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A Decision-Making Method for Selecting Cloud Computing Service based on Information Entropy

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Abstract

This paper proposes an information-entropy-based decision-making method for selecting cloud computing service. Firstly, an evaluation index system (EIS-DMSCS) is developed. Secondly, a decision-making method is constructed. Finally, the application example proves the scientificity, effectiveness and feasibility of this method.

Keywords: *Cloud Computing, Cloud Service, Decision-Making Method, Information Entropy*

1. Introduction

In recent years cloud computing becomes one of the most hottest and popular network computing paradigm in many fields, such as information industry, academic circles and government, etc. Cloud computing is the core for the new generation information technology change, representing the development trend of large scale, intensifying and specialization in IT field. This trend is inexorable for IT industry. In a cloud computing environment, data are stored on the cloud and users can obtain the powerful computing ability from the cloud, without purchasing those expensive infrastructures. A user would acquire the cloud computing service and achieve "service on demand" as long as they propose a request to the cloud service provider and pay the low cost. Cloud computing liberates the user from the costly infrastructure investment and the heavy management and maintenance, thus, the user can concentrate more on their core business development.

There are many famous cloud computing service providers, such as, Amazon, Google, IBM and Microsoft, etc. However, how to select the most suitable cloud service for own from the providers? It is a problem that needs to be considered seriously. However, there is still lack of normative and scientific decision-making method at present[1, 2]. [3-5] are all focus on cloud computing, but none of them involve this issue. In view of this, this paper addresses the issue and proposes an information-entropy-based decision-making method for the selection of cloud computing service. There are scientific significance and practical value in this research, for the former, it expands the application fields of information entropy, for the latter, it put forward an exercisable approach.

The rest of this paper is organized as follows. Section 2 introduces information entropy theory. Section 3 proposes an information-entropy-based decision-making method for selecting cloud computing service. Section 4 presents the application example. The conclusion is given in section 5.

2. Information Entropy Theory

Information entropy is an important theory in the area of systems science, which has been widely applied to many disciplinary fields, such as physics, chemistry, geography, biology, manages economics and computer science. Information entropy, which originated from physics, is a state function and a law of nature. Albert Einstein said:

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"Entropy Theory is the first principle for the whole natural science". Arthur Stanley Eddington, a Nobel Prize winner, regarded Entropy Law as a sovereign philosophy law in the whole universe. Information entropy is the main method in this study. It is abstract and cannot be easily understood. Therefore, a simple introduction is given as below.

Entropy is originated from thermodynamics. Based Energetics Entropy and Statistical Physics Entropy, Shannon[6] developed Information Entropy Theory. Let a probability space of discrete information source,

$$\begin{bmatrix} X \\ P(x) \end{bmatrix} = \begin{bmatrix} a_1 & a_2 & \cdots & a_n \\ P(a_1) & P(a_2) & \cdots & P(a_n) \end{bmatrix}$$

Then the information content transferred in the communication can be expressed quantificational as,

$$H(X) = -K \sum_{i=1}^{n} P_i \log P_i$$

where, K is a constant positive number, P_i is the occurrence probability of event X_i, they satisfy the condition $0 \le P_i$, $(i = 1,..., n)$ and $\sum_{i=1}^{n} P_i = 1$. Shannon called $H(X)$ as information entropy.

3. An Information-Entropy-based Decision-making Method for Selecting Cloud Service

3.1. Evaluation Index System for the Decision-Making

Cloud computing achieve the economic and social benefits by cloud service, and we evaluate the value of cloud service primarily through its quality[7]. The authors consider that the decision-making for selecting cloud service should depend mainly on the quality of cloud service as well as integrating their own requirements and the ability for paying. The quality of cloud service determines whether the cloud computing finds a wide application or not. Whether a user selects the cloud computing platform depends on whether the service meet its demand[8]. [9] defines the quality of cloud computing service as that the whole effect of user for using cloud computing service and the effect determines user satisfaction for the cloud computing service. [10-12] discuses evaluation index system about the quality of cloud service. Based on the existing studies, the paper develops an evaluation index system for the decision-making of selecting cloud service (EIS-DMSCS), shown as Table 1.

