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Abstract.Many organizations are seeking to contract services from cloud computing with many cloud services available and numerous criteria that should be counted in the selection process. Therefore, the selection process of cloud services can be considered as a type of multi-criteria decision analysis problems with multiples stakeholders. In this paper a framework for selecting cloud services taking into account consensus and using single valued neutrosophic numbers for indeterminacy representation is presented.The proposed framework is composed of five activities: framework, gathering parameters, eliciting preferences, computing consensus degree, advice generation, rating alternatives and cloud service selection. The model includes automatic search mechanisms for conflict areas and recommendations to the experts to bring closer their preferences.An illustrative example that corroborates the applicability of the model is presented.The paper ends with conclusion and further areas or research recommendations.

Keywords: Decision Analysis, SVN Numbers, Cloud Service, Consensus.

1 Introduction

Cloud Computing is experiencing a strong adoption in the market and this trend is expected to continue [1]. Due to the diversity of cloud service providers, it is a very significant defy for organizations to select the appropriate cloud services which can fulfil requirements, as numerous criteria should be counted in the selection process of cloud services and diverse stakeholders are involved. Therefore, the selection process of cloud services can be considered as a type of multi-criteria multi-expert decision analysis problems [2, 3]. In this research paper, we present how to aid a decision maker to evaluate different cloud services by providing a neutrosophic multi-criteria decision analysis including a consensus process. To demonstrate the pertinence of the proposed model and illustrative example is presented.

Neutrosophy is mathematical theory developed by Florentín Smarandache for dealing with indeterminacy[4-6]. It has been the base for developing of new methods to handle indeterminate and inconsistent information like neutrosophic sets and neutrosophic logic, especiallyused on decision making problems [6-8] . Because of the imprecise nature of the linguistic assessments new techniques have been developed. Single valued neutrosophic sets (SVNS) [9] for handling indeterminate and inconsistent information is a relatively new approach.In this paper a new model for cloud service selection is developed based on single valued neutrosophic numbers (SVN-number) allowing the use of linguistic variables [10, 11]. Group decision support and complex systems modelling makes recommendable to develop a consensus process [12-14]. Consensus is defined as a state of agreement among members of a group. A consensus reaching process is iterative process comprising several rounds where the experts adapt their preferences [13].

This paper is structured as follows: Section 2 reviews some preliminaries concepts about neutrosophic decision analysis and consensus process. In Section 3, a framework for selecting cloud computing services based on single valued neutrosophic numbers and consensus process is presented. Section 4 shows an illustrative example of the proposed model. The paper ends with conclusions and further work recommendations.

2 Preliminaries

In this section, we first provide a brief revision of neutrosophic multicriteria decision analysis, consensus process and cloud computing.

2.1Neutrosophic multicriteria decision analysis

Fuzzy logic was initiallyproposedby Zadeh [15], for helping in modeling knowledge in a more natural way. The basic idea is the notion of the membership relation which takes truth values in the interval [0, 1] [16].
The intuitionistic fuzzy set(IFS) on a universe was introduced by K. Atanassov as a generalization of fuzzy sets [17, 18]. In IFS besides the degree of membership ($\mu_A(x) \in [0,1]$) of each element $x \in X$ to a set A there was considered a degree of non-membership $\nu_A(x) \in [0,1]$, such that:

$$\forall x \in X \mu_A(x) + \nu_A(x) \leq 1 \qquad (1)$$

Neutrosophic set (NS) introduced the degree of indeterminacy (i) as independent component [6, 19].
The truth value in neutrosophic set is as follows [20, 21]:
Let N be a set defined as: $N = \{(T, I, F) : T, I, F \subseteq [0,1]\}$, a neutrosophic valuation n is a mapping from the set of propositional formulas to N , that is for each sentence p we have $v(\mathbf{p}) = (T, I, F)$.
Single valued neutrosophic set (SVNS) [9] was developed to facilitate real world applications ofneutrosophic set and set-theoretic operators. A single valued neutrosophic set is a special case of neutrosophic set proposed as a generalization of intuitionistic fuzzy sets in order to deal with incomplete information [10].
Single valued neutrosophic numbers (SVN number) are denoted by $A=(a,b,c)$, where $a,b,c \in [0,1]$ and $a+b+c \leq 3$[22] . In real world problems, sometimes we can use linguistic terms such as ‘good ’, ‘bad ’ to obtain preferences aboutan alternativeand cannot use some numbers to express some qualitative information [23, 24].Some classical multicriteria decision models[25, 26] have been adapted to neutrosophic for exampleAHP[27], TOPSIS[28] and DEMATEL [29].

