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Research on Two -Way Matching of Cloud Manufacturing Partners for Enterprise Requirements

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Abstract: The research on cloud manufacturing mechanism has evolved into a hot issue in the field of virtual enterprises in recent years. In order to solve the problem of partner selection in cloud manufacturing environment as well as refining the matching accuracy and satisfaction of both parties, a two-way matching model is proposed. Combining with the needs of various enterprises, based on psychological expectation from massive cloud data in cloud manufacturing environment, the prospect theory is adopted to construct the mutual evaluation profit and loss matrix of matching subjects through two-way multiattribute matching, and the satisfaction between enterprises is calculated. Then the partners are optimized and combined and an example is analyzed to prove the feasibility of the algorithm.

Keywords: Cloud manufacturing, Partner selection, Prospect theory, Two-way matching.

INTRODUCTION

The skyrocketing development of science and technology in the current society goads the intensifying trend of global economic integration day by day. In the face of diversified users, personalized demands and fierce market competition, modern enterprises must have a high degree of flexibility and rapid reflection ability. Networking, intelligence, agility and greening have become the development direction of modern enterprise operation mode. More and more enterprises realize that it is difficult to seize the market opportunity and participate in the competition by themselves to achieve development. The virtual enterprise, which integrates knowledge, technology, capital, materials, market and management, has emerged as the times require. The virtual enterprise with low operating cost, fast response speed and strong adaptability has become the organization and operation mode of the new enterprise in the 21st century. Cloud manufacturing is a new mode of networked intelligent manufacturing with service orientation, high efficiency, low consumption and knowledge-based. It integrates technologies such as information manufacturing, cloud computing, Internet of things, semantic Web, and high-performance computing, virtualizes and services all kinds of manufacturing resources and manufacturing capabilities, and conducts unified and centralized intelligent management and operation, providing users with services that can be obtained at anytime, used on demand, safe, reliable, high quality and low price[1]. It supports dynamic and convenient cooperation between enterprises and promotes optimization and cooperation of manufacturing resources in a wide area. The development and maturity of cloud manufacturing will help manufacturing enterprises seize opportunities, optimize resources, promote cooperation and participate in global manufacturing.

Body-building provides new platforms and opportunities, and virtual enterprises in cloud manufacturing environment have also become the focus of the industry and academia. The key to establishing a virtual enterprise is to choose a suitable partner, because this directly affects the success or failure of the virtual enterprise and its performance. In view of the choice of virtual enterprise partners, many scholars in China and abroad have studied it in different application fields. Wu et al.[2] proposed a two-stage partner selection model, but the model only takes cost and delivery date as key factors. Jia Ruiyu and others[3] gained objective index weights by virtue of the knowledge of rough set, and apply adaptive genetic algorithm to the selection of optimal partners. TAO et al.[4] proposed a GA-BHTR

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partner selection algorithm based on consideration of minimum cost and risk, maximum quality and flexibility. In order to solve the problem of asymmetric information in the process of partner selection in virtual enterprises, Ji Juhai et al. [5] established a model suitable for partner selection in virtual manufacturing enterprises based on vague sets and solved it by using improved particle swarm optimization algorithm. Huang et al.[6] proposed an improved particle swarm optimization algorithm based on fuzzy intuition considering the priority of tasks, delivery time, cost and other factors. Huang Bin et al.[7] established a partner selection model to maximize delivery time satisfaction for fuzzy completion time and delivery date, which takes into account such factors as delivery time satisfaction, cost and task timing. Zhang Wei et al.[8] built a trust-based partner selection model based on ability, motivation and persistence, aiming at the original virtual partner selection only quantitatively evaluating time, cost and risk. For multistage cooperation in manufacturing industry. Suet al.[9] combined with particle swarm optimization and genetic algorithm to optimize the selection of virtual enterprise partners. Kang Yanfanget al.[10] used the gray relational comprehensive evaluation model to determine the optimization index of cloud service market in the cloud computing environment, and used the multi objective optimization model to quantitatively analyze and study the partner selection problem of cloud service providers. The analysis presents that most of the previous studies have a certain application environment, and there are fewer partners to choose in cloud computing and cloud manufacturing environment. The selection mode is also that the core enterprises choose the best one-way among the limited candidate enterprises as partners. Cloud manufacturing environment has its particularity, such as: huge number of candidate enterprises; affected by factors such as technology and ability, enterprises generally have their market positioning and cooperation is expected. There are logistics among enterprises. Therefore, inconsideration of the particularity of cloud manufacturing environment and the actual situation of manufacturing industry, this paper uses prospect theory [11,12] to comprehensively evaluate the satisfaction among potential cooperative enterprises, selects the best satisfactory partners according to the working process, and verifies the validity and rationality of the model through experimental simulation.

