Research on cloud service selection based on rough set theory

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Abstract. Cloud manufacturing adopts contemporary information cutting-edge technologies including advanced concepts such as cloud computing to support the manufacturing industry. Under a wide range of network resource manufacturing environments, it can add high value-added products, reduce costs, and meet globalization. The optimization of cloud manufacturing services is based on the attributes of cloud manufacturing services as evaluation indicators, and corresponding optimization strategies are formulated to ensure the selection process of manufacturing services. Taking into account the uncertainty of cloud service, rough set is used to assign the weight to each evaluation index and furthermore solve the cloud manufacturing service selection. Finally, an example is used to verify the effectiveness of the proposed method.

1. Introduction
Cloud manufacturing adopts contemporary information cutting-edge technologies including advanced concepts such as cloud computing to support the manufacturing industry[1]. Under a wide range of network resource manufacturing environments, it can add high value-added products, reduce costs, and meet globalization.

The optimization of cloud manufacturing services is based on the attributes of cloud manufacturing services as evaluation indicators, and corresponding optimization strategies are formulated to ensure the selection process of manufacturing services. A wide variety of manufacturing resources are virtualized and encapsulated into the cloud pool on the cloud forging platform, which makes the cloud services in the cloud pool have a wide variety and scope. The realization of collaborative manufacturing of complex products makes cloud manufacturing service selection more complicated, with a wide range of service options and a wide variety of services. Wang proposed a fuzzy model and used this model to solve the selection of Web services based on Qos[2]; Zhang proposed a user preference model based on language variables, using the tomographic fuzzy logic method evaluated it[3]; TAO considered the influence of multiple factors, used intuitionistic fuzzy sets to evaluate the resource non-functional Qos and designed the corresponding optimization algorithm[4]; Wang integrated considering the user's fuzzy perception, functional attributes and non-functional Qos factors, the intuitionistic fuzzy set method is used to analyze and select Web services[5]. ZHENG have formulated corresponding resource optimization methods by combining users' preferences and needs[6]. XIA used fuzzy clustering method to eliminate some irrelevant Qos attribute information [7].

With the changes in the requirements of modern cloud manufacturing service providers, the demand for manufacturing resource services is gradually becoming more customized and complicated.
The specific knowledge, expertise and related equipment required for cloud manufacturing service are no longer the ability of a certain company or a few companies. The scope of capabilities it requires is far beyond the enterprise level and requires the joint efforts of the industry. Then, it will be difficult for a single company to adapt to the rapidly changing market with diversified demands. Therefore, this requires that in the manufacturing industry, in accordance with market needs, various cloud manufacturing service providers establish an in-industry information system, that is, a dynamic alliance of the entire industry, so as to realize the collaborative design of complex products in a short time and manufacturing.

In our previous research[8], an evaluation index system was established and here, we seek to assign corresponding weight by rough set theory for assistance of service determination.

2. Attribute index weight solution based on rough set theory

Most of the traditional weights are determined by experts' subjective experience, which is not objective. In this study, weights are solved based on rough set theory. The biggest advantage is that no prior or additional information about the data is required, and it is only based on the classification ability of the data, which is easy to master and apply. It has been successfully applied in data analysis and decision making, machine learning, pattern recognition and knowledge discovery because it can be used to measure the uncertainty contained in data and extract useful knowledge.

In the process of determining the weight of service optimization index, on the one hand, the objective weight P is obtained through rough set theory processing a large amount of data; on the other hand, the subjective weight Q is obtained based on expert experience and knowledge. Finally, the final weight is obtained by combining the results of the two parts.

Suppose that the knowledge expression system \( S = \{U, A, V, f\} \), \( P \subseteq A, U/IND(P) = \{x_1, x_2, \cdots, x_n\} \), Then the amount of information \( I(P) \) is:

\[
I(P) = \sum_{i=1}^{n} \frac{|X_i|U}{U} \left(1 - \frac{|X_i|U}{U}\right) = 1 - \frac{1}{|U|^2} \sum_{i=1}^{n} |X_i|^2
\]

For the index \( p \subseteq P \) the importance degree is:

\[
sig_{p-(p)} = I(P) - I(P-\{p\})
\]

Therefore, the weight of each preferred indicator \( p \subseteq P, P = \{p_1, p_2, \cdots, p_n\} \) can be calculated as follows:

\[
w_j = \frac{\sum_{i=1}^{n} \sig_{p-(p)}(p_i)}{\sum_{i=1}^{n} \sig_{p-(p)}(p_i)} = \frac{I(P) - I(P-\{p_i\})}{nI(P) - \sum_{i=1}^{n} I(D-\{d_i\})}
\]

After calculating the objective weight P, the final weight calculation formula is as follows:

\[
I = aP + (1-a)Q \quad (0 \leq a \leq 1)
\]

3. Case study

This study takes a company to issue a cloud manufacturing service request through the cloud service platform for selection. Table 1 is the classification criteria summarized by the relevant historical data of production system. By comparing the production standards in Table 1, the attribute optimization indexes of cloud manufacturing service in Table 1 are discretized, and the processing results are shown in Table 2. Table 2 is an information system for the above attribute optimization of cloud manufacturing services.