2.2 Consensus reaching process

Consensus is an active area of research in fields such as group decision making and learning [30, 31]. A consensus reaching process is defined as a dynamic and iterative process composed by several rounds where the experts express, discuss, and modify their opinions or preferences[13, 32]. The process is generally supervised by a moderator (Fig. 1), who helps the experts to make their preferences closer to each other’s.

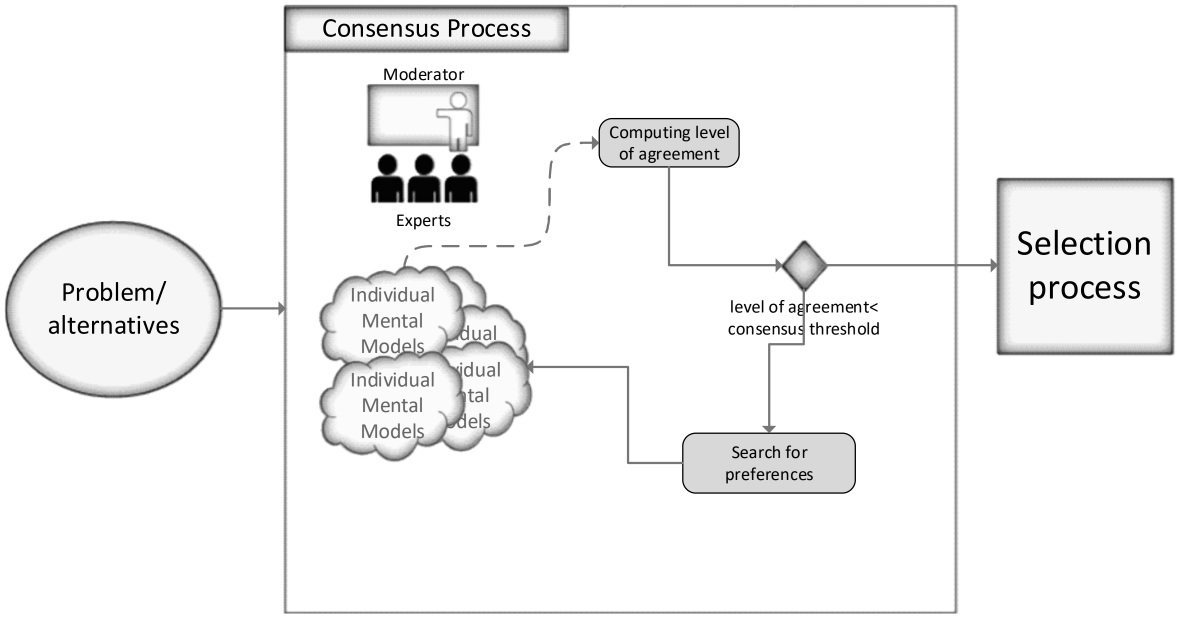

Figure1. Phases of the consensus process supervised by the moderator [32].

A frequent approach to consensus modeling involves the aggregation of preferences and the computing of individual differences with that value[33]. In each round the moderator helps to make closer the opinions with discussions and advices to experts to change preferences in case [12]. A consensus previous to group decision making allows the discussion and change of preferences helping to reach a state of agreement satisfying experts. Consensual points of view obtained from this process provide a stable base for decisions making[31].

2.3 Cloud computing services

Cloud computing has emerged as a paradigm to deliver on demand resources like infrastructure, platform, software, among others,to customers similar to other utilities. Traditionally, small and medium enterprises (SMEs) had to make high capital investment for procuring IT/software infrastructure, skilled developers and system administrators, which results in a high cost of ownership. Cloud computing aims to deliver virtual services so that users can access them from anywhere in the world on subscription at competitive costs for SMEs [34]..
Due to the fast expansion of cloud computing, many cloud services have been developed [35]. Therefore, given the diversity of Cloud service offerings, an important challenge for customers is to discover who are the ''right'' Cloud providers that can satisfy their requirements. Numerous criteria should be counted in the selection process of cloud services and various stakeholders are involved. Consequently, the selection process of cloud services can be considered as a type of multi-criteria multi-expert decision analysis problems [2, 3].

