Trusted Computing Based on Interval Intuitionistic Fuzzy Sets in Cloud Manufacturing

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Abstract. Aiming at the problem that the trust information is not complete in the existing cloud manufacturing and the single model lacks the multi-perspective, the model of the trust evaluation mechanism in the cloud manufacturing environment is established, at the same time, using the interval intuitionistic fuzzy set (IVIFS), this paper proposes a trusted computing model based on interval intuitionistic fuzzy sets in cloud manufacturing. Through experimental analysis, and finally through the results of sorting, to get the optimal solution of trust, which solves the problem that the information in the process of interaction between the demand side and the service side is not complete or the fuzzy uncertainty of the attribute itself is difficult to give the information of accurate preference.

Keywords: Cloud manufacturing · Trust assessment mechanism
Interval intuitionistic fuzzy sets · Trust · Multi-attribute group decision

1 Introduction

In the cloud manufacturing environment, the trust relationship between the subjects is formed in the process of continuous interaction with each other. The results of the trust assessment can visually express whether the information in the information exchange is trustworthy [1, 2]. One of the decisive factors of trust decision-making is trust. We make a comprehensive assessment through the calculation of the trust of the results of its trust. Although there are a lot of trust calculation method, but it is not very good to complete a more comprehensive trust calculation for the trust of such a multi-attribute comprehensive measurement body, and can not describe the trust decision-making state better [3–5], therefore, this paper will study the multi-attribute group decision algorithm of interval intuitionistic fuzzy sets and establish the relevant model of trust degree

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calculation in the form of IVIFS (interval intuitionistic fuzzy sets) to avoid that it is difficult to give precise preference information because of incomplete information or the attribute itself Fuzzy uncertainty, etc.

2 Establishment of Trust Degree Calculation Model Based on Interval Intuitionistic Fuzzy Sets

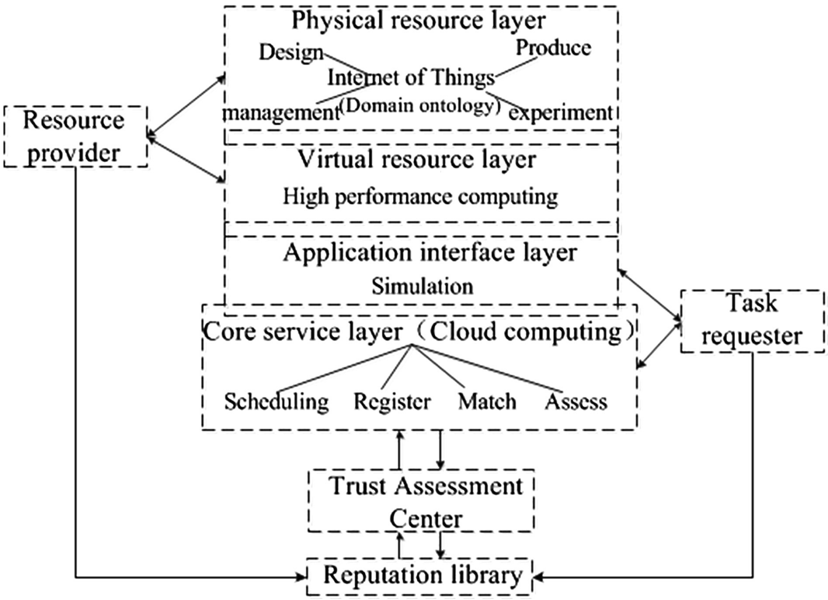

Fig. 1. Model of trust evaluation mechanism in cloud manufacturing

We give the following cloud manufacturing trust evaluation mechanism model in here, as shown in Fig. 1:

