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Research on Cloud Service Provider Recommendation Model Based on User Preference

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Abstract

Based on the rise and wide application of cloud services, this paper proposes and implements a cloud service provider recommendation model based on user needs and preferences. The model consists of three parts. First, based on users' needs, determine the subjective dimensions of users' demand for cloud services and realize the measurement of user preferences. Secondly, according to the cloud service provider's capability, the cloud service provider's ability to meet users' needs is measured. From the perspective of cloud service providers, after determining the indicators that can reflect the service capabilities of cloud service providers, innovatively establish a bridge between service capabilities and user needs. Realize the evaluation of cloud service providers from the perspective of demand realization to measure their demand satisfaction ability. Finally, according to the recommendation rules in this article, the similarity distance between the user and the candidate cloud service provider based on requirements is compared. A cloud service provider that matches the user's corresponding needs and preferences is recommended to the user, and personalized decision-making recommendations for the cloud service provider are realized. The recommendation system proposed and implemented in this paper is no longer limited to evaluating cloud service providers. Still, the recommendation process combines the needs and preferences of cloud service users and specific cloud service field characteristics and other information and combines fuzzy evaluation methods. Similar distances and different theories are used to give users more satisfactory recommendations and make personalized recommendations for users.

Keywords: *Cloud service, Demand preference, Personalized recommendation*

1. Introduction

Society has entered the era of big data. Cloud computing allocates and maintains virtual service resources through the network, which solves the problems of limited data processing capacity, long waiting time, and low efficiency [1]. Cloud services have also been widely used with the development of cloud computing technology from concept to maturity.

Cloud services refer to various types of user-oriented services based on the open system and standardized architecture of cloud computing technology, with strong professionalism [2]. The number of cloud service providers is increasing yearly, and the functions of cloud services developed are similar. It is difficult for users without professional knowledge to choose a cloud service provider that meets their needs. Therefore, the research on the

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recommendation of cloud service providers has become more and more important. Current research on the issue of cloud service provider recommendation mainly focuses on methods based on the Quality of Service (QoS) [4], methods based on cloud Service Level Agreement (SLA) [5][6], and methods based on multiple There are three aspects of target decision-making methods. However, these studies only recommend users from the perspective of cloud service providers and do not consider the actual needs of users. However, in the era of emphasizing user needs, the increase in the overall strength of enterprises will inevitably be accompanied by matching with user needs. Therefore, it is necessary to propose a recommendation model for cloud service providers that meets user needs and achieves matching between user needs and cloud service providers.

The recommendation system matches the user's interest needs with the characteristic information of the recommended object. At the same time, it uses the corresponding recommendation algorithm to screen, find the recommended object that the user may be interested in, and recommend it to the user. The current methods of constructing recommendation systems mainly include collaborative filtering [5], content-based methods [6][7], and hybrid recommendation methods [8]. The recommendation system based on the collaborative filtering method is a system model that analyzes and predicts the purchase intention of the following target user by reasoning about the user's history. It is suitable for industrial fields where users and rating information are fully available. The content-based recommendation system starts from both the user and the project, fully considers the user's personalized preferences and the characteristics of the project itself, establishes a connection between the supply and demand sides, does not rely on the user's historical data, and has a wider range of applications [9]. The hybrid recommendation method combines the advantages of multiple methods and appropriately combines two or more of the various recommendation methods to produce a fusion result to recommend to the user.

The cloud service industry is immature, and user historical data is lacking. Recommendation methods that rely on data analysis and predict user needs cannot guarantee the quality of the recommendation results. Therefore, this research adopts a recommendation method based on user preferences to achieve personalized recommendations for cloud service providers based on demand preferences. This research mainly includes three aspects: First, determine the demand measurement indicators and demand measurement methods of cloud service users. Second, the service capability indicators of cloud service providers and their evaluation methods are determined. Third, establish the relationship between the cloud service provider's capability indicators and user needs, determine the cloud service provider's ability to meet their needs, and then find the cloud service provider that best matches their preferences according to the user's needs so that users have a satisfactory cloud service experience.

2. Determination of the needs and preferences of cloud service users

Given the unique operating model of cloud computing, cloud services have brought convenience to users, and at the same time, they have also generated some concerns for users. First of all, cloud services can provide interactive functions. In this process, there are bound to be user privacy and information security issues [19]. Second, cloud services use shared virtual server images, and this public server image is vulnerable to security risks [11]. Finally, the reliability and stability of cloud services are extremely important to users, and various types of failures may exist in cloud computing, such as overflow failures, network failures, timeout failures, and resource loss failures. This paper sorts out and corresponds to the main features of cloud services and user concerns, as shown in Table 1.

