes of complex product design are usually complicated, yet traditional case model cannot clearly describe the case reasoning nor combine quantitative and qualitative attributes, which influences the modelling of design case with various attributes, categories and information. Secondly, traditional CBR system mainly uses qualitative case indexing research, such as inductive indexing method, approximate indexing method and knowledge guidance method. But the design of large complex product is always fuzzy and uncertain and traditional CBR can hardly deal with fuzzy research questions that combined with qualitative and quantitative methods. At present, scholars have carried out some research upon these questions. Zhao Yanwei studied the product configuration design method and applied the calculation of extension distance in chain saw configuration design [5]. Dou Zengfa studied the hybrid expert system based on extension theory and case based research. [6] Wang Tichun and his colleagues studied the multiple-level case research model for product design based on knowledge reuse [7]. Therefore, based on past research, this article will describe complex design case through case space elementary system and case subject index elementary model and build design case research and reuse model based on extension correlation function, in order to study the product design case reuse based on extension theory and testify the calculation method.

2 Extension theory and extension cases

Extension theory was first proposed by Chinese scholar, Professor Cai Wen, in 1983 as a new trans-disciplinary subject. It aims to study the transformation rules and solutions of contradictory problems. It uses elementary model (as the basic logical unit to understand and analyze problems) to carry out formalized and modeled presentation of the study object and objective. Meanwhile, in order to quantify the solving process and realize the computerization of the transformation of contradictory problems, extension theory establishes corresponding extension set, correlation function and other mathematical tools, to describe the object's attribute and transformation.[8-10] The extension unit describes the design question's extension affiliates and the essence of extension transformation. Correlation functions are concepts used to describe the correlation between objects within the extension unit. At present, the theoretical framework and technical method of extension theory are based on elementary theory, extension unit theory and extension logic. Their respective application technologies in each field are called extension engineering and have generated related engineering results. [11-15]

Elementary is one of logic cells of extension theory. It presents the design object in a formalized and modelled

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way. Elementary is expressed by a sequential triad $J=(N,c,v)$, among which *N* represents the name of the design object, *c* its features and *v* means the object *N*'s magnitude about the design feature *c*. One design object can have several features. The design object *N*'s features $c_1, c_2, ..., c_n$ and corresponding magnitudes $v_1, v_2, ..., v_n$ can be expressed as:

$$J=\begin{bmatrix} N & c_1 & v_1 \\ & c_2 & v_2 \\ & \dots & \dots \\ & c_3 & v_3 \end{bmatrix}=\begin{bmatrix} J_1 \\ J_2 \\ \dots \\ J_n \end{bmatrix}, \tag{1}$$

where *J* is called *n*-dimensional elementary. The introduction of multi-dimensional elementary can describe the design object in a more formalized and modelled way, thus providing a new thought for the design of large complex products. No matter how many design layers or how complicated the design problem, it can always be expressed by multi-dimensional elementary and examined in case space.

Definition 1 Case space elementary system J_S Gather all design cases and related design information, build a model based on the elementary to form a design case space elementary system J_S. Every elementary of the design case is one element in the case space elementary system. The case space elementary system represents design results and conditions corresponding the past design requirements.

$$J_S=(J_D, J_R, J_O, J_{CON}). \tag{2}$$

In the formula, J_D represents the identification of design case elementary space system, which is the attribute of design case elementary. J_R represents design case elementary, J_O the design objective and J_{CON} the design restrictive information in the system.

As can be seen, the design case space elementary proposed by this article extends the presentation of design case. The features of design objects can describe the design result of the case, namely case information including both the static basic attributes and the design behaviours during the process of developing a design. They can also express the design objectives, which determine the essence of design case in different design cases. Furthermore, they can express the initial conditions that give rise to the case and the restrictive information, which the case should also stick to when satisfying the design objectives. It is beneficial for the rapid design of products with huge information, various categorization and complicated attributes.

Definition 2 Design case subject index elementary J_{IND} is the concentration and representation of design case elementary and also an important signal that distinguish it from other design case elementary.

$$J_{IND}=\begin{bmatrix} N(J_{IND}) & cx_1 & v_1|f(cx_1) \\ & cx_2 & v_2|f(cx_2) \\ & \dots & \dots \\ & cx_n & v_n|f(cx_n) \end{bmatrix}, \tag{3}$$

where $N(J_{IND})$ represents the name of design case subject index, *cx* the features of subject index and $v|f(cx)$ the magnitude function of subject index.