2.1 Interval Intuitionistic Fuzzy Entropy and Solution of Group Decision Weight

Entropy measure is an important measure in the research of fuzzy sets theory, which is used to measure the degree of uncertainty of fuzzy sets. For any of the $A = \{(x, \mu_A(x), v_A(x))|x \in X\}$ and $B = \{(x, \mu_B(x), v_B(x))|x \in X\}$, The interval intuitionistic fuzzy entropy E (A) can be defined as follows

$$E(A) = \cos\frac{\mu_A^2(x) - v_A^2(x)}{2}\pi \tag{1}$$

We give the formulan λ_{ij} for calculating the group decision weight by the above formula,

$$\lambda_{ij} = \frac{KC - E_{ij}^{l}}{k - KC - \sum_{l}^{k} E_{ij}^{l}} (i = 1, 2 \cdots, m; j = 1, 2, \cdots n) \tag{2}$$

among them, K is the number of group decisions KC is a constant, in general, the value of 1. In principle, the attribute's maximum and minimum weights should be within 1x. Through the decision of the group decision weights λ_{ij}, combined with $IVIFHA_{\omega,w}$ to compute the comprehensive decision matrix of group decision matrix $D_i(i = 1, 2, \cdots k)$, and calculate the attribute weight ω_j, among them, $\overline{E}_{ij} = E(\gamma_{ij})$.

$$\omega_j = \frac{KC - \sum_{i=1}^{m} \overline{E}_{ij}}{n \times KC - \sum_{j=1}^{n} \sum_{i=1}^{m} \overline{E}_{ij}} \tag{3}$$

2.2 Ranking and Distance Formula of Interval Intuitionistic Fuzzy Numbers

When we can not determine the sorting results are good or bad, we need to use the interval exact function to determine the sort. We set $\alpha_i = \left(\left[a_i^L, a_i^R\right], \left[b_i^L, b_i^R\right]\right)$ $(i = 1, 2, \cdots n)$ is a set of intuitionistic fuzzy numbers in here, the probability of $IS(\alpha_i)$ and $IS(\alpha_j)$ is $p_{ij}(IS) = p(IS(\alpha_i) \geq IS(\alpha_j))$, then we can say the matrix $p(IS) = \left[p_{ij}(IS)\right]_{m \times n}$ as follows:

$$p(IS) = \begin{bmatrix} p_{11}(IS) & p_{12}(IS) & \dots & p_{1n}(IS) \\ p_{21}(IS) & p_{22}(IS) & \cdots & p_{2n}(IS) \\ \vdots & \vdots & \ddots & \vdots \\ p_{11}(IS) & p_{11}(IS) & \dots & p_{11}(IS) \end{bmatrix} \tag{4}$$

We calculate the matrix $p(IS)$ from the above formula, we can compare by the following formula:

$$\delta_i^{IS} = \frac{\sum_{j=1}^{n} p_{ij}(IS) + \frac{n}{2} - 1}{n(n-1)} i = 1, 2, \cdots, n \tag{5}$$

2.3 Gray Correlation Coefficient Matrix

According to the comprehensive decision matrix, we can calculate the gray correlation coefficient matrix $\left(\xi_{ij}\right)_{m \times n}$, the formula is as follows:

$$\xi_{ij} = \frac{\min\limits_{1 \leq j \leq n} \min\limits_{1 \leq i \leq n} d(\gamma_{ij}, \gamma_j^{+}) + v \max\limits_{1 \leq j \leq n} \max\limits_{1 \leq i \leq n} d(\gamma_{ij}, \gamma_j^{+})}{d(\gamma_{ij}, \gamma_j^{+}) + v \max\limits_{1 \leq j \leq n} \max\limits_{1 \leq i \leq n} d(\gamma_{ij}, \gamma_j^{+})} \tag{6}$$

where the resolution coefficient $v \in [0, 1]$, in general, $v = 0.5$

On the basis of the above formula, we attribute the weighted values of the gray correlation coefficients for each of the alternative attribute values to get the interval gray correlation degree for each alternative:

$$\overline{\xi}_i = \sum_{j=1}^{n} \omega_j \xi_{ij} \tag{7}$$

Using the interval possibility to compare the sorting size of the gray correlation degree of each alternative, and find the sorting result of the corresponding sorting value of the alternatives:

$$\delta_i^{\overline{\xi}} = \frac{\sum_{j=1}^{m} p_{ij}(\overline{\xi}) + \frac{m}{2} - 1}{m(m-1)} i = 1, 2, \cdots, m \tag{8}$$