| level | Shared cost C (yuan/day) | Interaction time T (hours) | The quality of service Q (%) |
|-------|--------------------------|---------------------------|-----------------------------|
|       |                          |                           | Reliability Q_1 Credibility Q_2 Availability Q_3 |

Table 1. Evaluation criteria of attribute indexes
Table 2. Information System

| Cloud forging resource service | C  | T  | Q1 | Q2 | Q3 |
|-------------------------------|----|----|----|----|----|
| A1                            | 3  | 2  | 1  | 1  | 1  |
| A2                            | 1  | 1  | 1  | 2  | 2  |
| A3                            | 2  | 2  | 2  | 1  | 2  |
| A4                            | 2  | 2  | 2  | 2  | 2  |
| B1                            | 2  | 1  | 3  | 3  | 3  |
| B2                            | 2  | 1  | 1  | 2  | 3  |
| B3                            | 1  | 2  | 2  | 2  | 2  |
| B4                            | 2  | 1  | 1  | 1  | 1  |
| C1                            | 2  | 2  | 2  | 2  | 2  |
| C2                            | 2  | 3  | 1  | 1  | 2  |
| C3                            | 2  | 2  | 2  | 3  | 2  |
| C4                            | 3  | 2  | 2  | 2  | 2  |
| C5                            | 1  | 1  | 1  | 2  | 1  |
| D1                            | 2  | 1  | 1  | 2  | 1  |
| D2                            | 1  | 2  | 1  | 3  | 2  |
| D3                            | 1  | 2  | 2  | 1  | 2  |
| D4                            | 2  | 3  | 2  | 1  | 1  |
| D5                            | 2  | 2  | 2  | 2  | 2  |

The weight of attribute optimization index of computing cloud forging resource service is calculated as follows:

\[ U/IND(Z) = \{\{A_1\}, \{A_2\}, \{A_3\}, \{A_4\}, \{B_1\}, \{B_2\}, \{B_3\}, \{B_4\}, \{C_1\}, \{C_2\}, \{C_3\}, \{C_4\}, \{C_5\},\] \[\{D_1\}, \{D_2\}, \{D_3\}, \{D_4\}, \{D_5\}\] \[\vdash U/IND(Z) = \{\{A_1\}, \{A_2\}, \{A_3\}, \{A_4\}, \{B_1\}, \{B_2\}, \{B_3\}, \{B_4\}, \{C_1\}, \{C_2\}, \{C_3\}, \{C_4\}, \{C_5\},\] \[\{D_1\}, \{D_2\}, \{D_3\}, \{D_4\}, \{D_5\}\]

Among them, \(card(A_1) = \ldots = card(D_5) = 1\).

\[ U/IND(C) = \{\{A_1, C_1\}, \{A_2, C_2, C_3, D_2, D_3\}, \{A_3, A_4, B_1, B_2, B_4, C_1, C_2, C_3, D_4, D_5\}\] \[\vdash U/IND(C) = \{X_1, X_2, X_3\}\]

Among them, \(card(X_1) = 2, card(X_2) = 5, card(X_3) = 11\).

Calculate the weight value of each attribute index according to the aforementioned weight determination method:
Finally, the objective weight of each attribute index of cloud forging resource service is obtained as follows:

\[ w_C = 0.213, w_T = 0.196, w_{Q_1} = 0.206, w_{Q_2} = 0.174, w_{Q_3} = 0.213 \]

The attribute index weight of cloud forging resource service is suggested according to the subjective experience of experts, as shown in Table 3:

| Attribute index layer | Shared cost C | Interaction time T | Quality Q |
|-----------------------|---------------|--------------------|-----------|
|                       |               |                    | Reliability Q1 | Credibility Q2 | Availability Q3 |
| Subjective weight value | 0.274         | 0.219              | 0.186      | 0.176       | 0.145           |

Select the experience factor here \( \alpha = 0.7 \). Then the final weight of the attribute index of cloud forging resource service is:

\[
I_C = 0.213 \times 0.7 + (1 - 0.7) \times 0.274 = 0.2313 \\
I_T = 0.196 \times 0.7 + (1 - 0.7) \times 0.219 = 0.2029 \\
I_{Q_1} = 0.206 \times 0.7 + (1 - 0.7) \times 0.186 = 0.2 \\
I_{Q_2} = 0.174 \times 0.7 + (1 - 0.7) \times 0.176 = 0.1746 \\
I_{Q_3} = 0.213 \times 0.7 + (1 - 0.7) \times 0.145 = 0.1926
\]

4. Conclusion

In case that candidate services have been determined, a cloud manufacturing service selection method based on rough set is presented. In this paper, a multi-objective service selection optimization is described in detail and the weight of each attribute index is solved by rough set theory.

Acknowledgments

This paper was supported by the fifth period 226 project of Nantong (Grant No: 2019-226-03).
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