A membership degree algorithm of collaborative design roles in distributed design transaction

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Abstract

As there is a priority in multiple design transaction and multiple design roles in the distributed design traction, this paper studies the distribution hierarchy of collaborative design roles and proposes a membership degree algorithm based on grey related analysis. In this algorithm, design constraint degree about the design roles is acquired through grey related analysis. Under different design constraint degree, design roles and incidence coefficient are acquired together with corresponding matrix. Then the membership degree can be available by the constraint degree and the matrix. Empirical test proves the efficacy and practicability of this algorithm.

Keywords: distributed design, collaborative design, membership degree, algorithm, artificial intelligence

1 Introduction

With the rapid development of computer science, distributed collaborative design has become a big concern of intelligent design. The quick design of huge and complicated modern manufacturing equipment requires multiple design roles in the process of distributed design or manufacturing, as these designs need collaboration of a team or the design is distributed in different enterprises or regions [1-3].

Some researchers have already studied the distributed design and multiple roles collaborative design with satisfactory progress. But as the weight and hierarchy of the design is limited, there are few researches involving fuzzy design roles. Design constraints and standards need to be considered for the hierarchy of fuzzy design roles. Therefore, it is significant to determine the priority of different roles in the collaborative design, which will ease the coupling and conflicts in multiple design and support complicated design that promote the development of artificial intelligent design.

Currently, comprehensive evaluation method and Access Hierarchy Process (AHP) [8-10] are major ways to determine the priority of design roles. However, these methods rely much on people's subjective judgment and experience that may overlook constraint information or uncertain information, resulting in a biased design. Therefore, this paper analyses the membership degree of collaborative design roles based on grey system theory [11-14]. In this theory, the more similar the curves of the sequence are to each other, the more incidences they have. Multiple design constraint is set as the standard for membership degree. The incidence coefficient and incidence matrix between design constraint and design roles are acquired. Then this paper proposes a multiple design membership degree algorithm based on grey incidence analysis and apply it to empirical study to prove its feasibility.

2 Multiple design roles priority distribution standard

Multiple design roles distribution is key to the collaborative design, the process of which involves in weight distribution affected by various factors. Some factors can be measured up accurately in a quantitative way. Some call for qualitative analysis mixed with uncertain design factors. Thus, multiple design roles distribution is a system decision-making problem with multi-attribute.

Multiple design roles distribution based on grey incidence analysis requires the calculation of grey incidence degree of various design roles and the sequence of roles characteristic and judgment standard. A combination of quantitative and qualitative analysis will make it easier to standardized and do statistics of the priority distribution standard and eliminate human factors so that the result will be more scientific, objective and accurate. Grey incidence analysis serves to the nature of collaborative design represented by priority distribution standard of multiple design roles.

2.1 DETERMINATION OF MULTIPLE DESIGN ROLES DISTRIBUTION STANDARD

Factors that affect the priority distribution of design roles are multifaceted, including organization factor, intrapersonal factor, theme factor, object factor, knowledge sharing, intelligent integration, design demand, etc. Some factors are fuzzy and uncertain. What's more, it also looms large to transmit these factors to an information

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model that is easy to be identified by the computer, which will ease the priority distribution of design roles.

There is a necessity to set standard and construct a model for standard of the priority distribution of roles. Standards are set based on the abstract and fuzzy constraint factors of collaborative design in the way of semantic segmentation. The purpose is to acquire the minimum, complete and independent unit of constraint information of multiple design roles and transmit the semantics by units to standards that are coped easily.

This paper introduces the concept of unit to describe the priority distribution standard. The priority distribution standard O, standard characteristics C and value of O about C consist a three-element set $J=(O,C,V)$, which serves as the unit of priority distribution standard with one dimension. As the priority distribution standard has various characteristics, they are usually multi-dimensional. Here prescribes that the standard O, n characteristics $c_1,c_2,...,c_n$ and corresponding value $v_1,v_2,...,v_n$ consist of rows and lines with n dimensions. It is a standard unit with n dimensions:

$$J=(O,C,V)=\begin{bmatrix} O & c_1 & v_1 \\ & c_2 & v_2 \\ & & \\ & c_n & v_3 \end{bmatrix}. \tag{1}$$