Definition 3 Design case elementary base J_B. It is the physical embodiment of design case space elementary system in a well-organized and managed way. The base should include design elementary related information, subject index information and information correlation.

$$J_B=(J_s, J_{IND}, J_C), \tag{4}$$

where J_C represents the correlated elementary in design case.

3 Model and calculation method of complex product design based on extension theory

During the process of rapid design of large complex products, the CBR technology, based on design case space, needs to divide the product design into subspaces, establish allocation platform for the design space, describe the design case space with elementary, establish the design needs with elementary and transform them into objective elementary. Then use design case subject index elementary to carry out matching research in the design case space. If a certain design case subspace satisfies the needs of the design objective elementary, then the design case in this design case subspace can be used as reusing objects. Thus, the objective of rapid design for large complex products is achieved.

3.1 ELEMENTARY MODELS IN CLASSICAL DOMAIN AND JOINT DOMAIN IN DESIGN CASE SPACE

Assume there are *m* design case sub-spaces in a design case space. The No. *i* sub-space J_{Si} has *n* subject index, then the classical domain elementary model can be expressed a follows:

$$\boldsymbol{J}_{Si}=\left[N_i,C,V\right]=\begin{bmatrix} N_i & C_{i1} & V_{i1} \\ & C_{i2} & V_{i2} \\ & \vdots & \vdots \\ & C_{in} & V_{in} \end{bmatrix}=\begin{bmatrix} N_i & C_{i1} & v_{i1}\mid f(C_{i1}) \\ & C_{i2} & v_{i2}\mid f(C_{i2}) \\ & \vdots & \vdots \\ & C_{in} & v_{in}\mid f(C_{in}) \end{bmatrix}=\begin{bmatrix} N_i & C_{i1} & \langle v_{ai1},v_{bi1}\rangle\mid f(C_{i1}) \\ & C_{i2} & \langle v_{ai2},v_{bi2}\rangle\mid f(C_{i2}) \\ & \vdots & \vdots \\ & C_{in} & \langle v_{ain},v_{bin}\rangle\mid f(C_{in}) \end{bmatrix}, \quad (5)$$

where $C_{i1},C_{i2},...,C_{in}$ are the different subject indexes for N_i . $V_{i1},V_{i2},...,V_{in}$ are the classical domains for N_i corresponding the different subject indexes $C_{i1},C_{i2},...,C_{in}$ respectively. $v_{i1},v_{i2},...,v_{in}$ show the range of the subject indexes $C_{i1},C_{i2},...,C_{in}$, namely the classical domain of N_i , which satisfies $V_{ij}=\langle v_{aij},v_{bij}\rangle(i=1,2,...,m,\ j=1,2,...,n)$. $f(C_{i1}),f(C_{i2}),...,f(C_{in})$ are the matching functions for the different subject indexes $C_{i1},C_{i2},...,C_{in}$ for N_i .

Based on the classical domain of design case space elementary model, there can be another joint domain J_P:

$$\boldsymbol{J}_P=\left(N_0,C,V\right)==\begin{bmatrix} N_0 & C_{01} & V_{01} \\ & C_{02} & V_{02} \\ & \vdots & \vdots \\ & C_{0n} & V_{0n} \end{bmatrix}=\begin{bmatrix} N_0 & C_{01} & v_{01}\mid f(C_{01}) \\ & C_{02} & v_{02}\mid f(C_{02}) \\ & \vdots & \vdots \\ & C_{0n} & v_{0n}\mid f(C_{0n}) \end{bmatrix}=\begin{bmatrix} N_0 & C_{01} & \langle v_{a01},v_{b01}\rangle\mid f(C_{01}) \\ & C_{02} & \langle v_{a02},v_{b02}\rangle\mid f(C_{02}) \\ & \vdots & \vdots \\ & C_{0n} & \langle v_{a0n},v_{b0n}\rangle\mid f(C_{0n}) \end{bmatrix}, \quad (6)$$

$C_{01},C_{02},...,C_{0n}$ are the different subject indexes for N_0, and $V_{01},V_{02},...,V_{0n}$ are the classical domains for indexes. $v_{i1},v_{i2},...,v_{in}$ are the corresponding range of $C_{01},C_{02},...,C_{0n}$, namely the joint domain of N_0 , which satisfies $V_{oj}=\langle v_{a0j},v_{b0j}\rangle=(j=1,2,...,n)$. $f(C_{01}),f(C_{02}),...,f(C_{0n})$ are the matching functions of the subject indexes $C_{01},C_{02},...,C_{0n}$. Apparently, $V_{ij}\subseteq V_{oj}\left(i=1,2,...,m,\ j=1,2,...,n\right)$.