Table 1. The advantages of cloud services and user concerns

The characteristics of cloud computing	Advantages of cloud services	User concerns
Service Resource Virtualization	Shorten single machine intensive processing time, more efficient	Whether it is safe or not
Hardware Independence	Reduce spending on big hardware purchases	Whether it has stable reliability
interactive	Cloud services can be requested in real-time and dynamically according to business needs	Whether to have quick processing
scalability	Service resources can be easily expanded	Whether it has portability

The problems that cloud service users pay attention to when facing choices in Table 1 are the reflection of users' own needs in the actual service process, which can be used to describe the demand dimension of cloud services. The evaluation research on cloud services mainly uses indicators such as responsibility, cost, price, security, agility, availability, and timeliness [12]. Combining the concerns of cloud service users, this article uses five dimensions, including availability, reliability, timeliness, security, and affordability, to describe the needs of cloud service users and defines the set of cloud service user needs as $R = \{r_1, r_2, \ldots, r_s\}$, $s = 5$. The specific meanings of these five demand dimensions are introduced as follows.

Usability: Mainly determined by easy access, easy operation, easy expansion, etc., reflecting the convenience of user operation and continuous use.

Reliability: Cloud service products must be able to complete specified services under given time and conditions.

Timeliness: It is expressed as the quickness of system feedback when users put forward requirements, reflecting the ability of cloud service products to meet user needs changes and quickly deploy related services.

Security: In terms of data security, privacy protection, access control, etc., it reflects the ability of users' data to avoid interference from hidden security hazards.

Price affordability: It is expressed as the degree to which users can accept the price of cloud services, which reflects the price elasticity of users; that is, the degree to which prices within the industry can be accepted.

It is easy for users to describe their needs for a certain service in terms of degrees, but it may not be easy to quantify their service needs. The text requirements must be converted into numerical values for easy calculation in the recommendation process. Accordingly, to determine the individual needs of users, this paper adopts the triangular fuzzy evaluation method to measure the degree of preference of user needs. The triangular fuzzy evaluation method refers to the degree and literal judgment of multiple attributes and indicators of a given thing. It generally contains 3 to 7 levels of different degrees. Each level can be quantified by matching its membership equation. Due to the uncertainty of user evaluation, the judgment value is given as a triangular fuzzy number [13][14]. The triangular fuzzy number M can be denoted as (l, m, u), $l \le m \le u$, l and u respectively represent the lower and upper bounds of M support, and m is the median value of M. M (l,m,u) represents the degree of deviation of M from m.

Based on the fuzzy evaluation method of triangular fuzzy number, this article selects a total of 7 levels of "very low," "low," "medium-low," "moderate," "medium-high," "high," and "very high," to measure the demand preferences of cloud service users and the ability of cloud service providers. The membership function is shown in Figure 1 [15]. According to its membership function, the seven literal levels can be quantified separately, and the corresponding quantization conversion relations are shown in Table 2. Users can choose appropriate options from "very low," "low," "medium-low," "moderate," "medium-high," "high," and "very high," which is important for each dimension of demand—subjective evaluation of the degree of sexuality [16]. Then, it is transformed into a triangular fuzzy vector according to Table 2, in which user U's demand for the triangular vector indicates the degree of preference, thereby constructing a cloud service user demand set.

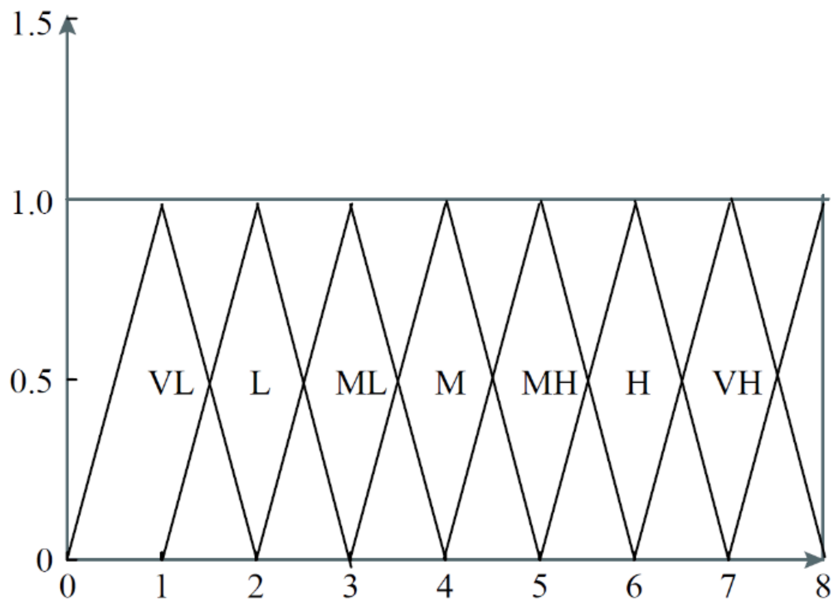

Figure 1. Membership functions of triangular fuzzy numbers (Grades 7)

Table 2. Translation of text descriptions and triangular fuzzy arrays

Verbal fuzzy evaluation	Triangular fuzzy number
Very low (VL)	<0,1,2>
Low (L)	<1,2,3>
Medium-low (ML)	<2,3,4>
Medium (M)	<3,4,5>
Medium-High (MH)	<4,5,6>
Height (H)	<5,6.7>
Very high (VH)	<6,7,8>