3 Proposed framework.

Our aim is to develop a framework for cloud service provider selection based on a consensus process. The model consists of the following phases (fig. 2).

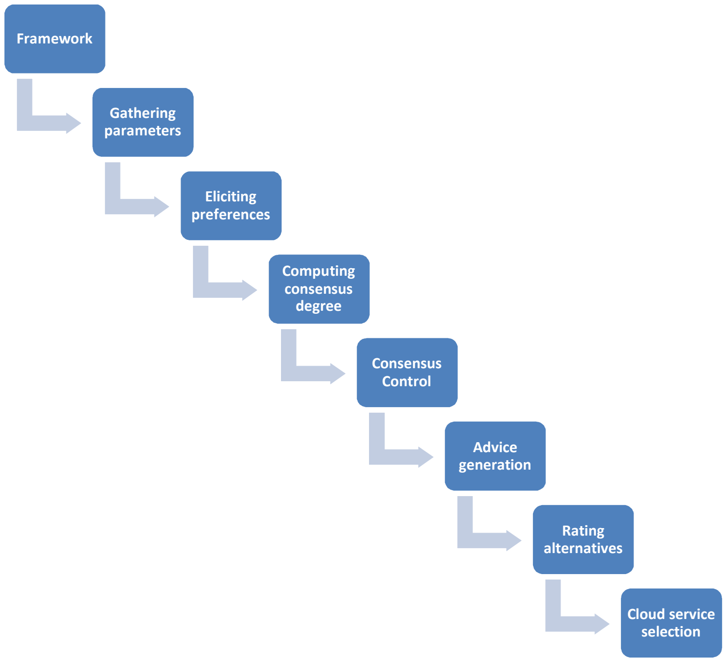

Figure 2: A framework for cloud serivece selection.

The proposed framework is composed of five activities:

- Framework
- Gathering parameters
- Eliciting preferences
- Computing consensus degree
- Advice generation
- Rating alternatives
- Cloud service selection.

Following, the proposed decision method is described in further detail, showing the operation of each phase

1. Framework: In this phase, the evaluation framework, for the decision problem of cloud serviceselection is defined. The framework is established as follows:

- C=$\{c_1, c_2, \ldots, c_n\}$ with $n \geq 2$, a set of criteria.
- E=$\{e_1, e_2, \ldots, e_k\}$ with $k \geq 2$, a set of experts.
- $X = \{x_1, x_2, \ldots, x_m\}$ with $m \geq 2$, a finite set of information technologies cloud services alternatives.

Criteria and experts might be grouped. The set of experts will provide the assessments of the decision problem. Main criteria for cloud service selection are visually summarizes as follows.

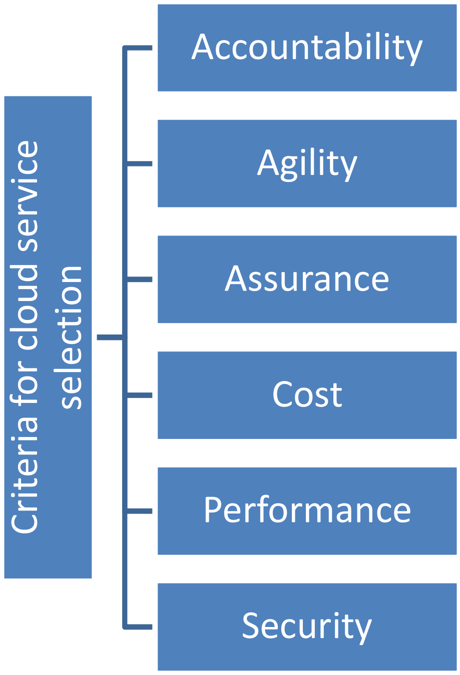

Figure 3. Cloud service selection criteria.

2. Gathering parameters: The granularity of the linguistic term is selected. Parameters are gathered for controlling the consensus process: consensus threshold $\mu \in [0,1]$ and $MAXROUND \in \mathbb{N}$ to limit the maximum number of discussion rounds. Acceptability threshold $\varepsilon \geq 0$, to allow a margin of acceptability for prevents generating unnecessary recommendations is also gathered.