To ensure the reliability of the membership degree distribution, authenticity and completeness of priority distribution standard should be guaranteed. After decomposition, what the original priority distribution standards stand for should be passed down to decomposed standards and the constraint information shouldn't be overlapped. It is expressed by:

$$(\forall J_s,J_t)J_s\cap J_t\wedge(J_s\in J,J_t\in J)=\varnothing,\ s\neq t.$$

2.2 MODEL OF PRIORITY DISTRIBUTION STANDARD

Suppose there are M priority distribution standards and none of them are overlapped in information, and there are K decision subjects to do the grey decision analysis. Here gets the grey decision analysis sequence for standard J_i:

$$\Psi_i=(\varphi_i(1),\varphi_i(2),...,\varphi_i(K)),\ i=1,2,...,M.$$

Construct the ideal grey incidence sequence Ψ_Θ of priority distribution standard:

$$\Psi_\Theta=(\varphi_\Theta(1),\varphi_\Theta(2),...,\varphi_\Theta(K))=\left(\max_{1\le i\le M}(\varphi_i(1)),\max_{1\le i\le M}(\varphi_i(2)),...,\max_{1\le i\le M}(\varphi_i(K))\right), \tag{2}$$

If $\varphi_i(j)$ is a quantitative value, then the grey incidence coefficient between sequence Ψ_i and sequence Ψ_Θ about j is described as:

$$\delta_i(j)=\frac{\min_i\min_j|\varphi_\Theta(j)-\varphi_i(j)|+\beta\max_i\max_j|\varphi_\Theta(j)-\varphi_i(j)|}{|\varphi_\Theta(j)-\varphi_i(j)|+\beta\max_i\max_j|\varphi_\Theta(j)-\varphi_i(j)|}, \tag{3}$$

where β is the identification coefficient, and $\beta=0.5$.

If $\varphi_i(j)$ is fuzzy and uncertain value interval, that is when $\varphi_i(j)=[\varphi_i^a(j),\varphi_i^b(j)]$ and fits $\varphi_i^a(j)\le\varphi_i^b(j)$, then the grey incidence coefficient between sequence Ψ_i and sequence Ψ_Θ about j is described as:

$$\delta_i(j)=\frac{\min_i\min_j\sqrt{\frac{|\varphi_\Theta^a(j)-\varphi_i^a(j)|^2+|\varphi_\Theta^b(j)-\varphi_i^b(j)|^2}{2}}+\beta\max_i\max_j\sqrt{\frac{|\varphi_\Theta^a(j)-\varphi_i^a(j)|^2+|\varphi_\Theta^b(j)-\varphi_i^b(j)|^2}{2}}}{\sqrt{\frac{|\varphi_\Theta^a(j)-\varphi_i^a(j)|^2+|\varphi_\Theta^b(j)-\varphi_i^b(j)|^2}{2}}+\beta\max_i\max_j\sqrt{\frac{|\varphi_\Theta^a(j)-\varphi_i^a(j)|^2+|\varphi_\Theta^b(j)-\varphi_i^b(j)|^2}{2}}}. \tag{4}$$

The grey incidence degree between sequence Ψ_i and sequence Ψ_Θ are:

$$\lambda(i)=\frac{1}{K}\sum_{j=1}^{K}\delta_i(j). \tag{5}$$

The priority degree of standard J_i is described as:

$$\kappa_i=\lambda(i)/\sum_{i=1}^{M}\lambda(i). \tag{6}$$

The priority degree of all priority distribution standards of multiple design roles are expressed by:

$$\kappa=(\kappa_1,\kappa_2,...,\kappa_M)^T. \tag{7}$$

3 Calculation method and algorithm of membership degree of multiple design roles

3.1 CALCULATION METHOD OF MEMBERSHIP DEGREE

Suppose there are H collaborative design roles in the distributed design and K decision subjects to do the grey decision analysis. The grey decision sequence for roles J_t is described as:

$$\Phi_r=(\phi_r(1),\phi_r(2),...,\phi_r(K)),\ r=1,2,...,H.$$

In order to measure better the membership degree, here sets the priority distribution standard Ψ_i as the ideal grey incidence sequence Φ_Θ. Calculate the grey incidence degree between design roles sequence Φ_r and ideal grey incidence sequence Φ_Θ as well as the incidence coefficient $\xi_r(k)$ between priority distribution standard and design roles.

