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Dynamic Evaluation Model of Networked Manufacturing Resources Based on Grey Target Decision

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Abstract: To choose suitable manufacturing resources according to different requirements of manufacturing task, a dynamic evaluation model of manufacturing resources based on grey target decision is proposed. An evaluation indicator system of manufacturing resource dynamic is designed, which consists of two types of indicators: performance and information quality. This study proposes a weighted grey target decision-making algorithm, which is more suitable for dynamic evaluation of manufacturing resources with the addition of the expert weight evaluation method. Finally, the effectiveness of the model based on grey target decision is validated by a networked manufacturing resource evaluation case.

Key words: Weighted grey target decision, manufacturing resources evaluation, networked manufacturing

INTRODUCTION

Under the backdrop of economic globalization, the market life of products is becoming shorter and shorter and productionbatches are becoming smaller and smaller. The customer requirements are more and more diverse. The product development, production and sales are expected to be at high speed. The increasing product complexity and globalization trend of manufacturing industry require the cooperation and coordination of manufacturing enterprises around the world (Huang *et al*., 2001). The resource sharing and reuse among these enterprises are essential for networked product development and innovation (Dong *et al*., 2008). Complex manufacturing engineering generally requires a higher quality of manufacturing resources (Tian *et al*., 2002).

The focus of world manufacturing competition has turned into how to seize the market opportunities, organize the global resources immediately for rapid development of new products and effectively mobilize the productive management system to push the product to market (Ju *et al*., 2007).

Standard information representation in the manufacturing business has always focused on products with information relating to their design, geometry and required processes. However there is no standardized information model available to represent the manufacturing equipment used to produce such products (Vichare *et al*., 2009). Manufacturing resources refer to the sum of the hardware and software involved in the equipment, material, personnel and product life cycle of manufacturers.

Manufacturing resources evaluation is the premise for selecting and using rational manufacturing resources. Manufacturing resources selection is a dynamic evaluation, with the changes in the cost of product manufacturing, time to market and quality requirements, the combination plans of manufacturing resources are also different. The current evaluation methods include: TOPSIS method (Li *et al*., 2007), neural networks method (Sun, 2005; Anastassiou, 2011) and multi-granularity hierarchical method (Zhang *et al*., 2010). Based on the complexity of algorithm and the response time, this study presents a dynamicevaluation model of manufacturing resources based on grey target decision. Grey target decision is an evaluation method with satisfactory effects. Due to the different targets having different influences on manufacturing resources and even if there are different circumstances in the same manufacturing resources information, the requirements are different to the same target. Therefore, this paper proposes a weighted gray target decision method, which can calculate an advantageous effective solution under the premise of comprehensively analyzing the importance of various targets.

Manufacturing resource evaluation indicator system is an indicator set for evaluating manufacturing resources. This system reflects application performance status in different perspectives and different levels (Table 1). According to its own characteristics, the manufacturing

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Table 1: Evaluation indicator system of design knowledge

Indicators classification	Indicators name	Remarks
Performance indicators	Time requirement (T)	Negative
	Cost requirement (C)	Negative
	Quality requirement (Q)	Positive
	Environmental impact (E)	Negative
	Geographic location (G)	Negative
	Personnel impact (P)	Negative
Quality indicators	Reliability (R)	Positive
	Degree of correlation (D)	Positive
	Support degree (S)	Positive

resource evaluation can be divided into two groups: One is performance indicators which reflect the processing capacities that different manufacturing resources can achieve. These include time requirement (T), cost requirement (C), quality requirement (Q), environmental impact (E), geographic location (G), personnel impact (P) and so on. The other is information quality indicator, which reflects the information quality of manufacturing resources, such as: reliability(R), Degree of correlation (D), support degree (S), etc. After application of all the manufacturing resources, users are requested to give their evaluations to every indicator of the manufacturing resource and the resulting value will be stored into the knowledge base.

DYNAMIC EVALUATION MODEL

Weight setting: According to the requirements of manufacturing tasks, the application targets of manufacturing resources are determined and sorted and then the corresponding weights are given according to the importance of each target to the manufacturing resources.