PARTNER MATCHING MODEL CONSIDERING ENTERPRISEPSYCHOLOGICAL EXPECTATION

Amid the cloud manufacturing environment, an enterprise (core enterprise) is assumed to choose on a new product or service after market research and analysis, but cannot complete all functions due to its own resource and capacity constraints, so it decides to set up a virtual enterprise to complete the task by looking for a partner. The two-way matching model of partners considering psychological expectations is shown in Figure 1.

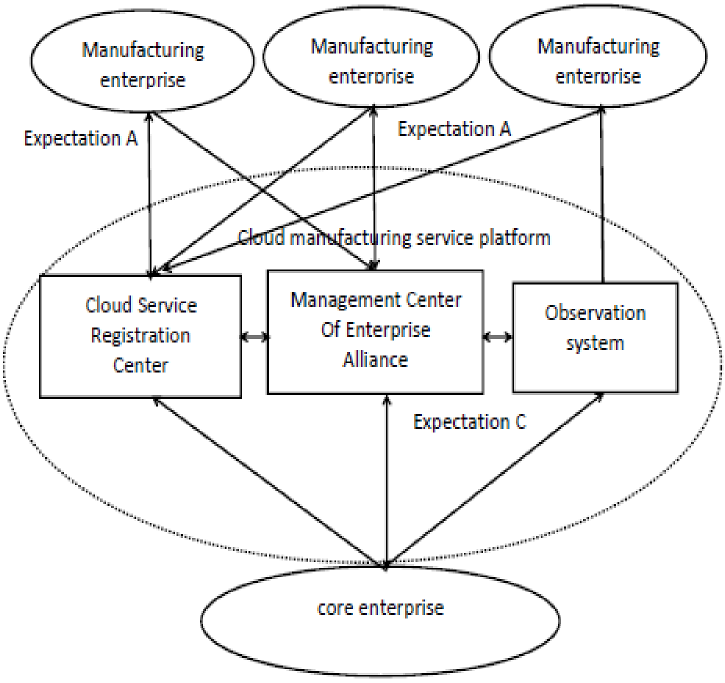

Figure 1: Model of Partners' Two-way Matching

The first step is for the core enterprise to determine the product structure, then define the cooperative task and break it down into multiple sub-tasks according to the working process. The backbone enterprise targets the QoS requirements of each sub-task according to the product market positioning, and submits service requests with psychological expected QoS constraints to each sub-task to the enterprise alliance management center. After receiving the request, the enterprise alliance management center queries the monitoring system for services that meet the functional requirements, and calculates the comprehensive prospect value of the core enterprise's satisfaction with each candidate enterprise by using the prospect theory. Then, according to the expected cooperation conditions of the candidate enterprises, the comprehensive prospect value of the candidate enterprises' satisfaction with the core enterprises and projects is calculated by using the prospect theory. In consideration of the degree of mutual satisfaction, the management center of enterprise alliance uses adaptive genetic algorithm to select enterprises that are both satisfied as partners, and sends a request for cooperation intention to partner enterprises. The partner enterprise manually evaluates whether to accept the invitation or not, if so, registers the new service with the manufacturing cloud service registration center, otherwise, re-selects it. The pillar enterprise is responsible for the overall operation, maintenance and cancellation of new services and coordinate the operation of new services. C={c1, c2, …, cf} is the attribute set of core enterprises' service satisfaction evaluation to partner enterprises, c1,c2, …, cf are independent of each other. A = { a1, a2 ,..., ag } isa set of attributes for partner enterprises to evaluate the satisfaction of core enterprises and projects, a1, a2 ,..., ag are independent of each other. The set of attributes can be described as numeric values or evaluation phrases. Requirements for attribute are called constraints, constraints equal to are called hard constraints, and the rest are called soft constraints. Soft constraints can be generally divided into three types:

(1)Benefit-type attribute constraint: the greater the attribute of this class is, the better it will be, such as the higher the reliability of the service for the demand side.