3. Determine the service capabilities of cloud service providers

Currently, the services provided by the cloud service industry are very different from those provided by traditional industries. When choosing evaluation indicators for cloud service providers, it is necessary to combine the characteristics of cloud services: light assets, service virtualization, large-scale computing capabilities, Internet as the core, on-demand services, high-cost performance, etc. [17]. This article also refers to the existing cloud service QoS evaluation indicators and selects the five basic indicators of performance: availability, security, reliability, and price, as shown in Figure 2. These five indicators can not only reflect the characteristics of the cloud service itself but also measure the service capabilities of the cloud service provider. In practice, cloud service providers may not be able to judge these indicators accurately. Therefore, this article defines specific indicators based on the five basic indicators. Specific indicators are more conducive to obtaining data because cloud service providers can easily provide corresponding data based on the indicators, which facilitates the evaluation of cloud service providers' service capabilities.

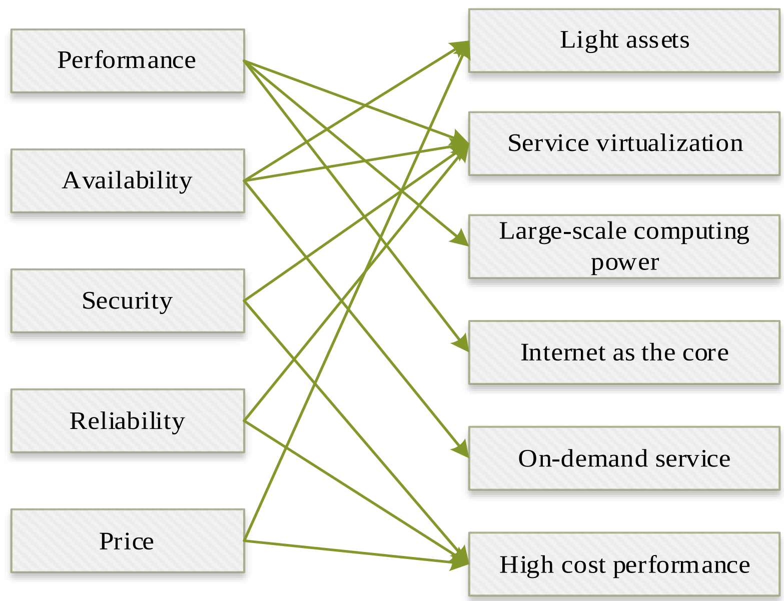

Figure 2. Basic indicators of cloud service characteristics

As shown in Figure 3, this article builds an indicator system from the characteristics of cloud services. First, it determines five first-level indicators (performance, availability, security, reliability, and price). It combines the actual operation of cloud service providers to build 10 Two secondary indicators (response time, throughput rate, accuracy, robustness, etc.). 10 secondary indicators together constitute the cloud service provider service capability evaluation indicator set $I = \{i_1, i_2, \ldots, i_v\}, v = 5$. On the one hand, these 10 service capability indicators can more comprehensively reflect the comprehensive strength of cloud service providers. On the other hand, they also value cloud service providers in meeting user needs. The specific meanings of these indicators are introduced as follows.

(1) Performance: Performance is an important aspect of service quality, which refers to the speed with which a cloud service completes a request. It includes two parts: response time and throughput rate. Response time is the time required to use cloud services: the sum of waiting time, execution time, and communication time. The throughput rate measures the speed of invoking cloud services.

(2) Usability: Usability requirements mainly reflect the ability of cloud service providers to accomplish user-specific goals. It includes three parts: accuracy, robustness, and scalability. Accuracy means that cloud service providers can accurately formulate service fees and accurately complete user tasks. Robustness, also known as resistance to transformation,

refers to the ability of the system to maintain certain characteristics of itself when the environment is abnormal. Scalability measures the cloud service provider's ability to meet users' ever-expanding needs.

(3) Security: Reflects the ability of cloud service products to avoid interference from hidden security hazards. It includes two parts: data management capability and authorized access. Data management capability measures the security of cloud service providers when managing data. Authorized access refers to managing user permissions while using cloud services.

(4) Reliability: the proportion of normal work in a given period of use. Including the mean time between failures and system stability, the mean time between failures refers to the average time between two adjacent failures, and system stability refers to the ability of the system to remain active.

(5) Price: Measure the price level of the industry's resource prices provided by cloud service providers.