Step 1: According to the requirements of the manufacturing task, select the associated target from the target system of manufacturing tasks

Step 2: According to the importance of the selected target to the overall target, distribute the weight (Table 2)

Let $w^{(x)}$ be the weight value of the target X-for the sub-goal number of each manufacturing resource is 6- in order to ensure the weight of every single goal $3 \geq w^{(Xi)} \geq 0$. Now take the sum of weight for $18 \geq W = \sum w^{(xi)} \geq 0$ and the sub-goal number of the manufacturing resource is 6.

Establish the situation set:

Step 1: Establish the manufacturing resource set $M = \{m_1, m_2, ..., m_n\}$ where, m_i is one of the individual manufacturing resources

Table 2: Settingstan dards for weights

Weight value	Relationship between sub-goal and manufacturing task
0	No influence
1	Minimum influence
2	Moderate influence
3	Maximum influence

Step 2: Establish the target set $G = \{g_1, g_2, ..., g_m\}$ of the manufacturing resource m_i, where g_i is one of the manufacturing task sub goals

Step 3: Calculate the cartesian:

$$S = M \times G = \begin{bmatrix} (m_1g_1) & (m_1g_2) & \cdots & (m_1g_m) \\ (m_2g_1) & (m_2g_2) & \cdots & (m_2g_m) \\ \cdots & \cdots & \cdots & \cdots \\ (m_ng_1) & (m_ng_2) & \cdots & (m_ng_m) \end{bmatrix}$$

where $s_{ij} = (m_i, g_i) | m_i \in M, g_i \in G$.

Step 4: Calculate the result set. If the initial effecting value of the situation s_{ij} is u'_{ij}, then the value of the situation S can be shown as the initial effect matrix:

$$U' = \begin{bmatrix} u'_{11} & u'_{12} & \cdots & u'_{1m} \\ u'_{21} & u'_{22} & \cdots & u'_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ u'_{n1} & u'_{n1} & \cdots & u'_{nm} \end{bmatrix}$$

Effecting value treatment: Do the dimensionless processing for the initial value sets A and B and let the following matrix (Formula 1) be the set of all the quantitative effecting values, where A, B, ..., X, ..., Z are the individual quantitative targets, $u_1^{(x)}, \cdots, u_n^{(x)}$ is the intermediate state value of the target A which has already been preprocessed but not yet been blurred. Among them, each element in the above formula is divided by the maximum value of the elements in its column. The fuzzy degree of membership is now obtained in order to eliminate the dimension of the indicators. After the standardization of eliminating the dimension of the matrix $F = (V_{ij})\ m \times n$, a new matrix $F' = (V'_{ij})\ m \times n$ (Formula 2) is attained:

$$F = \begin{bmatrix} U^{(A)} \\ \cdots \\ U^{(X)} \\ \cdots \\ U^{(Z)} \end{bmatrix} = \begin{bmatrix} u_1^{(A)} & \cdots & u_i^{(A)} & \cdots & u_n^{(A)} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ u_1^{(X)} & \cdots & u_i^{(X)} & \cdots & u_n^{(X)} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ u_1^{(Z)} & \cdots & u_i^{(Z)} & \cdots & u_n^{(Z)} \end{bmatrix} \quad (1)$$

After dividing each element in the above matrix by the maximum value of each row in the matrix, the matrix F can be converted into the following matrix F':

$$F' = \begin{bmatrix} V^{(A)} \\ \cdots \\ V^{(X)} \\ \cdots \\ V^{(Z)} \end{bmatrix} = \begin{bmatrix} v_1^{(A)} & \cdots & v_i^{(A)} & \cdots & v_n^{(A)} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ v_1^{(X)} & \cdots & v_i^{(X)} & \cdots & v_n^{(X)} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ v_1^{(Z)} & \cdots & v_i^{(Z)} & \cdots & v_n^{(Z)} \end{bmatrix} \quad (2)$$

The initial values corresponding to the dimensionless processed targets are divided by the fuzzy membership evaluation method. If the grades are excessive, then the calculated amount will increase substantially; if the grades are not sufficient, then the accuracy of the evaluation effect will be reduced. Considering the two factors, the accuracy and calculated amount of the evaluation, we divide the fuzzy processed attribute values into 5 categories: lowest, lower, acceptable, higher and highest. Before the qualitative effecting values are stored into the knowledge base, they should be fuzzed and scored (3).