3 Experiment Analysis

In order to evaluate the effectiveness of the proposed trust calculation model, in this paper, through the relevant manufacturing enterprises to provide gear inspection services on time, economy, processing quality, service attitude, scale of operation of the five demand indicators, we carry out experimental analysis about four attributes for the direct trust, indirect trust, recommended trust, trust attenuation for of each indicator, and get interval intuitionistic fuzzy matrices Di (i = 1,2,3), as follows:

$$D_1 = \begin{bmatrix} ([0.49, 0.58], [0.31, 0.42])([0.49, 0.58], [0.21, 0.32])([0.21, 0.32], [0.59, 0.68])([0.12, 0.21], [0.68, 0.79]) \\ ([0.59, 0.68], [0.21, 0.32])([0.68, 0.79], [0.12, 0.21])([0.68, 0.79], [0.12, 0.21])([0.32, 0.41], [0.38, 0.49]) \\ ([0.49, 0.58], [0.32, 0.41])([0.38, 0.49], [0.32, 0.41])([0.49, 0.58], [0.21, 0.32])([0.59, 0.68], [0.21, 0.32]) \\ ([0.77, 0.88], [0.03, 0.12])([0.49, 0.58], [0.32, 0.41])([0.21, 0.32], [0.38, 0.49])([0.21, 0.32], [0.49, 0.58]) \\ ([0.59, 0.68], [0.21, 0.22])([0.32, 0.41], [0.38, 0.49])([0.67, 0.78], [0.03, 0.12])([0.49, 0.58], [0.31, 0.42]) \end{bmatrix}$$

$$D_2 = \begin{bmatrix} ([0.32, 0.41], [0.28, 0.29])([0.38, 0.49], [0.22, 0.31])([0.13, 0.22], [0.47, 0.58])([0.02, 0.12], [0.58, 0.68]) \\ ([0.59, 0.68], [0.21, 0.32])([0.58, 0.69], [0.02, 0.11])([0.48, 0.59], [0.02, 0.11])([0.31, 0.41], [0.39, 0.49]) \\ ([0.48, 0.59], [0.22, 0.31])([0.31, 0.41], [0.29, 0.39])([0.39, 0.49], [0.11, 0.21])([0.48, 0.59], [0.22, 0.31]) \\ ([0.68, 0.79], [0.02, 0.11])([0.48, 0.59], [0.12, 0.21])([0.22, 0.32], [0.28, 0.38])([0.12, 0.21], [0.48, 0.59]) \\ ([0.48, 0.59], [0.12, 0.21])([0.29, 0.39], [0.21, 0.31])([0.59, 0.79], [0.01, 0.11])([0.39, 0.49], [0.21, 0.31]) \end{bmatrix}$$

$$D_3 = \begin{bmatrix} ([0.32, 0.42], [0.48, 0.58])([0.49, 0.49], [0.41, 0.59])([0.11, 0.21], [0.69, 0.69])([0.02, 0.12], [0.78, 0.88]) \\ ([0.48, 0.58], [0.32, 0.42])([0.59, 0.69], [0.21, 0.31])([0.59, 0.59], [0.31, 0.41])([0.32, 0.42], [0.48, 0.58]) \\ ([0.42, 0.42], [0.38, 0.48])([0.41, 0.49], [0.49, 0.51])([0.39, 0.49], [0.31, 0.41])([0.48, 0.58], [0.32, 0.42]) \\ ([0.68, 0.78], [0.12, 0.22])([0.48, 0.58], [0.42, 0.42])([0.22, 0.32], [0.48, 0.58])([0.12, 0.22], [0.58, 0.68]) \\ ([0.48, 0.58], [0.32, 0.32])([0.21, 0.31], [0.39, 0.59])([0.58, 0.68], [0.12, 0.22])([0.39, 0.48], [0.31, 0.42]) \end{bmatrix}$$

First of all, for the above three matrices,we first use the formula (1) to calculate the attribute entropy of the decision matrix, and then use the formula (2) to calculate the group decision weight λ.