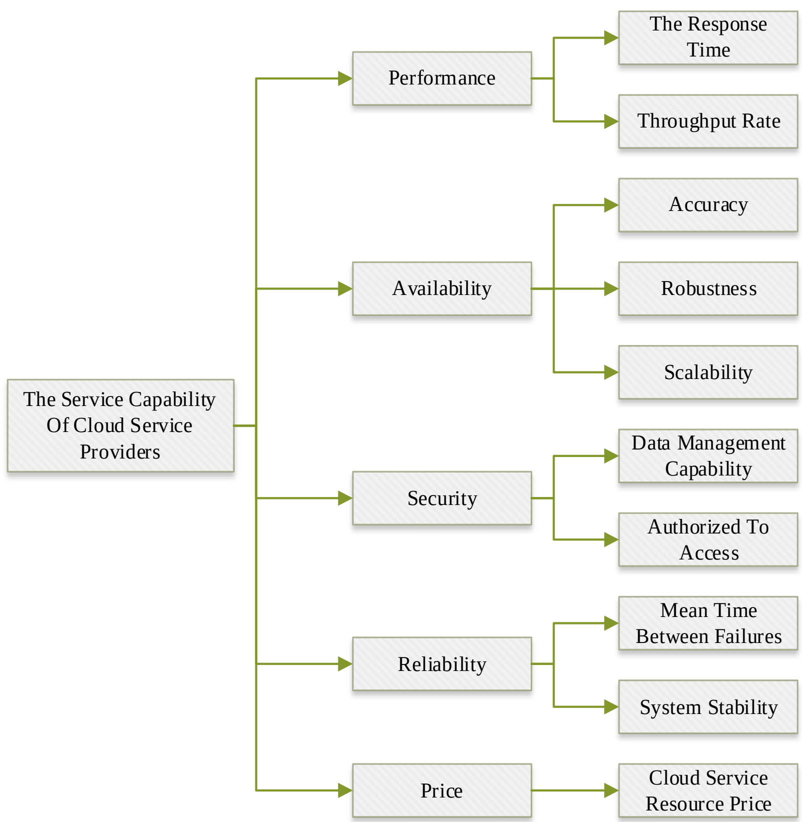

Figure 3. Service capacity indicators of cloud service providers

In this article, cloud service providers will provide their evaluation of various secondary indicators, obtain various service capability indicators of candidate cloud service providers, and collect them into the database of candidate cloud service providers. Cloud service providers must evaluate the evaluation index set $I = \{i_1, i_2, \ldots, \}$ iv, including 10 capabilities, response time, throughput rate, accuracy, and robustness. To ensure the uniformity of the evaluation standards, each cloud service provider still measures its capabilities through the fuzzy evaluation method, choosing from 7 levels, including "low," "moderate," and "high" options. Then, according to Table 2, it transformed into a triangular fuzzy vector $c_{jh} = \langle c_{jh}^1, c_{jh}^2, c_{jh}^3 \rangle, where\ c_{jh}$ is the triangular fuzzy evaluation value measured by the cloud service provider on the h-th capability index, thereby constructing the cloud service provider service capability index set $I = \{i_1, i_2, \ldots,\}$ ⅳ.

4. Matching and recommendation between cloud service providers and users

As shown in Figure 4, the recommendation of cloud service providers oriented to user needs and preferences is mainly divided into three parts: cloud service user demand preference acquisition, cloud service provider service capability acquisition, and cloud service provider and user matching and recommendation [18]. The main purpose of the first two parts is to obtain data on users and cloud service providers. The last part aims to establish a match between cloud service providers and users and complete recommendations. First, the user needs are matched with the cloud service provider's service capabilities. The cloud service provider's demand-satisfying ability is calculated. Then, the similar distance between the user's demand and the cloud service provider's demand-satisfying ability is calculated, the sort distance is sorted, and the user is recommended to the appropriate supplier.

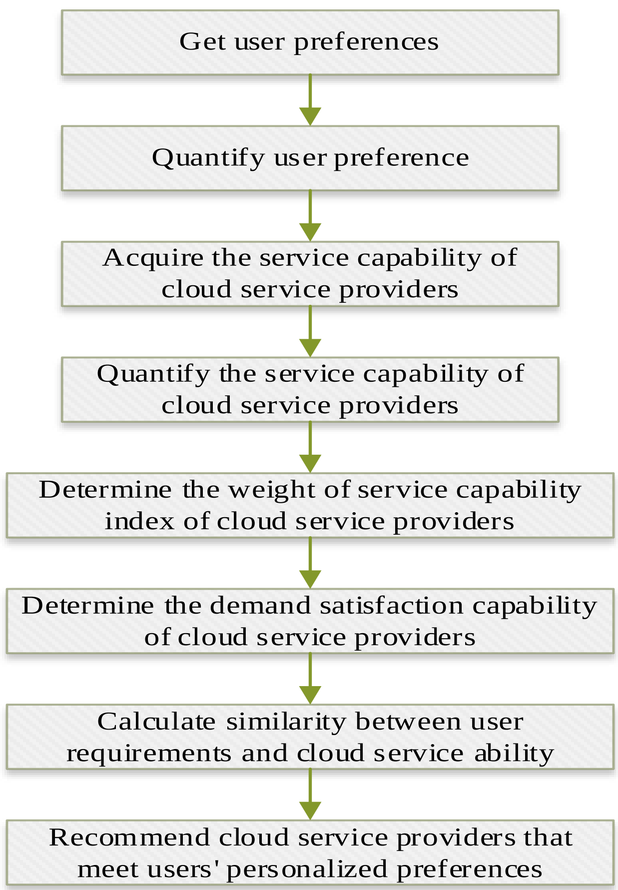

Figure 4. Recommendation process of cloud service providers based on user demand preferences