3.2 THE BUILDING OF EXTENSION-RELATED FUNCTION BASED ON EXTENSION DISTANCE IN DESIGN CASE SPACE

Assume the corresponding the design objective is G. Building an elementary model for G, as follows:

$$\boldsymbol{J}_G=\begin{bmatrix} N_G & C_{g1} & V_{g1} \\ & C_{g2} & V_{g2} \\ & \vdots & \vdots \\ & C_{gn} & V_{gn} \end{bmatrix}. \quad (7)$$

If the magnitude V_{gj} of design case subject index C_{gj} concerning the design object J_G is a point value, namely $V_{gj}=v_{gj}$, then the extension distance between C_{gj} of the design object J_G and the No. i design case subspace J_{Si} is:

$$\rho\left(V_{gj},V_{ij}\right)=\left|v_{gj}-\frac{v_{aij}+v_{bij}}{2}\right|-\frac{1}{2}\left(v_{bij}-v_{aij}\right). \quad (8)$$

Correspondingly, the extension distance between the design case subject index C_{gj} of the design object J_G and the design case space J_P is:

$$\rho\left(V_{gj},V_{0j}\right)=\left|v_{gj}-\frac{v_{a0j}+v_{b0j}}{2}\right|-\frac{1}{2}\left(v_{b0j}-v_{a0j}\right). \quad (9)$$

If the magnitude V_{gj} of the design case subject index C_{gj} of the design object J_G is a fussy value, namely $V_{gj}=\langle v_{agj},v_{bgj}\rangle$, the extension distance between the design case subject index C_{gj} of the design object J_G and the No. i design case subspace J_{Si} is:

$$\rho\left(V_{gj},V_{ij}\right)=\frac{1}{2}\left[\rho\left(V_{agj},V_{ij}\right)+\rho\left(V_{bgj},V_{ij}\right)\right]$$
$$=\frac{1}{2}\left[\left(\left|v_{agj}-\frac{v_{aij}+v_{bij}}{2}\right|-\frac{1}{2}\left(v_{bij}-v_{aij}\right)\right)+\left(\left|v_{bgj}-\frac{v_{aij}+v_{bij}}{2}\right|-\frac{1}{2}\left(v_{bij}-v_{aij}\right)\right)\right]. \quad (10)$$

Correspondingly, the extension distance between the design case subject index C_{gj} of the design object J_G and the design case space J_P is:

$$\rho\left(V_{gj},V_{0j}\right)=\frac{1}{2}\left[\rho\left(V_{agj},V_{0j}\right)+\rho\left(V_{bgj},V_{0j}\right)\right]$$
$$=\frac{1}{2}\left[\left(\left|v_{agj}-\frac{v_{a0j}+v_{b0j}}{2}\right|-\frac{1}{2}\left(v_{b0j}-v_{a0j}\right)\right)+\left(\left|v_{bgj}-\frac{v_{a0j}+v_{b0j}}{2}\right|-\frac{1}{2}\left(v_{b0j}-v_{a0j}\right)\right)\right] . \quad (11)$$

Therefore, the extension correlation function value $K_i\left(V_{gj}\right)$ between the design case subject index C_{gj} of the design object J_G and the No.*i* design case space J_{Si} is:

$$K_i\left(V_{gj}\right)=\begin{cases}\dfrac{-\rho\left(V_{gj},V_{ij}\right)}{\left|V_{ij}\right|} & V_{gj}\in V_{ij}\\[2ex] \dfrac{\rho\left(V_{gj},V_{ij}\right)}{\rho\left(V_{gj},V_{0j}\right)-\rho\left(V_{gj},V_{ij}\right)} & V_{gj}\notin V_{ij}\end{cases} . \quad (12)$$

When considering the matching function $f\left(C_{ij}\right)$ of different design case subject index, the extension-related level $K_i\left(G\right)$ between all the design case subject indexes of the design object J_G and the No. *i* design case subspace J_{Si} is:

$$K_i\left(G\right)=\sum_{j=1}^{n}\left(f(C_{ij})*K_i\left(V_{gj}\right)\right) . \quad (13)$$

