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The Assessment of Cloud Computing Service under Intuitionistic Fuzzy Environment

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With the rapid development of advanced technology, cloud computing technology has appeared and attracted much attention in academia and the business community. In cloud computing technology, cloud computing service is a very important issue. Up to now, although cloud computing service achieved some success with the development to the deepening of the application, owing to security, technology, management, and other constraints, not all businesses are suitable for the use of this service model, so the business need consider their own actual situation and select a method to make effective evaluation of the comprehensive capacity of the cloud computing services. Thus, according to these characteristics, in this paper, we analysis cloud computing service from security and risk, data, services, resources, economic dimensions and then introduce a new multiple attribute decision making method to assess cloud computing service where a cloud computing service adaptability evaluation system is constructed. Finally, the proposed method is applied in an illustrative example to demonstrate its applicability and validity.

1. Introduction

Since cloud computing appeared, it has attracted a huge amount of attention from academia and the business community. Some researchers insist that cloud computing has emerged as a paradigm to deliver on demand resources such as infrastructure, platform, software and so on to customers similar to other utilities as water, electricity and gas (Garg et al. 2013; Karthic et al. 2012). In general, there are three main services provided by cloud computing architecture based on the needs of IT customers including software, platform and infrastructure (He. 2012). The aim of cloud computing is to deliver a network of virtual services so that users can access them from anywhere in the world on subscription at competitive costs depending on their quality service requirements (Zheng et al. 2013). In general, cloud computing services can offer significant benefits to businesses and communities by freeing them from the low-level task of setting up IT infrastructure (Sobel et al. 2008). Because of business benefits provided by cloud computing, many organizations have started to construct applications on the cloud infrastructure and elastic cloud services (Zhang et al. 2012). Each cloud provider offers similar cloud services as different prices and performance levels with different sets of features (Iosup et al. 2011). Thus, given the diversity of cloud service offerings, a critical problem for customers is to discover cloud computing service which is the appropriate one that satisfies the requirements of the organizations. However, up to now, although cloud computing service achieved some success with the development to the deepening of the application, owing to security, technology, management, and other constraints, not all businesses are suitable for the use of this service model, so the business need consider their own actual situation and select a method to make effective evaluation of the comprehensive capacity of the cloud computing services.

Thus, how to select an optimal cloud computing service is a big challenge in the study of cloud computing. Many researchers devoted to develop methods to deal with this challenge. Techniques including the analytic hierarchy process, analytic network process (Buyukazici and Sucu. 2003), outranking (Xu and Shen, 2014), VIKOR, TOPSIS and so on are introduced to solve this problem. Hereinto, multiple attribute decision making method (Chen. 2014; Zeleny. 1982) is a popular way to handle this problem. Multiple attribute decision making method which address decision situations where a decision maker express preferences on multiple attribute

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and attempt to find a common solution has been widely discussed in recent years. Generally, the decision maker expresses their judgments depending on both the nature of the features describing the alternatives and on their own knowledge and experience. But there is also a challenge about how to obtain the preference of the decision maker exactly and objectively. Many attempts have been done such as interval-value, fuzzy numbers, intuitionistic fuzzy numbers (Atanassov. 1986), hesitant fuzzy numbers and dual hesitant fuzzy numbers. Because of the characteristics of intuitionistic fuzzy numbers (Atanassov. 1994), this paper introduced intuitionistic fuzzy numbers to express the preference of the decision maker related to several alternatives on several attributes.

In this paper, based on the framework of multiple attribute decision making, we analyze cloud computing service from security and risk, data, services, resources, economic dimensions. Then based on t-conorm an t-norm we define an intuitionisitc fuzzy Hamacher operator to aggregate the intuitionistic fuzzy assessments of each alternative on all attributes. Then, using score function and accuracy function, the comprehensive assessment of each cloud computing service will be calculated. Based on the mentioned work, the optimal alternative can be generated.

The rest of this pape is demonstrated in the following. Section 2 describes the basic concepts of intuitionistic fuzzy sets and their operational laws. In addition, a cloud computing service adaptability evaluation system is constructed as the base of this paper. Section 3 demonstrates the proposed multiple attribute decision making method and its procedure. Section 4 shows the appliction of the proposed method to verify the applicability of the proposed method. Stection 5 concludes this paper. Section 6 gives the references in this paper.

2. Preliminary

In this section, the concept of intuitionistic fuzzy set is introduced and corresponding operational laws are demonstrated. Then, assessment systems of cloud computing service is constructed in order to the implement of the proposed method in section 3.

2.1 Intuitionistic fuzzy sets

In this section, some concepts of intuitionistic fuzzy sets are introduced to deal with multiple criteria decision making problem.