4.1. The determination of the weight of cloud service providers' service capabilities

The capability weight reflects the proportion of the service capability indicator's contribution to the completion of the service. This paper defines the weight of capability, that is, the proportion of the service capability index overall. It uses the entropy weight method to determine the weight of the service capability index of cloud service providers. The entropy weight method is a relatively mature quantitative research method for determining weights. It calculates the information entropy value to determine the degree of dispersion of an indicator and obtains a more objective indicator weight. It is widely used in the process of determining weights. If the entropy value of an indicator is smaller, it means that the degree of dispersion of the indicator is greater. The information provided is more, and the weight should be greater [19]. Conversely, suppose the entropy value of an indicator is larger. In that case, it means that the degree of dispersion of the indicator is smaller, the amount of information provided is less, and its weight should be smaller.

Assuming there are m candidate cloud service providers $S = \{S_1, S_2, \ldots, S_m\}$, v cloud service provider service capability indicators $I = \{i_1, i_2, \ldots, i_v\}$, from the original evaluation matrix $X = (c_{hj})_{mxv}, where, c_{jh} = \langle c_{jh}^1, c_{jh}^2, c_{jh}^3 \rangle$ is the triangular fuzzy evaluation value measured by the fuzzy evaluation method on the h-th service capability index of the j-th candidate cloud service provider. The steps for determining the weight of the cloud service provider's service capability index are as follows:

Step 1. The evaluation matrix is obtained by defuzzifying the original data by formula (1) $X^{'} = (c_{hj})_{mxv}$. In this paper, the method of finding the best non-fuzzy performance (BNP) of the triangular fuzzy number is used to preprocess the original evaluation matrix X, and the evaluation values in the original matrix X are defuzzified. which is

$$c_{jh} = \frac{\left[\left(c_{jh}^3 - c_{jh}^1\right) + \left(c_{jh}^2 - c_{jh}^1\right)\right]}{3} + c_{jh}^1 \#(1)$$

Step 2. The standard matrix $R = (r_{jh})_{mxv}$ is obtained by standardizing the evaluation matrix through formula (2). Since each service capability index is a benefit-based positive evaluation index, the standardized formula (2) calculates each c_{jh}in the cloud service provider evaluation matrix X.

$$r_{jh} = \frac{c_{jh}}{\sqrt{\sum_{j=1}^{m} c_{jh}^2}} \times 100 \#(2)$$

where r_{jh} represents the standardized evaluation value of the h-th service capability indicator of the jth candidate cloud service provider.

Step 3. Calculate the proportion p_{jh} of the h-th service capability of the j-th cloud service provider by formula (3).

$$p_{jh} = \frac{r_{jh}}{\sum_{j=1}^{m} r_{jh}} \#(3)$$

Step 4. Calculate the entropy value of the h-th service capability by formula (4).

$$e_h = -\frac{1}{lnm}\sum_{j=1}^{m} p_{jh} \cdot lnp_{jh}, ln0 = 0\#(4)$$

Step 5. Calculate the entropy weight w_h of the h-th service capability by formula (5).

$$w_h = \frac{(1 - e_h)}{\sum_{h=1}^{v}(1 - e_h)}\#(5)$$

4.2. Determination of the ability to meet the needs of cloud service providers

Connect cloud service providers and user needs, and use various service capability indicators as a bridge to measure the ability of cloud service providers to meet user needs. Although each service capability is related to the realization of user needs, each service capability index corresponds to the degree of relevance and contribution to realizing a specific user service demand [20]. Through in-depth interviews with experts and scholars in cloud computing and cloud services, the corresponding relationship between the service capabilities of cloud service providers and user demand dimensions, as shown in Table 3 was determined. This establishes a bridge between cloud service providers and user needs.

Table 3 The relationship between user demand and service capability of the service provider

The user needs	Relevant service capability indicators
Availability	Accuracy
	Robustness
	Scalability
Reliability	Mean time between failures
	System stability
Timeliness	The response time
	Throughput
Security	Data management capability
	Authorized to access
Price affordability	Cloud service resource price

Match the service capabilities of cloud service providers with corresponding weights and measure the ability of cloud service providers to meet user needs through the weighted average method based on the relationship between the service capabilities of cloud service providers and the ability to realize user needs. For example, the service capability index value of candidate cloud service provider S_j is $c_{jh} = \langle c_{jh}^1, c_{jh}^2, c_{jh}^3 \rangle$, and its corresponding ability weight is w_h. Therefore, the ability of the cloud service provider S_j to meet user needs will be calculated according to equation (6).