3.3 THE REUSE MODEL AND CALCULATION OF DESIGN CASE BASED ON EXTENSION THEORY

With the extension correlations between design object J_G and all design case subspaces, we can get an extension correlation array $K(G)=\left(K_1(G),K_2(G),...,K_n(G)\right)$. Therefore, the design case subspace of the best reusing object should satisfy:

$$K_0=MAX\left(K_1\left(G\right),K_2\left(G\right),\cdots,K_n\left(G\right)\right) . \quad (14)$$

We can get the reusing object from the design case subspace of the best reusing object.

Meanwhile, the design case subspace of the reusing object should satisfy:

$$K^*=\left(K_i\left(G\right)|\left(K_1\left(G\right),K_2\left(G\right),\cdots,K_s\left(G\right)\right)\wedge K_i\left(G\right)\geq 0\right),\quad 1\leq s\leq n . \quad (15)$$

Based on these design case subspaces, the transformation design or improvement design of the design objectives can be carried out. Due to word limit, this article will focus on the acquisition research of the best design case subspace. The analysis of the transformation design or improvement design of the design objectives based on design case subspaces will be explained in another article.

Thus, when dealing with complex product design with various information, categories and attributes, we can build a design case subspace and design case subject index and carry out elementary description of it. Then based on the design case subject index elementary, we can carry out matching research for the design subspace in the design case space in order to acquire the design case subspace belonging to the best reusing design case. This can provide support for the realization of rapid design of complex products. Graph 1 shows the flow chart of the product design case reuse model based on the extension theory.

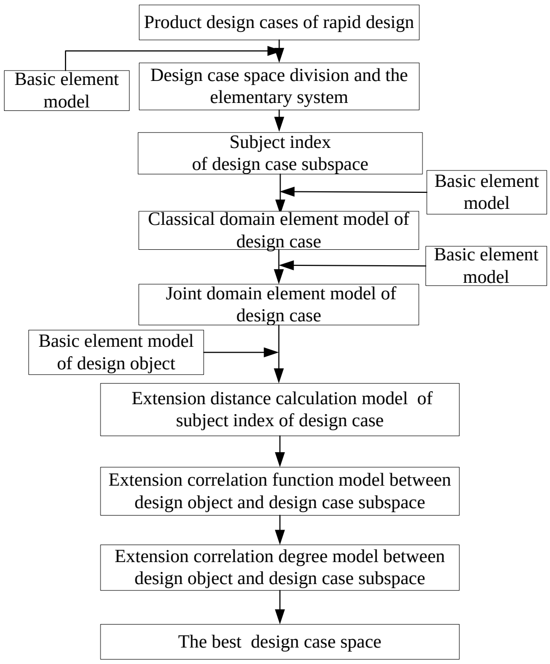

FIGURE 1 The product design case reuse model based on the extension theory

To conclude, the realization of the product design case reuse model based on the extension theory shown in graph 1 can be calculated as follows:

Step1 Divide the design case subspace based on the data about the product rapid design case. Meanwhile, build a design case subspace elementary system based on definition 1.

Step 2 Build corresponding design case subject index for the established design case subspace and also build a design case subject index elementary model based on definition 2.

Step 3 Build corresponding classical domain elementary model and joint domain elementary model for the established design case subspace and subject index elementary.

Step 4 If the magnitude of the design case subject index concerning the design object is a point value, calculate the extension distances between the different design case subject indexes of the design object and each design case subspace, according to formula (8) and (9) respectively.

Step 5 If the magnitude of the design case subject index concerning the design object is a fuzzy value, calculate the extension distances between the different design case subject indexes of the design object and each design case subspace, according to formula (10) and (11) respectively.

Step 6 Calculate the extension correlation function values between the design case subject indexes of the design object and each design case subspace according to formula (12). Calculate the comprehensive extension correlation levels between design case subject indexes of design object and each design case subspace according to formula (13).

Step 7 According to the acquired comprehensive extension correlation order, acquire the design case subspace of the best reusing object with formula (14) and the design case subspace with the reusing object according to formula (15).

Step 8 Carry out matching for best reusing case within the design case subspace of the best reusing objects and reuse. Acquire reusing objects within the design case subspace of the reusing objects and provide support for product design.