Definition 1. Let X be a universe of discourse, then a fuzzy set is defined as:

$$A=\{[x,u_A(x)] \mid x\in X\} \tag{1}$$

which is characterized by a membership function $u_A:X\to[0,1]$, where u_A denotes the degree of membership of the element x to the set A.

Definition 2. Let X be an ordinary finite non-empty set. An intuitionisitc fuzzy set (Atanassov. 1986) in X is an expression A given by

$$A=\{[x,u_A(x), v_A(x)] \mid x\in X\} \tag{2}$$

where $u_A:X\to[0,1]$ denotes the degree of membership and $v_A:X\to[0,1]$ denotes the degree of non-membership with the condition: $0\le u_A+v_A\le 1$, for all elements x in the set X.

For each intuitionistic fuzzy set A in X, if the amount

$$\pi_A(x)=1-u_A(x)-v_A(x), \forall x\in X .$$

For computational convenience, in this paper, $(u_A(x), v_A(x))$ is called as an intuitionistic fuzzy number.

Definition 3. Let $a=(u_a, v_a)$ and $b=(u_b, v_b)$ be two intuitionistic fuzzy numbers, then it can be obtained that

(1) $a\oplus b=(u_a+u_b-u_a u_b, v_a v_b)$;

(2) $a\otimes b=(u_a u_b, v_a+v_b-v_a v_b)$;

(3) $\lambda a=(1-(1-u_a)^{\lambda}, (v_a)^{\lambda}), \lambda>0$;

(4) $a^{\lambda}=((u_a)^{\lambda}, 1-(1-v_a)^{\lambda}), \lambda>0$.

Definition 4. Given two intuitionistic fuzzy values A and B, the following operations are valid:

(1) $a\oplus b=b\oplus a$;

(2) $\lambda_1(a\oplus b)=\lambda_1 a\oplus\lambda_1 b$;

(3) $\lambda_1 a \oplus \lambda_2 a = (\lambda_1 + \lambda_2) a$.

Definition 5. Let a = (u, v) be an intuitionsitic fuzzy number, a score function S of an intuitionistic fuzzy number can be represented in the following.

$$S(a) = u - v, \quad S(a) \in [-1, 1] \tag{3}$$

Definition 6. Let a = (u, v) be an intuitionsitic fuzzy number, an accuracy function H of an intuitionistic fuzzy number can be represented in the following.

$$H(a) = u + v, \quad H(a) \in [0,1] \tag{4}$$

According to the score function S and the accuracy function H, an order relation between two intuitionistic fuzzy numbers is defined as below.
Definition 7. Let $a_1 = (u_1, v_1)$ and $a_2 = (u_2, v_2)$ be two intuitionistic fuzzy numbers, $S(a_1) = u_1 - v_1$ and $S(a_2) = u_2 - v_2$ be the scores of a_1 and a_2, respectively, and let $H(a_1) = u_1 + v_1$ and $H(a_2) = u_2 + v_2$ be the accuracy degrees of a_1 and a_2, respectively, then we can acquire the following characteristics:
(1) if $S(a) < S(b)$, then a is smaller than b, denoted by a< b;
(2) if $S(a) < S(b)$, then we can obtain that
if $H(a) < H(b)$, then a is smaller than b, denoted by a< b;
if $H(a)$ < Hb), then a is equal to b, denoted by a = b.

2.2 Assessment system of cloud computing service

Based on the analyses in Introduction, cloud technology connects a network of virtualized computers that are dynamically provisioned as computing resources. Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider iteration. Although the development of cloud computing is still in the primary stage and relevant technology and schema are not mature, due to the advantages of cloud computing service, many companies are interested in cloud computing service. Then, how to help the company which is the user to select appropriate and adaptive cloud computing service is an important problem. In order to deal with this problem, the first step is to construct a cloud computing service adaptability evaluation system in Figure 1.