$$\tilde{a_{jt}} = \langle a_{jt}^1, a_{jt}^2, a_{jt}^3 \rangle = \sum_{c_h \in r_t} [w_h \times c_{jh}^k]\#(6)$$

4.3. Cloud service provider recommendation

User Triangular Fuzzy Number Demand Set $p_1 = \langle p_t^1, p_t^2, p_t^3 \rangle$, where p_t^k is the user U's preference for the demand r_i expressed as a triangle vector, reflecting the user's subjective characteristics of the desired cloud service provider. The ability of cloud service providers to achieve user needs $a_{jt} = \langle a_{jt}^1, a_{jt}^2, a_{jt}^3 \rangle$, $where\ a_{jt}^k$ is the triangular fuzzy value of demand satisfaction ability. Reflects the objective capability characteristics of candidate cloud service providers. The Euclidean fuzzy distance formula (7) can calculate the similarity distance between the user U and the cloud service provider S_j based on the demand dimension r_t[21]. Since five demand dimensions, including availability, reliability, etc., have been determined, the comprehensive similarity distance between user U and cloud service provider S_j can be obtained by adding up the similarity distance of each demand dimension and taking the absolute value—formula (8).

$$S_{u,s_j}(t) = 1 - \frac{1}{\sqrt{3}}\left[\sum_{k=1}^{3}\left(p_t^k - a_{jt}^k\right)^2\right]^{\frac{1}{2}} \#(7)$$

$$S_{u,s_j} = \left|\sum_{t=1}^{s} S_{u,s_j}(t)\right| \#(8)$$

The comprehensive similarity distance between the user and each candidate cloud service provider can be measured by analogy. The comprehensive similarity distance reflects the degree of demand-based matching between the user and each candidate cloud service provider. Among them, the smaller the similarity distance value, the higher the matching degree between the user and each candidate cloud service provider; conversely, the larger the similarity distance value, the lower the matching degree between the user and each candidate cloud service provider.

5. Case analysis

A user U needs to choose a cloud service provider. The requirements for cloud services are as follows: cloud services must be available and relatively timely. Reliability and security are not required, and prices are not considered. Based on this, the user's requirements for various indicators are extracted. The requirements for availability are very high, the requirements for timeliness of cloud services are relatively high, the requirements for reliability are relatively low, the requirements for security are relatively low, and the criteria for price are very low. We can accept higher pricing in the industry. Demand preference and demand preference fuzzy numbers are shown in Table 4.

Table 4. User U’s preference for cloud service requirements

Demand for dimension	Textual demand preference	Demand preference fuzzy number
availability	Very high (VH)	<6,7,8>
reliability	Low (L)	<1,2,3>
timeliness	Medium-High (MH)	<4,5,6>
security	Low (L)	<1,2,3>
Price affordability	Very low (VL)	<0,1,2>

Assume three cloud service providers, S1, S2, and S3, meet the requirements and collect relevant information. Their various service capabilities are shown in Table 5, and the most suitable cloud service provider needs to be selected for users.

Table 5. The service capability of cloud service providers S_1、S_2 *and* S_3

Service Capability Index	S1	S2	S3
Accuracy	Medium-low (ML)	Height (H)	Very high (VH)
Robustness	Medium (M)	Very high (VH)	Medium-low (ML)
Scalability	Medium-low (ML)	Medium (M)	Height (H)
Mean time between failures	Low (L)	Medium-low (ML)	Medium-High (MH)
System stability	Very high (VH)	Low (L)	Low (L)
The response time	Medium-low (ML)	Medium-low (ML)	Medium-High (MH)
Throughput	Low (L)	Medium-low (ML)	Medium-High (MH)
Data management capability	Very high (VH)	Low (L)	Low (L)
Authorized to access	Medium-low (ML)	Medium-low (ML)	Medium-High (MH)
Cloud service resource price	Medium-High (MH)	Low (L)	Medium (M)

5.1. Cloud service provider recommendation based on user behavior preferences

According to Table 2, the service capabilities of the three cloud service providers are converted into the corresponding triangular fuzzy number form, and triangular fuzzy numbers represent their 10 service capabilities to form the following initial evaluation matrix $X = (c_{hj})_{3\times10}$.

$$X = \begin{bmatrix} \langle 2,3,4\rangle & \langle 3,4,5\rangle & \langle 2,3,4\rangle & \langle 1,2,3\rangle & \langle 6,7,8\rangle & \langle 2,3,4\rangle & \langle 1,2,3\rangle & \langle 6,7,8\rangle & \langle 2,3,4\rangle & \langle 4,5,6\rangle \\ \langle 5,6,7\rangle & \langle 6,7,8\rangle & \langle 3,4,5\rangle & \langle 2,3,4\rangle & \langle 1,2,3\rangle & \langle 2,3,4\rangle & \langle 2,3,4\rangle & \langle 1,2,3\rangle & \langle 2,3,4\rangle & \langle 1,2,3\rangle \\ \langle 6,7,8\rangle & \langle 2,3,4\rangle & \langle 5,6,7\rangle & \langle 4,5,6\rangle & \langle 1,2,3\rangle & \langle 4,5,6\rangle & \langle 4,5,6\rangle & \langle 1,2,3\rangle & \langle 4,5,6\rangle & \langle 3,4,5\rangle \end{bmatrix}$$