Determine the bull's-eye: Let the origin of the bull's-eye be the n-dimensional vector $R_0=\left[r_0^{X_1}\ r_0^{X_2}\ \cdots\ r_0^{X_n}\right]$. The numeric value area of the dimensionless effecting value is among (1, 5), the value of r_0^{X} is usually equal to 1, which is the minimum value. The actual distance between it and the n-dimensional sphere is $\sqrt{n}$.

Calculate the off-set distance: Calculate the off-set distance of different countermeasure effecting values respectively:

$$r_9=\left\|u_9-r_0\right\|=\sqrt{w^{(x_1)}\left(u_9^{(X_1)}-r_0^{X_1}\right)^2+w^{(x_2)}\left(u_9^{(X_2)}-r_0^{X_2}\right)^2+\cdots+w^{(x_n)}\left(u_9^{(X_n)}-r_0^{X_n}\right)^2} \quad (3)$$

where, $(\sum m^{(x_i)}=10 \text{ and } m^{(x_i)}\geq 1)$, it can similarly be calculated that $r_{ij}=\left|u_{ij}-r_0\right|\ (1\leq i\leq n, 1\leq j\leq m)$. According to the calculated results, the decision S_{ij} corresponding to the minimum value of r_{ij} is the optimal solution.

CASE ANALYSIS

The available manufacturing resource set of a manufacturing task isM = {m_1, m_2, m_3, m_4, m_5} where time requirement (T), cost requirement (C), quality requirement (Q), environmental impact (E), geographic location (G) and personnel impact (P) are the 6 performance targets of the manufacturing resources and reliability (R), degree of correlation (D) and support degree (S) are the 3 quality targets of the manufacturing resources. Assume that the effecting value of the manufacturing resource set composed of eleven sub-targets can be expressed as:

$$V=\left[\begin{array}{c|cccccc:ccc} s_{ij} & T & C & Q & E & G & P & R & D & S \\ \hline m_1 & 2 & 2 & 2 & 4 & 3 & 2 & 2 & 3 & 2 \\ m_2 & 3 & 3 & 3 & 2 & 2 & 3 & 2 & 2 & 3 \\ m_3 & 2 & 3 & 2 & 1 & 1 & 2 & 2 & 3 & 2 \\ m_4 & 5 & 2 & 4 & 2 & 3 & 4 & 3 & 4 & 3 \\ m_5 & 4 & 4 & 3 & 4 & 2 & 2 & 2 & 3 & 4 \end{array}\right] \quad (4)$$

Table 3: The distribution of sub-target weight values

Sub-targets	T	C	Q	E	G	P
Weight values	3	2	3	1	1	1

According to the effect level of each manufacturing task sub-target on the manufacturing general task, the sub-target weight is designed by way of expert scoring and the results are shown in the Table 3:

Let, R_0 = $[1\ \ldots\ 1\ \ldots\ 1]_9$ be the ideal bull's-eye value of the 9 dimensional spherical grey target and the grey target radius is $\sqrt{9}$, take the values of each row in the matrix (4) and calculate the value of $\left|v_i^{(X)}-r_0^{(X)}\right|$:

$$V'=\left[\begin{array}{c|cccccc:ccc} \left|v_i^{(X)}-r_0^{(X)}\right| & T & C & Q & E & G & P & R & D & S \\ \hline m_1 & 2\text{-}1 & 2\text{-}1 & 2\text{-}1 & 4\text{-}1 & 3\text{-}1 & 2\text{-}1 & 2\text{-}1 & 3\text{-}1 & 2\text{-}1 \\ m_2 & 3\text{-}1 & 3\text{-}1 & 3\text{-}1 & 2\text{-}1 & 2\text{-}1 & 3\text{-}1 & 2\text{-}1 & 2\text{-}1 & 3\text{-}1 \\ m_3 & 2\text{-}1 & 3\text{-}1 & 2\text{-}1 & 1\text{-}1 & 1\text{-}1 & 2\text{-}1 & 2\text{-}1 & 3\text{-}1 & 2\text{-}1 \\ m_4 & 5\text{-}1 & 2\text{-}1 & 4\text{-}1 & 2\text{-}1 & 3\text{-}1 & 4\text{-}1 & 3\text{-}1 & 4\text{-}1 & 3\text{-}1 \\ m_5 & 4\text{-}1 & 4\text{-}1 & 3\text{-}1 & 4\text{-}1 & 2\text{-}1 & 2\text{-}1 & 2\text{-}1 & 3\text{-}1 & 4\text{-}1 \end{array}\right] \quad (5)$$