$$\lambda_1 = \begin{bmatrix} 0.34 & 0.35 & 0.33 & 0.32 \\ 0.35 & 0.37 & 0.39 & 0.33 \\ 0.33 & 0.33 & 0.34 & 0.35 \\ 0.40 & 0.33 & 0.33 & 0.32 \\ 0.36 & 0.33 & 0.37 & 0.34 \end{bmatrix}$$

$$\lambda_2 = \begin{bmatrix} 0.33 & 0.33 & 0.31 & 0.28 \\ 0.35 & 0.32 & 0.31 & 0.33 \\ 0.34 & 0.33 & 0.33 & 0.33 \\ 0.31 & 0.35 & 0.32 & 0.33 \\ 0.33 & 0.33 & 0.33 & 0.33 \end{bmatrix}$$

$$\lambda_3 = \begin{bmatrix} 0.34 & 0.32 & 0.36 & 0.40 \\ 0.31 & 0.30 & 0.30 & 0.34 \\ 0.32 & 0.33 & 0.32 & 0.31 \\ 0.29 & 0.32 & 0.35 & 0.36 \\ 0.32 & 0.34 & 0.30 & 0.33 \end{bmatrix}$$

The second step, computing the intuitionistic intuitionistic fuzzy decision matrix by the decision of the group decision weight λ combined with $IVIFHA_{\omega,w}$ operator, at the same time using the formula (3) to calculate the trust-related attribute weight ω:

$$\omega = [\,0.24 \quad 0.26 \quad 0.25 \quad 0.25\,]$$

The third step, according to formulas (4) and (5), the ideal scheme $A^+ = \{\gamma_1^+, \gamma_2^+, \gamma_3^+, \gamma_4^+\}$ is determined by comparing the magnitude of the different scheme attribute values

$$\begin{aligned} \gamma_1^+ &= ([0.72, 0.83]\ [0.00, 0.12]) & \gamma_2^+ &= ([0.67, 0.77]\ [0.00, 0.18]) \\ \gamma_3^+ &= ([0.63, 0.78]\ [0.00, 0.12]) & \gamma_4^+ &= ([0.56, 0.66]\ [0.18, 0.29]) \end{aligned}$$

The fourth step, select the resolution $v = 0.5$, using the formula (6) can be calculated gray correlation coefficient matrix $\xi = [\xi_{ij}]_{m \times n}$

$$\xi = \begin{bmatrix} [0.25, 1.11] & [0.30, 1.56] & [0.21, 0.79] & [0.22, 0.80] \\ [0.32, 1.79] & [0.38, 2.36] & [0.35, 2.36] & [0.30, 1.40] \\ [0.29, 1.38] & [0.27, 1.25] & [0.31, 1.80] & [0.42, 2.36] \\ [0.41, 2.36] & [0.31, 1.77] & [0.24, 0.99] & [0.25, 1.01] \\ [0.33, 1.78] & [0.25, 1.13] & [0.38, 2.36] & [0.37, 2.32] \end{bmatrix}$$

The fifth step, calculate the gray relational degree $\overline{\xi}$ using the formula (7)

$$\bar{\xi} = \begin{bmatrix} [0.25, 1.07] \\ [0.34, 1.99] \\ [0.33, 1.69] \\ [0.30, 1.53] \\ [0.33, 1.89] \end{bmatrix}$$

The sixth step, according to the gray correlation degree obtained above, through the interval possibility degree formula and the alternative probability matrix, finally, using the formula (8) to find the corresponding sort value $\sigma = [\, 0.15 \quad 0.23 \quad 0.21 \quad 0.19 \quad 0.22 \,]$, By final ranking we can determine the optimal trust of different indicators, so as to make the best choice of program A_2.

4 Conclusion

This paper first analyzes the important trust relationship between cloud manufacturing entities. A trusted computing model based on interval-based intuitionistic fuzzy sets in cloud manufacturing is proposed by studying the multi-attribute group decision-making of interval intuitionistic fuzzy sets. Through experimental analysis, Through the optimal solution, the demand side and the service side in the information exchange will be able to get more convincing, more comprehensive trust information. Of course, this study is not particularly deep, there are many deficiencies, hope in the future to continue to carry out more in-depth study.

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