(2)Cost-type attribute constraint: the smaller the attributes of this class is, the better it will be, such as the lower the price of services for the demand side.

(3)Interval-type attribute constraint: the attribute change is required to be within an interval range, such as the completion of the construction period within a certain period of time.

MATCHING PROCESS BASED ON PROSPECT THEORY

Introduction to Prospect Theory

This theory was first explicitly proposed by Kahneman and Tversky, who won the 2002 Nobel Prize in Economics for their Prospect Theory. It holds that human beings are limited and rational, and their attitudes towards loss and gain are different in decision-making, and they tend to "risk averse" in dealing with gains. Treatment of losses tends to be "risk loving". In the Prospect Theory, the expected value V is determined jointly by the value function V (x) and the decision function π(p), which can be expressed as in the following formula:

$$V = \sum_{i=1}^{n} \pi(p_i) v(x_i) \tag{1}$$

The value function is an "S" shaped function, and the center point is the reference point for decision-making. The value function has three basic characteristics: (1)the gain and loss are relative to the reference point, not absolute; (2) Risk aversion for gains and risk loving for losses; (3)Decision makers are more sensitive to losses than profits. The value function given by Tversky et al. is a power function:

$$v(\Delta x) = \begin{cases} \Delta x^{\alpha}, \Delta x \geq 0 \\ -\theta(-\Delta x)^{\beta}, \Delta x < 0 \end{cases} \tag{2}$$

A and β represent the concavity and convexity of the power function of gain and loss, respectively, while α and β< 1 indicates the decreasing sensitivity. θ indicates that the loss area is steeper than the gain area, if θ>1 indicates aversion to loss. As is shown in Figure 2.

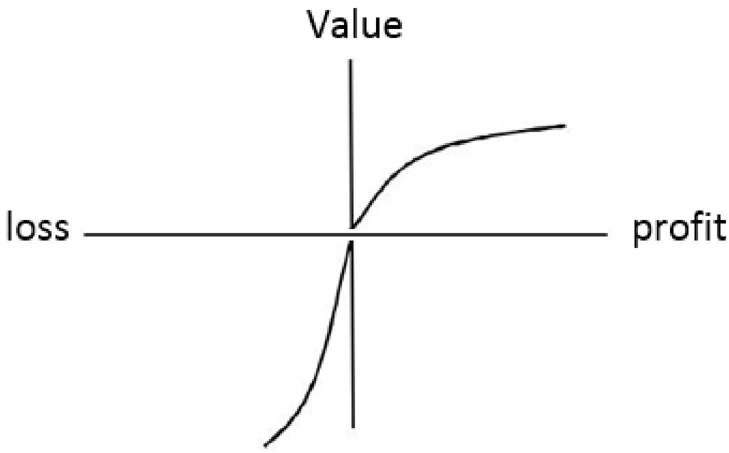

Figure 2: Value function

The decision weight is deduced from the expected selection. It is found that there is a non-linear relationship between the decision weight function π(p) and the objective probability P in the expected utility, which is the ratio of the weight of probability P to the weight of deterministic events. It neither accords with the probability formula nor can it be understood as subjective probability. The formula given by Tversky et al. is as follows:

$$W(A_i) = \pi(p(A_i)) \tag{3}$$

W in this formula is the weight function, π represents the probability weight function under risk, p is the judgment probability, Ai is the event under consideration.

The judgment probability p(Ai) is given by the evaluator's judgment. Considering the emphasis of system application and the influence of some risk uncertainties on unknown probability events, the weight can be calculated by equation (4).

$$\left\{ \begin{aligned} \pi^{+}(p) &= \frac{p^{\gamma}}{(p^{\gamma}+(1-p)^{\gamma})^{1/\gamma}} \\ \pi^{-}(p) &= \frac{p^{\delta}}{(p^{\delta}+(1-p)^{\delta})^{1/\delta}} \end{aligned} \right\} \tag{4}$$

γ, δ are model parameters.

Comprehensive Satisfaction Calculation on the Basis of Prospect Theory

Aiming to determine the profit and loss value in the prospect theory, the distance between the actual value and the reference value is calculated with the psychological expectation of the core enterprise for each sub-task attribute and the psychological expectation of the partner enterprise for the core enterprise and the product attribute as reference points, and the profit and loss value is calculated according to whether the attribute is cost-type or benefit-type .