Calculate $\left|v_i^{(X)}-r_0^{(X)}\right|^2$ in formula (5), we can get a new matrix:

$$V''=\left[\begin{array}{c|cccccc:ccc} \left|v_i^{(X)}-r_0^{(X)}\right| & T & C & Q & E & G & P & R & D & S \\ \hline m_1 & 1 & 1 & 1 & 9 & 4 & 1 & 1 & 4 & 1 \\ m_2 & 4 & 4 & 4 & 1 & 1 & 4 & 1 & 1 & 4 \\ m_3 & 1 & 4 & 1 & 0 & 0 & 1 & 1 & 4 & 1 \\ m_4 & 16 & 1 & 9 & 1 & 4 & 9 & 4 & 9 & 4 \\ m_5 & 9 & 9 & 4 & 9 & 1 & 1 & 1 & 4 & 9 \end{array}\right] \quad (6)$$

In this case, the value of the weight of each indicator is expressed by following matrix:

$$W=\left[\begin{array}{ccccccccc} w^{(T)} & w^{(C)} & w^{(Q)} & w^{(E)} & w^{(G)} & w^{(P)} & w^{(R)} & w^{(D)} & w^{(S)} \\ \hline 3 & 2 & 3 & 2 & 1 & 1 & 2 & 1 & 1 \end{array}\right] \quad (7)$$

Take the weight factors in and calculate the value of $w^{(X)}\left|v_i^{(X)}-r_0^{(X)}\right|^2$, we can get a new V"W, which is shown as follows:

$$V''W=\left[\begin{array}{c|cccccc:ccc} w^{(X)}\left|v_i^{(X)}-r_0^{(X)}\right|^2 & 3 & 2 & 3 & 2 & 1 & 1 & 2 & 1 & 1 \\ \hline m_1 & 3 & 2 & 3 & 18 & 4 & 1 & 2 & 4 & 1 \\ m_2 & 12 & 8 & 12 & 2 & 1 & 4 & 2 & 1 & 4 \\ m_3 & 3 & 8 & 3 & 0 & 0 & 1 & 2 & 4 & 1 \\ m_4 & 48 & 2 & 27 & 2 & 4 & 9 & 8 & 9 & 4 \\ m_5 & 27 & 18 & 12 & 18 & 1 & 1 & 2 & 4 & 9 \end{array}\right] \quad (8)$$

According to the formula (3), we can calculate the weighted distance between the comprehensive target and the grey target center:

$$\left\|M-R_0\right\|=\begin{bmatrix} \left\|m_1-r_0\right\| \\ \left\|m_2-r_0\right\| \\ \left\|m_3-r_0\right\| \\ \left\|m_4-r_0\right\| \\ \left\|m_5-r_0\right\| \end{bmatrix}=\begin{bmatrix} \sqrt{38} \\ \sqrt{46} \\ \sqrt{22} \\ \sqrt{113} \\ \sqrt{92} \end{bmatrix} \quad (9)$$

For:

$$\|m_3 - r_0\| \succ \|m_1 - r_0\| \succ$$
$$\|m_2 - r_0\| \succ \|m_5 - r_0\| \succ \|m_4 - r_0\|$$

so the optimal solution is m_3 which means the manufacturing resource m_3 is the most reasonable manufacturing resource to the manufacturing task.

CONCLUSION

This study presents a dynamicevaluation model of manufacturing resources based on grey target decision, which can evaluate the manufacturing resources dynamically according to the influence of the performance indicator and the information quality indicator on the current manufacturing task. In the application of this method, special attention should be paid to the setting of the weight size. The setting of the weight depends mainly on the experience. Therefore, it is suggested to use the multiple-expert scoring method in order to avoid incorrectly setting the weight, which will influence the results of the evaluation of manufacturing resources. The grey target decision-making method improves the efficiency and accuracy of evaluation effectively and promotes the likelihood of choosing the reasonable manufacturing resources dynamically in different manufacturing resources.

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