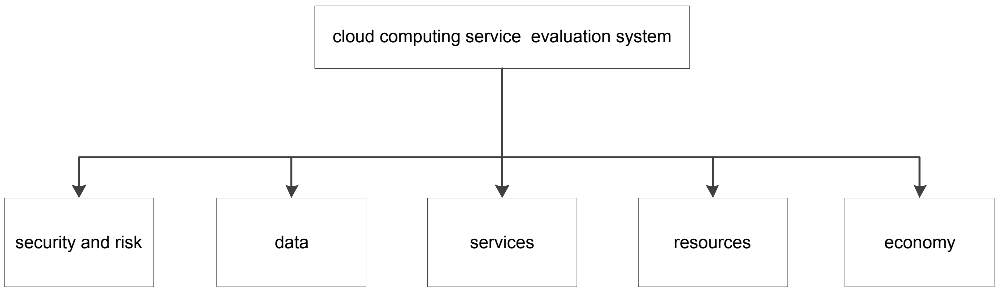

Figure 1: The attributes of cloud computing service evaluation system

In general, how to construct a scientific and rational evaluation system is a difficult task. There are some criteria that should be complied including objectivity, operability, systematic, the combination of qualitative and quantitative and so on. The mentioned five attributes including security and risk, data, services, resources, economy are also based on these criteria. These five attributes are the second level of evaluation system. They can be divided into many other sub-attributes in the third or fourth level. However, the purpose of this paper is to assess cloud computing service from the view of global level. Thus, the first level of attributes is enough to achieve this goal. Then, in the next section, we will introduce the proposed method and the procedure of the method in detail.

3. Multiple attribute decision making method

In this section, in order to evaluate the performance of cloud computing service evaluation system, we propose a new multiple attribute decision making method with intuitionistic fuzzy information.

3.1 Construction of the basic model

For an evaluation problem, the first step is to construct the decision matrix $D=[a_{ij}]_{m\times n}$, where all the arguments

a_{ij}(i=1,2,…m; j=1,2,…n) are intuitionistic fuzzy numbers provided by the decision maker. As for every alternative a_i(i=1,2,…m), the decision maker is invited to express assessment or preference based on each attribute c_j(j=1,2,…n) by a intuitionistic fuzzy number $a_{ij}=(u_{ij}, v_{ij})$(i=1,2,…m; j=1,2,…n), where u_{ij} indicates the hesitant degree that the decision maker considers what the alternative a_i should satisfy the attribute c_j, v_{ij} indicates the hesitant degree that expert e considers what the alternative a_i should not satisfy the attribute c_j.Then according to the mentioned above, a decision making matrix can be obtained in the following:

$$D=\begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & \cdots & \cdots & a_{mn} \end{pmatrix}$$

3.2 Hamacher t-conorm and t-norm

T-norm and t-conorm are widely applied in fuzzy context to define generalized intersection and union operations of fuzzy set.

Definition 8. Given a function T:[0,1]×[0,1]→[0,1], it is called a t-norm when it satisfies the following four constraints:

(1) $T(1, x) = x$, for all x;
(2) $T(x, y) = T(y, x)$, for all x and y;
(3) $T(x, T(y, z)) = T(T(x, y), z)$, for all x, y, and z; and
(4) If $x \le x_1$ and $y \le y_1$, then $T(x, y) \le T(x_1, y_1)$.

Definition 9. Given a function S:[0,1]×[0,1]→[0,1], it is called a t-conorm when it satisfies the following four constraints:

(1) $S(0, x) = x$, for all x;
(2) $S(x, y) = S(y, x)$, for all x and y;
(3) $S(x, S(y, z)) = S(S(x, y), z)$, for all x, y, and z;
(4) If $x \le x_1$ and $y \le y_1$, then $S(x, y) \le S(x_1, y_1)$.

A strict Archimedean t-norm $T(x, y) = p^{-1}(p(x) + p(y))$ can be created from a strictly decreasing function $p:[0,1]\rightarrow[0,+\infty]$ such that $p(1) = 0$, whose dual function $q(x) = p(1-x)$ can be used to construct a strict Archimedean t-conorm $S(x, y) = q^{-1}(q(x) + q(y))$.

Given a specific $p(x)$, i.e.,

$$p(x) = \log\left(\frac{r+(1-r)x}{x}\right),\ r > 0, \tag{5}$$

It is clear that

$$q(x) = p(1-x) = \log\left(\frac{r+(1-r)\cdot(1-x)}{1-x}\right). \tag{6}$$

Under this condition, strict Archimedean t-norm and t-conorm are called Hamacher t-norm $T_r(x, y)$ and t-conorm $S_r(x, y)$, which are calculated by

$$T_r(x,y)=\frac{xy}{r-(r-1)\cdot(x+y-xy)} \text{ and} \tag{7}$$

$$S_r(x,y)=\frac{x+y+(r-2)xy}{1+(r-1)xy},\ r>0. \tag{8}$$

$T_r(x, y)$ and $S_r(x, y)$ are also called Hamacher product $\otimes$ and Hamacher sum $\oplus$. Specifically, $T_r(x, y)$ and $S_r(x, y)$ reduce to algebraic t-norm and t-conorm when $r = 1$; while they become Einstein t-norm and t-conorm when $r = 2$ (Liu. 2014).