(1) When the attribute value is a numerical value, both the attribute value and the desired value are real numbers, and the distance between the actual value of the attribute and the reference value can be calculated directly:

$$d_i = | q_i - \overline{e_i} | \tag{5}$$

(2) While the attribute value is the number of regions, the actual size of attribute interval and the reference attribute interval need to be compared first and then calculate their distance respectively.

$$x(q_i) = (q^{low}{}_i + q^{up}{}_i)/2 \quad (6)$$

$$x(\overline{e_i}) = (\overline{e_i}^{low} + \overline{e_i}^{up})/2 \quad (7)$$

$$y(p_i) = p_i^{up} + p_i^{low} \quad (8)$$

$$y(\overline{e_i}) = \overline{e_i}^{up} + \overline{e_i}^{low} \quad (9)$$

When $x(q_i) \neq x(\overline{e_i})$,the comparison method will be:

If $x(q_i) > x(\overline{e_i})$, $q_i > \overline{e_i}$; If $x(q_i) < x(\overline{e_i})$, $q_i < \overline{e_i}$.

When $x(q_i) = x(\overline{e_i})$, the comparison approach can adopt:

If $y(p_i) > y(\overline{e_i})$, $q_i < \overline{e_i}$; If $y(p_i) < y(\overline{e_i})$, $q_i > \overline{e_i}$.

The formula for calculating the distance between interval attribute values is as follows:

$$d_i = \sqrt{\frac{1}{2}\left[(q_i^{low} - e_i^{low})^2 + (q_i^{up} + e_i^{up})^2\right]} \quad (10)$$

When the attribute value is a language evaluation phrase, it needs to be quantified as a numeric value first. In this paper, the fuzzy trigonometric function method is used to quantify. Set up an ordered set of evaluation phrases: G={g1,g2,...,gL}, gk is the k-thgrad（k=1,2,...,L. In general, the common classification levels of human beings has 7 levels . According to the actual situation, the comment set is divided into seven levels, namely g1=(extremely poor/ extremely dissatisfied) , g2=(very poor/very dissatisfied) , g3=(poor/dissatisfied), g4= (general/medium) , g5= (good/ satisfied) , g6= (very good/very satisfied) and g7=(excellent/ super satisfied). The evaluation phrase gk can be converted from triangular fuzzy formula to numerical value, and the formula is as follows:

$$\tilde{g}_k = \left(\max\left\{\frac{k-1}{L}, 0\right\}, \frac{k}{L}, \min\left\{\frac{k+1}{L}, 1\right\}\right) \quad (11)$$

The number of triangular ambiguities in which the actual attribute values can be achieved is qi qi1, qi2, qi3, The desired triangular fuzzy number of attribute values is $\overline{e}_i = \left(\overline{e}_i^1, \overline{e}_i^2, \overline{e}_i^3\right)$.

Then, the distance between the attribute value and the reference value can be obtained as follows:

$$d_i = \sqrt{\frac{1}{3}\left[\left(q_i^1 - \overline{e}_i^1\right)^2 + \left(q_i^2 + \overline{e}_i^2\right)^2 + \left(q_i^3 + \overline{e}_i^3\right)^2\right]} \quad (12)$$

In order to remove the influence of different dimensions on the calculation results, the distance is normalized to a value of [0,1].

$$\tilde{d}_i = \frac{d_i}{\max|d_i|} \quad (13)$$

On this basis, the profit and loss decision matrix of each sub-task of the core enterprise to each partner enterprise can be established:

$$B_i(i) = \begin{cases} \tilde{d}_i, q_i \geq \overline{e}_i \\ -\tilde{d}_i, q_i < \overline{e}_i \end{cases} \quad (14)$$

While qi ≥ ei , it is called the returns of attribute values relative to reference points; While qi <ei, it is called the loss of the attribute value relative to the reference point. Considering the main body's different risk attitudes towards profit and loss, the attribute prospect matrix of core enterprises to partner enterprises can be obtained from equation (2) as follows:

$$v_l(i) = \begin{cases} (B_l(i))^{\alpha}, q_i \ge \overline{e}_i \\ -\theta(B_l(i))^{\beta}, q_i < \overline{e}_i \end{cases} \quad (15)$$