Table 1. Evaluation Index System for the Decision-Making of Selecting Cloud Service (EIS-DMSCS)

First Grade Index	No.	Second Grade Index
Resource Condition	1	State of IaaS
	2	State of PaaS
	3	State of SaaS
Service Utility	4	Usability
	5	Reliability
	6	Response Time

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Security	7	Privacy Security
	8	Technology Security
	9	Operation Management Security
Service-Level Agreement	10	Sigmacompleteness
	11	Transparency and Creditability
	12	Punishment Mechanism
Economic Factors	13	Service Price
	14	Payment Ability

3.2. An Information-Entropy-Based Method

There are m cloud service options, and n indexes need to be considered (where $n = 14$) for every optional service, then a matrix can be gotten as below,

$$X = (X_{ij})_{m\times n} = \begin{pmatrix} X_{11} & X_{12} & \cdots & X_{1n} \\ X_{21} & X_{21} & \cdots & X_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ X_{m1} & X_{m1} & \cdots & X_{mn} \end{pmatrix}$$

Because the evaluation cannot be evaluated full automatically, we take a method of experts group decision making. Every expert mark each alternative cloud service based on EIS-DMSCS. The marking value range from 1 to 5, respectively, 1,2,3,4 and 5, namely, $(X_{ij})_{m\times n} \in \{1,2,3,4,5\}$, 5 represents the best, others respectively represents the inferior place.

The weight of each evaluation index of cloud service is different from another. Let the weight of first grade index,

$a = \{a_1, a_2, a_3, a_4, a_5\}$, $\sum_{i=1}^{5} a_i = 1$,

and let the weight of second grade index,

$b_1 = \{b_{11}, b_{12}, b_{13}\}$, $\sum_{i=1}^{3} b_{1i} = 1$; $b_2 = \{b_{21}, b_{22}, b_{23}\}$, $\sum_{i=1}^{3} b_{2i} = 1$;

$b_3 = \{b_{31}, b_{32}, b_{33}\}$, $\sum_{i=1}^{3} b_{3i} = 1$; $b_4 = \{b_{41}, b_{42}, b_{43}\}$, $\sum_{i=1}^{3} b_{4i} = 1$; $b_5 = \{b_{51}, b_{52}\}$, $\sum_{i=1}^{2} b_{5i} = 1$.

Then, the weight of each index, $c = \{c_1, c_2, \cdots, c_{14}\} = \{a_1 \times b_1, a_2 \times b_2, a_3 \times b_3, a_4 \times b_4, a_5 \times b_5\}$, where, $a_1 \times b_1 = \{a_1 \times b_{11}, a_1 \times b_{12}, a_1 \times b_{13}\}$, $a_2 \times b_2 = \{a_2 \times b_{21}, a_2 \times b_{22}, a_2 \times b_{23}\}$, $a_3 \times b_3 = \{a_3 \times b_{31}, a_3 \times b_{32}, a_3 \times b_{33}\}$, $a_4 \times b_4 = \{a_4 \times b_{41}, a_4 \times b_{42}, a_4 \times b_{43}\}$, $a_5 \times b_5 = \{a_5 \times b_{51}, a_5 \times b_{52}\}$. The weights are set by the related domain experts and the decision-makers.

Information entropy is a state function for a system, can be used not only to measure information content and measure uncertainty, but also to measure disorder degree[13]. As

mentioned before, the weights in table 1 are set subjectively. How to reduce the subjective influence as much as possible and let the decision-making is more reasonable, which are need to deeply studied. In matrix $(X_{ij})_{m\times n}$, for an index, if the evaluations values come from different experts are large diversity, then, the information entropy will be small. Namely, information content provided by this index is large, and the effect come from the index is great in the evaluation. Therefore, the weight of this index should be set largely. On the contrary, if the difference between the experts' evaluation is small, then, information entropy will be large. Namely, the information content provided by the index is little, and the effect come from this index is slight in the integrative evaluation. Accordingly, the weight should be small. Therefore, according to the difference degree of evaluation values given by experts for each index, we can use information entropy to adjust the initial weight set by the experts subjectively, which will be make the weight tend to be a more objective and reasonable state.

To sum up, the whole algorithm for the decision-making as follows:

Step 1: determine the experts and the cloud service options

Step 2: set the initial weights of evaluation index system $c = \{c_1, c_2, \cdots, c_{14}\}$

Step 3: the evaluation experts evaluate each cloud computing service according to the index system in table 1, and obtain the value of matrix $X = (X_{ij})_{m\times n}$

Step 4: calculate information entropy $H(X)$ of each index, the information entropy $H(j)$ of j th index

$$H(j) = -K\sum_{i=1}^{m} P_i \log P_i = -K\sum_{i=1}^{m} \left(\left(\frac{X_{ij}}{\sum_{i=1}^{m} X_{ij}}\right)\ln\left(\frac{X_{ij}}{\sum_{i=1}^{m} X_{ij}}\right)\right)$$