3. Eliciting preferences: for each expert his /her preference is gathered using the linguistic term set chosen. In this phase, each expert, $e_k$provides the assessments by means of assessment vectors:
$U^K = (v_i^k, i = 1, .., n, j = 1, .., m)$ (2)
The assessmentv_i^k, provided by each experte_k, for each criterion c_i of each cloud service alternativex_j, is expressed using SVN numbers.

4. Computing consensus degree: The degree of collective agreement is computed in [0,1].
For each pair of experts e_k, e_t, $(k < t)$, a similarity[36, 37] vector $SM_{kt} = (sm_i^{kt})$, $sm_i^{kt} \in [0,1]$, is computed:

$$\mathrm{sm}_i^{kt} = 1 - \left(\frac{1}{3}\sum_{j=1}^{n}\left\{\left(\left|t_i^k - t_i^t\right|\right)^2 + \left(\left|i_i^k - i_i^t\right|\right)^2 + \left(\left|f_i^k - f_i^t\right|\right)^2\right\}\right)^{\frac{1}{2}} \quad (3)$$

$(i = 1,2, \ldots, m)$

A consensus vector $CM = (cm_i)$ is obtained by aggregating similarity values:

$$cm_i = OAG_1(SIM_i) \quad (4)$$

where $OAG_1$is an aggregationoperator, $SIM_i = \{sm_i^{12}, \ldots, sm_i^{1m}, \ldots, sm_i^{(m-1)m}\}$ represents all pairs of experts' similarities in their opinion on preference between (v_i, v_j) and cm_i is the degree of consensus achieved by the group in their opinion.

Finally, an overall consensus degree is computed:

$$cg = \frac{\sum_{i=1}^{n} cv_i}{n} \quad (5)$$

5. Consensus Control: Consensus degree cg is compared with the consensus threshold (μ). If $cg \geq \mu$, the consensus process ends; otherwise, the process requires additional discussion. The number of rounds is compared with parameter $MAXROUND$ to limit the maximum number of discussion rounds.

6. Advice generation: When $cg < \mu$, experts must modify the preferences relations to make their preferencescloser to each other and increase the consensus degree in the following round. Advice generation begin computing a collective preferences W^c. This collective preference model is computed aggregating each experts'preference vector:

$$w_i^c = OAG_2(v_1^1, \ldots, v_i^m) \quad (6)$$

where $v \in U$ and $OAG_2$is anaggregation operator.

After that, a proximity vector (PP^k) between each one of the $e_k$experts and W^c is obtained.Proximity values, $pp_{ij}^k \in [0,1]$ are computed as follows:

$$pp_i^k = 1 - \left(\frac{1}{3}\sum_{j=1}^{n}\left\{\left(\left|t_i{}^k\text{-}t_i^c\right|\right)^2+\left(\left|i_i{}^k\text{-}i_i^c\right|\right)^2+\left(\left|f_i{}^k\text{-}f_i{}^c\right|\right)^2\right\}\right)^{\frac{1}{2}} \quad (7)$$

Afterwards, preferences relations to change (CC) are identified. preference relation between criteriac_i andc_j with consensus degree under the defined (μ) are identified:

$$CC = \{w_i^c | cm_i < \mu\} \quad (8)$$

Later, based on CC, those experts who should change preference are identified. To compute an average proximity pp_i^A , proximity measures are aggregate

$$pp_i^A = OAG_2(pp_i^1, \ldots, pp_i^m) \quad (9)$$

where OAG_2 is a SVN aggregation operator.

Experts e_k whose $pp_i^k < pp_i^A$ are advised to modify their preference relation $w_i{}^k$.

Finally direction rules are checked to suggest the direction of changes proposed. Threshold$\varepsilon \geq 0$is established to prevents generating an excessive number of unnecessary advice .

DR 1: If $v_i^k - w_i^c < -\varepsilon$then e_k should increase his/her the value of preference relation v_i.

DR 2: If $v_i^k - w_i^c > \varepsilon$ then e_k should decrease his/her the value of preference relation v_i.

DR 3: If$-\varepsilon \leq v_i^k - w_i^c \leq \varepsilon$ then e_k should not modify his/her the value of preference relation v_i.

Step from3-6 are repeated until consensus reachedor maximum number of rounds.

7. Rating alternatives: The aim of this phase is to obtain a global assessment for each alternative. Taking into account the previous phase, an assessment for each alternative is computed, using the selected solving process that allows managing the information expressed in the decision framework.