In view of the subject's preference for each evaluation attribute and the influence of uncertain factors on the unknown probability events, the formula for calculating the preference weight of each attribute index of the core enterprise to the partner enterprise is obtained from equation (4) :

$$\begin{cases} \pi^{+}(w_j) = \dfrac{w_j^{\gamma}}{(w_j^{\gamma} + (1-w_j)^{\gamma})^{1/\gamma}}, profit \\ \pi^{-}(w_j) = \dfrac{w_j^{\delta}}{(w_j^{\delta} + (1-w_j)^{\delta})^{1/\delta}}, \ loss \end{cases} \quad (16)$$

According to the equation (1), the comprehensive prospect value V(i) of the core enterprise for each potential partner can be obtained. In the same way, it is also possible to calculate the comprehensive prospect value V~(i) of each potential partner for core enterprises and new services.

EXPERIMENTAL SIMULATION

Since there is no standard test platform and test data at present, an experimental simulation environment has been set up in the laboratory to verify the rationality and practicability of this model. Choose to regard JDK8 +eclipse 4.3 +SQL Server 2005 as the development environment, meanwhile, Tomcat 7.0 is used as the server, and a simulation program has been composed in Java language to realize the virtual enterprise establishment process in the cloud manufacturing environment. A core enterprise is supposed to target to produce a new mold according to market research. After a panel of subdividing tasks, the working process is shown in Figure 3.

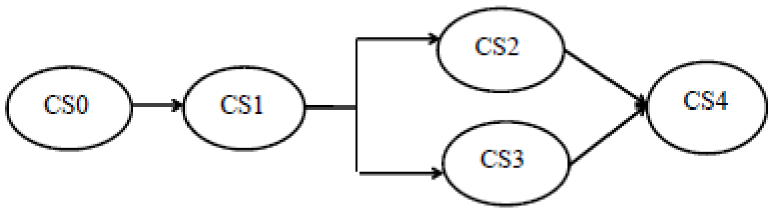

Figure 3: Processing flow chart of a certain mould

The core enterprise can complete task 0 and task 1.Other sub-tasks are made by core enterprises in the cloud service platform to search for various services that meet the functional requirements of the task to form a virtual enterprise. By virtue of the two-way selection model considering psychological expectations, the cloud manufacturing platform recommends the most suitable enterprise as a partner. The cloud manufacturing service as a test is automatically generated by the simulation program. Due to the differences in manufacturing industries, the evaluation indicators are also different, so the credibility of the service evaluation of partners by the core enterprises is considered here. Credibility c1 , Reliability c2 , Technical Level c3 , Taking the Delivery Date (c4, unit d),Price (c5, unitYuan), Distance(c6, unit km) and other indicators as examples; Partner enterprises ought to describe the evaluation of core enterprises and new services, including Credibility ( ) 1 a , Reliability ( ) 2 a , Project Risk a3 and Connection Cost a4. Taking task 2 as an example, this paper analyzes and considers the impact of corporate psychological expectations on the evaluation results, and compares it with the standard TOPSIS algorithm and comprehensive fuzzy algorithm. The core enterprise's psychological expectation for task 2 is { very good,

good, good, [8~12] ,and 3,000 }. When selecting task 2, 20 similar services were queried, and their services QoS are all listed in Table 1.

Table 1: Similar services of CS2 QO S

S_i	C1	C2	C3	C4	C5	C6
S_1	good	21/21	good	12~15	2610	337
S_2	very good	20/21	very good	7~10	3190	319
S_3	good	3/3	poor	18~24	2040	390
S_4	general	2/2	very good	4~6	3630	25
S_5	poor	3/5	general	17~21	2110	63
S_6	general	10/15	very good	6~9	3310	452
S_7	good	15/17	very good	8~11	2960	99
S_8	very good	9/9	general	14~17	2330	84
S_9	poor	1/2	good	11~14	2700	354
S_{10}	very good	30/30	good	12~15	2630	12
S_{11}	excellent	28/28	very good	6~9	3200	476
S_{12}	excellent	31/31	very good	16~19	2250	65
S_{13}	good	18/19	very good	5~7	3580	381
S_{14}	general	16/20	general	15~18	2290	141
S_{15}	good	8/8	very good	4~7	3680	480
S_{16}	very good	9/9	general	13~16	2470	299
S_{17}	general	7/10	good	9~12	2800	117
S_{18}	poor	0/1	poor	20~25	2020	286
S_{19}	very good	20/20	good	9~12	2830	327
S_{20}	general	8/11	general	12~15	2570	85

Immersing in the cloud manufacturing environment with physical transportation, distance is closely related to transportation cost, and the transportation cost of distance is transferred to the price parameter at 1.025 yuan perkilometer (last year's average transportation cost for molds). Reliability is expressed as "normal response times / called times".