Then, based on the mentioned analysis, we can obtain the Hamacher arithmetic weighted averaging operator of intuitionistic fuzzy numbers as below:

IFHWA(a_1, a_2,. . ., a_n) = = $w_1a_{i1} \oplus w_2a_{i2} \oplus \ldots \oplus w_na_{in}$ =

($q^{-1}(\sum_{j=1}^{n} w_j q(a_{ij}))$, $p^{-1}(\sum_{j=1}^{n} w_j p(a_{ij}))$) =

$$\left(\frac{\prod_{j=1}^{n}(1+(r-1)a_{ij})^{w_j}-\prod_{j=1}^{n}(1-a_{ij})^{w_j}}{\prod_{j=1}^{n}(1+(r-1)a_{ij)})^{w_j}+(r-1)\prod_{j=1}^{n}(1-a_{ij})^{w_j}},\frac{r\prod_{j=1}^{n}(a_{ij})^{w_j}}{\prod_{j=1}^{n}(1+(r-1)(1-a_{ij}))^{w_j}+(r-1)\prod_{j=1}^{n}(a_{ij})^{w_j}}\right). \tag{9}$$

3.3 The process of the multiple attribute decision making method

In this section, the process of the proposed method is demonstrated as below in order to help the decision maker obtain the optimal decision.

Step 1. The decision makers give their assessments of alternative $a_i(i=1,2,\ldots m)$ with respect to attribute $c_i(i=1,2,\ldots n)$, which are expressed by intuitionistic fuzzy numbers $a_{ij}(i=1,2,\ldots m;\ j=1,2,\ldots n)$. In addition, the intuitionistic fuzzy decision making matrix should be transformed into normalized matrix.

Step 2. The decision maker specifies the subject weights of attributes according to his knowledge, experience and provided information.

Step 3. For alternative a_i, all the intuitionistic fuzzy numbers should be aggregated into a global value by means of the intuitionistic fuzzy Hamacher weighted average (IFHWA) operator.

Step 4. Then, the scores and accuracy of the global intuitionistic fuzzy number can be calculated in accordance with Definition 7.

Step 5. Rank all the alternatives $a_i(i=1,2,\ldots m)$ and select the optimal alternative according to the scores and accuracy.

Step 6. End.

4. Illustrative example

In this section, the proposed multiple attribute decision making method is applied in a real case to verify applicability and availability of the proposed method.

Firstly, the decision maker is invited to select an optimal cloud computing service of a company from alternatives A_1, A_2, A_3 and A_4 on the attributes C_1, C_2, C_3, C_4 and C_5 including security and risk, data, services, resources, economy illustrated in Figure 1. Then, the decision maker gives the assessments of each alternative on each attribute in Table 1.

Table 1: Original intuitionistic fuzzy decision matrix

	C_1	C_2	C_3	C_4	C_5
A_1	(0.2,0.6)	(0.5,0.5)	(0.8,0.1)	(0.4,0.6)	(0.6,0.3)
A_2	(0.4,0.5)	(0.6,0.3)	(0.4,0.4)	(0.5,0.3)	(0.7,0.1)
A_3	(0.8,0.2)	(0.7,0.2)	(0.9,0.1)	(0.5,0.4)	(0.3,0.6)
A_4	(0.7,0.2)	(0.5,0.4)	(0.3,0.5)	(0.1,0.7)	(0.4,0.6)

Then, after obtaining the decision matrix, the decision maker specifies the subject weights of attributes denoted as w_i = {0.15, 0.2, 0.35, 0.2, 0.1}. Based on the Step 4 and Step 5 in Section 3.3, the decision result of this selection problem is acquired in Table 2. Here, the proposed operator and score or accuracy function are applied. So, the alternative A_4 should be selected as the optimal cloud computing service in the company. In this process, the proposed method is very useful for company to make this decision and can be extended into group decision making in the future.

Table 2: Ranking order of all alternatives

	rank
A_1	2
A_2	3
A_3	1
A_4	4

5. Conclusion

Clouds are next-generation data-storage and computing systems with virtualization as the core, enabling technology to interconnect and manage distributed computers where resources and dynamically provisioned on demand as a personalized inventory to meets a specific service level agreement. Now, although cloud computing service achieved some success with the development to the deepening of the application, owing to security, technology, management, and other constraints, not all businesses are suitable for the use of this service model, so the business need consider their own actual situation and select a method to make effective evaluation of the comprehensive capacity of the cloud computing services. Thus, in this paper, cloud computing service is analyzed from security and risk, data, services, resources, economic dimensions and then introduce a new multiple attribute decision making method to assess cloud computing service where a cloud computing service adaptability evaluation system is constructed. Finally, the proposed method is applied in an illustrative example to demonstrate its applicability and validity.

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