Suppose the ideal grey incidence sequence Φ_Θ is expressed as:

$$\Phi_\Theta = \Psi_i = \left(\varphi_i(1), \varphi_i(2), \ldots, \varphi_i(K)\right). \quad (8)$$

If $\varphi_i(j)$ is a quantitative value, then the grey incidence coefficient between sequence Φ_r and sequence Ψ_i about j is described as:

$$\tau_i^r(j) = \frac{\min_i \min_r \left|\varphi_i(j) - \phi_r(j)\right| + \beta \max_i \max_r \left|\varphi_i(j) - \phi_r(j)\right|}{\left|\varphi_i(j) - \phi_r(j)\right| + \beta \max_i \max_r \left|\varphi_i(j) - \phi_r(j)\right|}. \quad (9)$$

If $\varphi_i(j)$ is fuzzy and uncertain value interval, that is when $\phi_r(j) = \left[\phi_r^a(j), \phi_r^b(j)\right]$ and fits $\phi_r^a(j) \le \phi_r^b(j)$, then the grey incidence coefficient between sequence Φ_r and sequence Ψ_i about j is described as:

$$\tau_i^r(j) = \frac{\min_i \min_r \sqrt{\frac{\left|\varphi_i^a(j) - \phi_r^a(j)\right|^2 + |\varphi_i^b(j) - \phi_r^b(j)|^2}{2}} + \beta \max_i \max_r \sqrt{\frac{\left|\varphi_i^a(j) - \phi_r^a(j)\right|^2 + |\varphi_i^b(j) - \phi_r^b(j)|^2}{2}}}{\sqrt{\frac{\left|\varphi_i^a(j) - \phi_r^a(j)\right|^2 + |\varphi_i^b(j) - \phi_r^b(j)|^2}{2}} + \beta \max_i \max_r \sqrt{\frac{\left|\varphi_i^a(j) - \phi_r^a(j)\right|^2 + |\varphi_i^b(j) - \phi_r^b(j)|^2}{2}}}. \quad (10)$$

The incidence matrix τ between the priority distribution standard and the collaborative design roles:

$$\tau = \begin{bmatrix} \tau_1^1 & \tau_1^2 & \cdots & \tau_1^H \\ \tau_2^1 & \tau_2^2 & \cdots & \tau_2^H \\ \vdots & \vdots & \vdots & \vdots \\ \tau_M^1 & \tau_M^2 & \cdots & \tau_M^H \end{bmatrix}_{MxH}. \quad (11)$$

The absolute grey membership degree sequence of collaborative design roles is:

$$\omega = \kappa^T * \tau = \left(\omega_1, \omega_2, \ldots, \omega_P\right)^T, \quad (12)$$

The absolute grey membership degree ω_r of the collaborative design roles r is:

$$\omega_r = \sum_{i=1}^{M}\left(w_i * \tau_i^r\right),\ 1 \le r \le H. \quad (13)$$

The absolute grey membership degree ϖ_r of the collaborative design roles r is:

$$\varpi_r = \omega_r / \sum_{r=1}^{H} \omega_r. \quad (14)$$

The relative grey membership degree sequence of collaborative design roles is:

$$\varpi = \left(\varpi_1, \varpi_2, \ldots, \varpi_H\right)^T. \quad (15)$$

3.2 DISTRIBUTION ALGORITHM FOR MULTIPLE MEMBERSHIP DEGREE OF DESIGN ROLES BASED ON GREY INCIDENCE ANALYSIS

As is discussed above, the grey incidence sequence is constructed based on the priority distribution standard of collaborative design roles in the distributed design transaction. Then, the priority distribution standard sequence is set as the ideal grey incidence analysis sequence and absolute membership degree and relative membership degree are available by the improved grey incidence calculation method proposed in this paper. The membership degree distribution algorithm based on grey incidence analysis is described as follows:

Step 1 Construct roles model according to design demand to confirm the design roles and corresponding roles characteristics;

Step 2 Determine the priority distribution standard of collaborative design roles in distributed design transaction based on Chapter 1.1;

Step 3 According to section 1.2, conduct the grey decision analysis abased on priority distribution standard of decision subjects to multiple design roles and get the grey decision sequence;

Step 4 Construct the ideal grey incidence analysis incidence of the priority distribution standard based on Equation (2);

Step 5 According to specific characteristics of standard, get the grey incidence coefficient of priority distribution standard based on Equations (3) and (4);

Step 6 Get the grey incidence degree and priority degree of priority distribution standard based on Equations (5)-(7);

Step 7 Construct the priority distribution standard of multiple design roles as the ideal grey incidence sequence according to section 2.1 based on Equation (8);

Step 8 Get the grey incidence analysis coefficient based on Equations (9-11) and construct corresponding coefficient matrix;

Step 9 Get the absolute membership degree and relative membership degree based on Equations (12)-(15) and determine the hierarchy of roles;

Step 10 Complete the membership degree distribution.