Step 5: adjust the initial weight $c = \{c_1, c_2, \cdots, c_{14}\}$ to $w = \{w_1, w_2, \cdots, w_{14}\}$, where,

$$w_j = \frac{c_j \times (1 - H(j))}{\sum_{j=1}^{n} c_j \times (1 - H(j))}$$

Step 6: calculate the final score of each alternative cloud service, $Score = \{s_1, s_2, \cdots, s_m\}$, where, $s_i = \sum_{j=1}^{n} (X_{ij} \times w_j)$

Step 7: determine the cloud computing service which is selected finally, the largest one among $s_1, s_2, \cdots, s_m$ is the cloud service that should be selected.

4. Application Example

F Company decides to take cloud computing service and there are A, B, C and D four providers participate in the bid. The proposed method, shown in section 3, is adopted for the selection decision-making. The manager invited seven experts to evaluate these schemes. According to the indexes of EIS-DMSCS (shown in Table 1), the experts gave the following initial weights based on their expertise, experience and actual schemes.

$$a = \{a_1, a_2, a_3, a_4, a_5\}$$
$$= \{0.18, 0.25, 0.2, 0.22, 0.15\}$$

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$b_1 = \{b_{11}, b_{12}, b_{13}\} = \{0.33, 0.33, 0.34\}$, $b_2 = \{b_{21}, b_{22}, b_{23}\} = \{0.4, 0.4, 0.2\}$,

$b_3 = \{b_{31}, b_{32}, b_{33}\} = \{0.4, 0.35, 0.25\}$, $b_4 = \{b_{41}, b_{42}, b_{43}\} = \{0.4, 0.3, 0.3\}$,

$b_5 = \{b_{51}, b_{52}\} = \{0.5, 0.5\}$

Namely,

$c = \{c_1, c_2, \cdots, c_{14}\} = \{0.0594, 0.0594, 0.0612, 0.1, 0.1,$

$0.05, 0.08, 0.07, 0.05, 0.088, 0.066, 0.075, 0.075\}$

Scores of the four software's as follow,

$$X = (X_{ij})_{m \times n} = \begin{pmatrix} XA & XB & XC \\ XD & XE & XF \\ XG & XH & XI \\ XJ & XK & XL \end{pmatrix}$$

where,

$XA = (4 \quad 5 \quad 5 \quad 5 \quad 3)$, $XB = (5 \quad 4 \quad 5 \quad 5 \quad 4)$, $XC = (4 \quad 5 \quad 5 \quad 5)$,

$XD = (5 \quad 4 \quad 5 \quad 5 \quad 4)$, $XE = (4 \quad 5 \quad 5 \quad 5 \quad 3)$, $XF = (5 \quad 4 \quad 5 \quad 5)$

$XG = (4 \quad 4 \quad 4 \quad 3 \quad 2)$, $XH = (4 \quad 5 \quad 5 \quad 5 \quad 3)$, $XI = (4 \quad 5 \quad 5 \quad 4)$

$XJ = (5 \quad 5 \quad 4 \quad 3 \quad 5)$, $XK = (4 \quad 4 \quad 4 \quad 3 \quad 2)$, $XL = (5 \quad 5 \quad 4 \quad 3)$

According to Step 4 and Step 5,

$w = \{w_1, w_2, \cdots, w_{14}\}$

$= \{0.05873784, 0.05873784, 0.06051777,$

$0.10160783, 0.10385619, 0.04937939,$

$0.07910820, 0.06907936, 0.05019499,$

$0.08910667, 0.06526426, 0.06513197,$

$0.07401360, 0.07526402\}$

According to Step 6,

$Score = \{s_1, s_2, s_3, s_4\}$

$= \{4.50007061, 4.54468124, 3.93910123, 3.94644790\}$

According to the evaluation result, option B is the best. Therefore, the decision makers selected it in the end. To this day, it has been used by F Company for over one year in good conditions, showing that the evaluation method is scientific and reasonable.

5. Conclusions

This paper develops an evaluation index system for the decision-making of selecting cloud service (EIS-DMSCS) and proposes an information-entropy-based decision-making method for the selection of cloud computing service. Information entropy makes the

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decision-making more scientific and reasonable. The application example proves the scientificity, effectiveness and feasibility of this method. To have a better decision-making, service quality of cloud computing and evaluation of trustworthy service in cloud computing should be further studied in the future as far as the authors can see.

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