4 Applications

I will use the design of a power wheel, a core component of a certain power machine to testify and illustrate the abovementioned points. According to the suggestions and experience of design experts and the installation form of the power wheel, the design case subspace of it can be divided into 3 design spaces, namely the vertical power wheel design space, horizontal power wheel design space and side power wheel design space. Meanwhile taking into consideration the performance parameters, design structure attributes and other design parameters of the power wheel, establish the design case subject index attributes as power range, efficiency range, carrying capacity, diameter range and weight range. Thus, we can build the classical domain elementary model and joint domain elementary model corresponding the design case subspaces. The classical domain elementary model of the vertical power wheel design space J_Z, of the horizontal power wheel design space J_W and of the side power wheel design space $J_{Z\text{-}W}$ are shown respectively as follows:

$$\boldsymbol{J}_Z = \begin{bmatrix} N_Z & \text{power (kW)} & \langle 15.00, 20.00\rangle \mid 0.25 \\ & \text{efficiency (\%)} & \langle 85.00, 90.00\rangle \mid 0.25 \\ & \text{bearing capacity (kN)} & \langle 0.00, 18.00\rangle \mid 0.25 \\ & \text{diameter (m)} & \langle 0.00, 1.00\rangle \mid 0.15 \\ & \text{weight (kg)} & \langle 0.00, 500.00\rangle \mid 0.10 \end{bmatrix}, \quad (16)$$

$$\boldsymbol{J}_{Z-W} = \begin{bmatrix} N_{Z-W} & \text{power (kW)} & \langle 20.00, 35.00\rangle \mid 0.25 \\ & \text{efficiency (\%)} & \langle 90.00, 92.00\rangle \mid 0.25 \\ & \text{bearing capacity (kN)} & \langle 18.00, 30.00\rangle \mid 0.25 \\ & \text{diameter (m)} & \langle 1.00, 1.60\rangle \mid 0.15 \\ & \text{weight (kg)} & \langle 500.00, 1000.00\rangle \mid 0.10 \end{bmatrix}, \quad (17)$$

$$\boldsymbol{J}_W = \begin{bmatrix} N_W & \text{power (kW)} & \langle 35.00, 46.00\rangle \mid 0.25 \\ & \text{efficiency (\%)} & \langle 90.00, 92.00\rangle \mid 0.25 \\ & \text{bearing capacity (kN)} & \langle 30.00, 42.00\rangle \mid 0.25 \\ & \text{diameter (m)} & \langle 1.60, 2.20\rangle \mid 0.15 \\ & \text{weight (kg)} & \langle 1000.00, 1800.00\rangle \mid 0.10 \end{bmatrix}. \quad (18)$$

According to the classical domain elementary models of the established design case subspaces, the corresponding joint elementary model J_P is expressed as:

$$\boldsymbol{J}_P = \begin{bmatrix} N_P & \text{power (kW)} & \langle 15.00, 46.00\rangle \mid 0.25 \\ & \text{efficiency (\%)} & \langle 85.00, 92.00\rangle \mid 0.25 \\ & \text{bearing capacity (kN)} & \langle 0.00, 42.00\rangle \mid 0.25 \\ & \text{diameter (m)} & \langle 0.00, 2.20\rangle \mid 0.15 \\ & \text{weight (kg)} & \langle 0.00, 1800.00\rangle \mid 0.10 \end{bmatrix}. \quad (19)$$

Convert it to the design project objective elementary J_G according to the design parameters as follows:

$$\boldsymbol{J}_G = \begin{bmatrix} N_G & \text{power (kW)} & \langle 19.00, 24.00 \rangle \\ & \text{efficiency (\%)} & \langle 88.00, 90.00 \rangle \\ & \text{bearing capacity (kN)} & \langle 26.00, 32.00 \rangle \\ & \text{diameter (m)} & \langle 1.50, 1.80 \rangle \\ & \text{weight (kg)} & \langle 900.00, 1200.00 \rangle \end{bmatrix} . \quad (20)$$