After the data preprocessing process, through the defuzzification formula (1) and standardized formula (2) in the initial evaluation matrix, a standardized cloud service provider evaluation matrix is obtained $R = (r_{hj})_{3\times10}$。

$$\boldsymbol{R} = \begin{bmatrix} 31 & 46 & 38 & 32 & 93 & 46 & 32 & 93 & 46 & 75 \\ 62 & 81 & 51 & 49 & 26 & 46 & 49 & 26 & 46 & 30 \\ 72 & 35 & 77 & 81 & 26 & 76 & 81 & 26 & 76 & 60 \end{bmatrix}$$

According to the standardized evaluation matrix of 3 candidate cloud service providers, $R = (r_{hj})_{3\times10}$. According to the steps of the above-mentioned entropy weight method, the entropy value and the capability weight w_h of each service capability index are calculated, as shown in Table 6.

Table 6. Calculation of the weight of service capability by entropy weight method

Service Capability Index	Entropy(*eh*)	Entropy weight (*wh*)
Accuracy	0.95	0.068 6
Robustness	0.94	0.079 5
Scalability	0.96	0.050 5
Mean time between failures	0.94	0.085 6
System stability	0.83	0.237 2
The response time	0.97	0.039 1
Throughput	0.94	0.085 6
Data management capability	0.83	0.237 2
Authorized to access	0.97	0.039 1
Cloud service resource price	0.94	0.077 5

According to the service capability level of the cloud service provider, S_1, in the previous example and the calculated capability weight, the demand satisfaction capability of the S_1 can be calculated. Similarly, the demand-satisfaction capabilities of cloud service providers S_2 and S_3 are shown in Table 7.

Ities of cloud service providers S_2 and S_3 are shown in Table 7. According to the needs and preferences of a cloud service user U and the calculated sample cloud service provider S_1's demand satisfaction ability, according to the similarity measurement process, the cloud service users are calculated Comprehensive similarity distance between U and cloud service provider S_1 based on demand. The results are shown in Table 8. In the same way, it is calculated that the distances between the user and the cloud service providers S_2 and S_3 are similar, at 8.98 and 8.15, respectively. Because the distance between the user and the cloud service provider S_3 is the closest, the cloud service provider S_3 has the highest matching degree with the user and best meets the user's needs; that is, the cloud service provider S_3 is recommended for the user.

Table 8. The calculation of cloud provider S2, S3's demand fulfillment capability

User demand	Demand satisfaction capability of cloud service provider S2	Demand satisfaction capability of cloud service provider S3
Availability	<0.97,1.17,1.37>	<0.82,1.02,1.22>
Reliability	<0.41,0.73,1.05>	<0.58,0.90,1.23>
Timeliness	<0.65,0.97,1.29>	<1.29,1.61,1.94>
Security	<0.32,0.59.0.87>	<0.39,0.67,0.95>
Price affordability	<0.08,0.16,0.23>	<0.23,0.31,0.39>

Table 9. The calculation of similarities between users and cloud service S1

User demand	Demand preference	Ability to meet the demand	Similarity distance between users and cloud service providers
Availability	<6,7,8>	<0.48,0.68,0.87>	$1-\frac{1}{\sqrt{3}}[(6-0.48)^2+(7-0.68)^2+(8-0.87)^2]^{1/2}$
Reliability	<1,2,3>	<1.51,1.83,2.15>	$1-\frac{1}{\sqrt{3}}[(1-1.51)^2+(2-1.83)^2+(3-2.15)^2]^{1/2}$
Timeliness	<4,5,6>	<0.41,0.73,1.05>	$1-\frac{1}{\sqrt{3}}[(4-0.41)^2+(5-0.73)^2+(6-1.05)^2]^{1/2}$
Security	<1,2,3>	<1.50,1.78,2.05>	$1-\frac{1}{\sqrt{3}}[(1-1.50)^2+(2-1.78)^2+(3-2.05)^2]^{1/2}$
Price affordability	<0,1,2>	<0.31,0.39,0.47>	$1-\frac{1}{\sqrt{3}}[(0-0.31)^2+(1-0.39)^2+(2-0.47)^2]^{1/2}$

Therefore, comprehensively considering the user's demand preference and the cloud service provider's ability preference and then ranking the similarity distance of cloud service providers, it is possible to find the cloud service provider that best meets the user's demand preferences.