4 Empirical test

This paper tests the algorithm by a supporting system of a product's distributed design. This distributed design system has five design groups as design roles to coordinate tasks. Organization factor, theme factor, object factor, knowledge sharing, intelligent integration, design demand are set as distribution standard for membership degree. The original sequences by grey incidence analysis of priority distribution standard of multiple design roles and collaborative design roles in the distributed design transaction are shown in Tables 1 and 2.

TABLE 1 Grey incidence analysis of priority distribution standard of multiple design roles

Distribution standard	Grey incidence analysis data
Organization factor	9, (7.5,8.5),9,9, (6.5,7.5),9,9, (7.5,8.5)
Theme factor	9,9,9,9,9, (7.5,8.5),9,9
Object factor	(7.5,8.5),9,9,9, (7.5,8.5),9, (7.5,8.5),9
Knowledge sharing	(7.5,8.5),9, (6.5,7.5),9, (6.5,7.5), (7.5,8.5),9, (7.5,8.5)
Intelligent integration	(7.5,8.5), (5.5,6.5), (6.5,7.5), (7.5,8.5),9, (7.5,8.5), (6.5,7.5), (7.5,8.5)
Design demand	9, (6.5,7.5), (7.5,8.5), (7.5,8.5), (7.5,8.5),9, (6.5,7.5), (7.5,8.5)

TABLE 2 Grey incidence analysis of collaborative design roles

Collaborative design roles	Grey incidence analysis data
Design roles 1	(5.5,6.5), (5.5,6.5), (6.5,6.5), (6.5,7.5), (7.5,8.5), (6.5,7.5),9, (6.5,7.5)
Design roles 2	(6.5,7.5), (5.5,6.5), (7.5,8.5), (5.5,6.5), (6.5,7.5), (7.5,8.5), (6.5,7.5), (5.5,6.5)
Design roles 3	9, (7.5,8.5), (7.5,8.5),9,9,9, (6.5,7.5), (7.5,8.5)
Design roles 4	(5.5,6.5), (5.5,6.5), (4.5,5.5), (5.5,6.5), (6.5,7.5), (5.5,6.5), (6.5,7.5), (5.5,6.5)
Design roles 5	(6.5,7.5), (5.5,6.5), (5.5,6.5), (5.5,6.5), (7.5,8.5), (5.5,6.5), (6.5,7.5), (5.5,6.5)

According to the description of algorithm in section 2.2, the grey incidence degree and priority degree are available and shown in Table 3.

TABLE 3 The grey incidence degree and priority degree of distribution standard

Distribution standard	Calculated data for grey incidence analysis
Grey incidence degree	0.926, 0.961,0.942,0.780, 0.731,0.794
Grey priority degree	0.180,0.187,0.183,0.152, 0.142,0.155

Select several distribution standards as ideal grey incidence sequence. According to the algorithm described in section 2.2, absolute membership degree and relative membership degree are available and shown in Table 4.

TABLE 4 Membership degree by grey incidence analysis

Membership degree	Calculated data for grey incidence analysis
Absolute membership degree	0.542, 0.581,0.812,0.458, 0.416
Relative membership degree	0.193,0.207,0.289,0.163, 0.148

From Table 4, it is clear that design roles 3 has the highest membership degree, design roles 2 and 1 have the medium membership degree and design roles 4 and 5 have the lowest membership degree. Therefore, the design roles with a higher membership degree should enjoy a higher priority so that it can support the distributed collaborative design better.

5 Conclusion

This paper proposes a membership degree algorithm based on grey related analysis. The priority of the multiple design roles is the standard for the judgment of roles distribution. This paper takes into consideration various factors that affect the distributed design transaction and enables the membership degree to meet the demand of the coordinative design to provide support for the distributed design. Based on grey related analysis, this paper improves the algorithm and makes it more scientific, objective and accurate. Finally, empirical test proves the efficacy and practicability of this algorithm.

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