With the extension distance calculation formulas (8) and (10), acquire the extension distance sequence $\rho(J_G \to J_Z)$, $\rho(J_G \to J_{Z-W})$, $\rho(J_G \to J_W)$ between the design object objective elementary J_G and the classical domain elementary J_Z, J_{Z-W} and J_W of the design case subspaces which satisfy the following:

$$\begin{aligned} \boldsymbol{\rho}(\boldsymbol{J_G} \to \boldsymbol{J}_Z) &= \left(\rho(V_{g1}, V_{11}), \rho(V_{g2}, V_{12}), \rho(V_{g3}, V_{13}), \rho(V_{g4}, V_{14}), \rho(V_{g5}, V_{15})\right) \\ &= (3.00, -2.00, 22.00, 1.30, 1100.00) \end{aligned} , \quad (20)$$

$$\begin{aligned} \boldsymbol{\rho}(\boldsymbol{J_G} \to \boldsymbol{J}_{Z-W}) &= \left(\rho(V_{g1}, V_{21}), \rho(V_{g2}, V_{22}), \rho(V_{g3}, V_{23}), \rho(V_{g4}, V_{24}), \rho(V_{g5}, V_{25})\right) \\ &= (7.00, 2.00, -2.00, 0.10, 100.00) \end{aligned} , \quad (21)$$

$$\begin{aligned} \boldsymbol{\rho}(\boldsymbol{J_G} \to \boldsymbol{J}_W) &= \left(\rho(V_{g1}, V_{01}), \rho(V_{g2}, V_{02}), \rho(V_{g3}, V_{03}), \rho(V_{g4}, V_{04}), \rho(V_{g5}, V_{05})\right) \\ &= (27.00, 2.00, 2.00, -0.10, -100.00) \end{aligned} . \quad (22)$$

With the extension distance calculation formulas (9) and (11), acquire the extension distance sequence $\rho(J_G \to J_P)$ between the design object elementary J_G and the joint domain elementary J_P of the design case subspaces.

$$\begin{aligned} \boldsymbol{\rho}(\boldsymbol{J_G} \to \boldsymbol{J_P}) &= \left(\rho(V_{g1}, V_{01}), \rho(V_{g2}, V_{02}), \rho(V_{g3}, V_{03}), \rho(V_{g4}, V_{04}), \rho(V_{g5}, V_{05})\right) \\ &= (-13.00, -5.00, -26.00, -1.10, -1500.00) \end{aligned} . \quad (23)$$

With the extension distance calculation formula (12), acquire the extension correlation function value sequences $K(J_G \to J_Z)$, $K(J_G \to J_{Z-W})$ and $K(J_G \to J_W)$ between the design object objective elementary J_G and the classical domain elementary J_Z, J_W and J_{Z-W} of design case subspaces, as follows:

$$\boldsymbol{K}(\boldsymbol{J_G} \to \boldsymbol{J_Z}) = \left(K_1(V_{g1}), K_1(V_{g2}), K_1(V_{g3})\right) = (-0.1875, 0.4000, -0.4583, -0.5417, -0.4231) , \quad 24$$

$$\boldsymbol{K}(\boldsymbol{J_G} \to \boldsymbol{J}_{Z-W}) = \left(K_2(V_{g1}), K_2(V_{g2}), K_2(V_{g3})\right) = (-0.3500, -0.2587, 0.1667, -0.0833, -0.0625) , \quad 25$$

$$\boldsymbol{K}(\boldsymbol{J_G} \to \boldsymbol{J}_W) = \left(K_3(V_{g1}), K_3(V_{g2}), K_3(V_{g3})\right) = (-0.6750, -0.2857, -0.0714, 0.1000, 0.0714) . \quad 26$$

According to formula (13) when introducing matching function for the design case subject indexes, the extension correlation sequence *K(G)* between design object objective elementary J_G and design case subspace should be:

$$\boldsymbol{K}(\boldsymbol{G}) = (-0.1850, -0.1360, -0.2359) . \quad (27)$$

According to formulas (14) and (15), the best design case subspace is J_{Z-W}. Therefore, we can make a choice of the best design case in this design case subspace and apply this design case in the development of new products.

5 Conclusion

This article proposes a design case model for complex products based on extension theory. This model clarifies the layers of the design for complex products by building design case subspace and design case subspace subject index for design product and making formalized presentation of elementary model. Meanwhile, this model achieves the rapid selection of design reusing case by processing the extension distance and extension correlation function of different design case subspace and acquiring the case space attribute of the design objective elementary based on the classical domain and joint domain of the design case space. Thus, the effectiveness of the complex product case reuse is enhanced and the product design period is shortened, providing support for the implementation of product rapid design.

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