5.2. Recommendations from traditional cloud service providers

The traditional method does not consider the user's demand preference, only measures the service capabilities of three cloud service providers, and adds the weighted service capabilities of the enterprise capabilities, as shown in equation (9), and the results are shown in Table 9.

$$S_j = \sum_{h=1}^{v} [w_h \times c_{jh}^k] \#(9)$$

Table 10. Comprehensive service capabilities

Service Capability Index	S_1	S_2	S_3
Accuracy	(0.14,0.21,0.27)	(0.34,0.41,0.48)	(0.41,0.48,0.55)
Robustness	(0.24,0.32,0.40)	(0.48,0.56,0.64)	(0.16,0.24,0.32)
Scalability	(0.10,0.15,0.20)	(0.15,0.20,0.25)	(0.25,0.30,0.35)
Mean time between failures	(0.09,0.17,0.26)	(0.17,0.26,0.34)	(0.34,0.43,0.51)
System stability	(1.42,1.66,1.90)	(0.24,0.47,0.71)	(0.24,0.47,0.71)
The response time	(0.17,0.26,0.34)	(0.17,0.26,0.34)	(0.34,0.43,0.51)
Throughput	(0.24,0.47,0.71)	(0.47,0.71,0.95)	(0.95,1.19,1.42)
Data management capability	(1.42,1.66,1.90)	(0.24,0.47,0.71)	(0.24,0.47,0.71)
Authorized to access	(0.08,0.12,0.16)	(0.08,0.12,0.16)	(0.16,0.20,0.23)
Cloud service resource price	(0.31,0.39,0.47)	(0.08,0.16,0.23)	(0.23,0.31,0.39)
Total	(4.12,5.37,6.60)	(2.42,3.62,4.81)	(3.32,4.52,5.72)

Formula (1) was used to defuzze the weighted results and get the comprehensive service capabilities of S_1 $, S2, and\ S_3$ to be 5.37, 3.62, and 4.52, respectively. Using the traditional recommendation method, cloud service provider S_1 is the best choice.

5.3. 2 Comparison of 2 recommended methods

The final recommendation results are different through two different cloud service provider recommendation methods: the cloud service provider is selected using the recommendation method based on user behavior preferences, and the cloud service provider S_1 is selected using the traditional recommendation method.

By comparing the service capabilities of the three cloud service providers, it can be found that the cloud service provider S_1 has strong system stability and data management capabilities, high reliability and security, and weaker availability and timeliness capabilities than the other two cloud service providers. The cloud service provider S_2 has strong accuracy, robustness, and high availability but low reliability and security. For cloud service provider S_3, in addition to robustness, system stability, and data management capabilities, other capabilities are beyond the average level, especially the two capabilities of accuracy and scalability, which are reflected in the ability to meet requirements, availability and timeliness scores, which are relatively high.

For users with high requirements on the availability and timeliness of cloud services, the cloud service provider S_3, which has both high capabilities, is the most suitable. Although the cloud service provider S_3 has low security and reliability requirements to meet the requirements, these two capabilities are unimportant for the user. And the higher usability and timeliness it can provide is exactly what users need. The cloud service provider S_3 selected based on the traditional recommendation algorithm only has the highest comprehensive ability and is not the most suitable cloud service provider for user U. Based on this, it can be seen that the traditional recommendation algorithm recommends the same cloud service provider to all users, neither taking into account the difference between the services provided by cloud service providers, nor taking into account the needs and preferences of users, which can meet the recommended cloud The service provider has the strongest comprehensive ability, but it does not meet the user's requirements. The recommendation method that considers user needs and preferences is more in line with users' needs than traditional methods. It extracts the differences between cloud services provided by cloud service providers and provides users with accurate matching to provide users with personalized needs.

6. Conclusion

Based on the rise and wide application of cloud services, this paper proposes and implements a cloud service provider recommendation model based on user needs and preferences. First, based on users' needs, the subjective dimensions of users' demand for cloud services are determined, and the measurement of user preferences is realized. Secondly, according to the cloud service provider's capability, the cloud service provider's ability to meet users' needs is measured. From the perspective of cloud service providers, after determining the indicators that can reflect the service capabilities of cloud service providers, innovatively establish a bridge between service capabilities and user needs, and realize the evaluation of cloud service providers from the perspective of demand realization, namely Measure its ability to meet needs. Finally, according to the recommendation rules in this article, the similarity distance between the user and the candidate cloud service provider based on requirements is compared. A cloud service provider that matches the user's corresponding needs and preferences is recommended to the user, and personalized decision-making recommendations for the cloud service provider are realized. By comparing with the recommendation of traditional cloud service providers, the difference in the results of the two recommendation methods shows that the method proposed in this article recommends more accurate results for users, so this method can more accurately match users' needs and provide users with personalities.

In summary, the recommendation system proposed and implemented in this paper is no longer limited to evaluating cloud service providers. Still, the recommendation process combines information such as cloud service users' needs and preferences and specific cloud service field characteristics. Combined with fuzzy evaluation methods and similar distance theories, it provides users with more satisfactory recommendations and provides reference significance and application value for solving similar research problems. However, the user's proposals in this article must be improved. In future research, we can extract the user's possible cloud service needs from the user's demographic characteristics to further enrich the demand dimension of cloud services, cloud service users, and cloud service providers. The similarity measurement standard perfects the personalized recommendation system.

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