In the experiment, the parameter of equation (15) is se tto: α=β=0.88、θ= 2.25; the parameter of equation (16)is: γ= 0.61、δ= 0.68 , majority scholars believe that this value can reflect the general behavior preference of decision makers[12,13,14]. In order to facilitate calculation, the preference weight of the core enterprise for each attribute is set as follows W = {0.2,0.2,0.2,0.1,0.3}. Comprehensive fuzzy mathematics algorithm, standard TOPSIS algorithm and this algorithm have been adopted respectively and those calculation outcomes are shown in Table 2.

Table 2 Calculation Outcomes of Various Methods

S_i	Fuzzy mathematics algorithm	TOPSIS	this algorithm
S_1	0. 6893	0. 0462	0. 0205
S_2	0. 7188	0. 0711	0. 0206
S_3	0. 6638	−0. 0039	−0. 1926
S_4	0. 7070	0. 0304	−0. 1250
S_5	0. 5674	−0. 1092	−0. 3670
S_6	0. 5815	−0. 0749	−0. 2558
S_7	0. 6942	0. 0535	0. 0075
S_8	0. 7339	0. 0770	0. 0079
S_9	0. 4973	−0. 1447	−0. 3782
S_{10}	0. 7440	0. 0973	0. 0894
S_{11}	0. 7578	0. 0983	0. 0370
S_{12}	0. 8275	0. 1567	0. 1444
S_{13}	0. 6935	0. 0187	−0. 1291
S_{14}	0. 6207	−0. 0374	−0. 2048
S_{15}	0. 6992	0. 0195	−0. 1475
S_{16}	0. 7010	0. 0551	−0. 0129
S_{17}	0. 5954	−0. 0465	−0. 1378
S_{18}	0. 4203	−0. 2578	−0. 6956
S_{19}	0. 7133	0. 0710	0. 0460
S_{20}	0. 5860	−0. 0604	−0. 2126

As is shown in Table 2, the ranking result of the comprehensive fuzzy algorithm is: s12>s11>s10>s8>s2>s19> s4>s16>s15>s7>s13>s1>s3>s14>s17>s20> s6>s5>s9>s18; the ranking result of TOPSIS is: s12>s11>s10>s8>s2>s19>s16>s7>s1>s4>s15>s13>s3>s14>s17>s20>s6>s5>s9>s18; the ranking result of the method adopting in this article is: s12>s10>s19 >s11>s2>s8>s7>s16> s1>s4>s13> s17>s15>s3>s14>s20>s6>s5>s9>s18.Although the ranking results of each service in this method are slightly different from the other two methods, the best results selected by each method are s12. The sensitivity of each method is compared by the following

$$\delta = \frac{\varphi_{\max} - \varphi_{\sec}}{\varphi_{\max}} \times 100\% \tag{17}$$

The sensitivities of the three methods are respectively listed in Table 3 below.

Table 3 Sensitivity Comparison

	Fuzzy method	TOPSIS	This method
sensitivity(%)	8.42	36.26	38.09

To sum up, this method has high sensitivity, and this method well integrates the psychological expectation of the enterprise into the partner selection process, analyzes the different attitudes of the enterprise towards "profit" and "loss", interprets the psychology of the enterprise in selecting partners, aiming to optimize the selection process to be more representative of human behavior characteristics.

CONCLUSION

Functioning as a new business model, cloud manufacturing has been recognized by the manufacturing industry, which has integrated the service resources of small and medium-sized manufacturing enterprises and develops the advantages of each enterprise to improve the overall competitiveness of the industrial alliance. Partner selection in cloud manufacturing environment is one of the important links. Based on the analysis of the actual application scenario and the existing research results, this paper proposes a two-way matching partner selection model considering the psychological expectations of enterprises. The prospect theory is used to calculate the comprehensive psychological expectation of both partners, and two-way matching is carried out in each link according to the task flow. The rationality and effectiveness of the model are verified by simulation. Experiments show that the model is a better solution for partner selection in cloud manufacturing environment and conforms to the actual thinking mode of human beings.

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