In this case alternatives are rated according to single valued neutrosophic weighted averaging (SVNWA) aggregation operator as proposed by Ye [38] for SVNSs as follows[10]:

$$F_w(A_1, A_2, \dots, A_n) = \langle 1 - \prod_{j=1}^{n}\left(1 - T_{A_j}(x)\right)^{w_j}, \prod_{j=1}^{n}\left(I_{A_j}(x)\right)^{w_j}, \prod_{j=1}^{n}\left(F_{A_j}(x)\right)^{w_j}\rangle \qquad)$$

where $W = (w_1, w_1, \dots, w_n)$ is the weighting vector of$A_j (j = 1, 2, \dots, n)$, $w_n \in [0, 1]$and $\sum_j^n w_j = 1$.

8. Cloudserviceselection: In this phase of the alternatives are rankedand the most desirable one is chosen-by the score function [39, 40].According to the scoring and accuracy functions for SVN-sets, a ranking order of the set of the alternatives can be generated [41]. Selecting the option(s) with higher scores.

   For ordering alternatives a scoring function is used [42]:

   $$s(V_j) = 2 + T_j - F_j - I_j \qquad (11)$$

Additionally an accuracy function is defined:

$$a(V_j) = T_j - F_j \qquad (12)$$

And then

1. If $s(Vj) < s(Vi)$, then Vj is smaller thanVi, denoted by $Vj < Vi$
2. If$s(Vj) = s(Vi)$
   a. If $a(Vj) < a(Vi)$, then Vj is smaller than Vi, denoted by $Vj < Vi$
   b. If $a(Vj) = a(Vi)$, then Vj and Vi are the same, denoted by $Vj = Vi$

Another option is to use the scoring function proposed in[28]:

$$s(V_j) = (1 + T_j - 2F_j - I_j)/2 \qquad (13)$$

where $s(V_j) \in [-1,1]$.

If $s(Vj) < s(Vi)$, then Vj is smaller thanVi, denotedby $Vj < Vi$

According to the scoring function ranking method of SVN-sets, the ranking order of the set of cloud service alternatives can be generated and the best alternative can be determined.

4 Illustrative example

In this case study three experts $E = \{e_1, e_2, e_3\} (n = 3)$ are inquired about their preferences. A linguistic term sets with cardinality nine (Table 1) is used.

Linguistic terms	SVNSs
Extremely good (EG)	(1,0,0)
Very very good (VVG)	(0.9, 0.1, 0.1)
Very good (VG)	(0.8,0,15,0.20)
Good (G)	(0.70,0.25,0.30)
Medium good (MG)	(0.60,0.35,0.40)
Medium (M)	(0.50,0.50,0.50)
Medium bad (MB)	(0.40,0.65,0.60)
Bad (B)	(0.30,0.75,0.70)
Very bad (VB)	(0.20,0.85,0.80)
Very very bad (VVB)	(0.10,0.90,0.90)
Extremely bad (EB)	(0,1,1)

Table 1. Linguistic terms used to provide the assessments [28]

The scope of the consensus processis defined by five criteria $C = (c_1, \dots, c_5)$ shown in Table 2.

Node	Description
A	Accountability
B	Agility
C	Assurance
D	Cost
E	Performance
F	Security

Table 2. Criteria for Cloud service selection

Parameters used in this case study are shown in Table 3.

Consensus threshold	$\boldsymbol{\mu = 0.9}$
Maximum number of discussion rounds	$MAXROND = 10$
Acceptability threshold	$\varepsilon = 0.15$

Table 3. Parameters defined

Initially, the experts provide the following preferences.

	A	B	C	D	E
E1	G	M	B	G	B
E2	VG	VG	M	G	VB
E3	G	G	G	G	VG

Table 4. Preferences Round 1.

First round

Similarity vector are obtained
S^{12}=[0.9, 0.682, 0.782, 1,0.9]
S^{13}=[1, 0.782, 0.564, 1,0.465]
S^{23}= [0.9, 0.9, 0.782, 1, and 0.365]
The consensus vector CV=[0.933, 0.676, 0.79, 1, 0,577]

Finally, an overall consensus degree is computed:$cg = 0.795$

Because cg $= 0.795 < \mu = 0.9$ the advice generation is activated.

The collective preferences is calculated using the SVNWA operator giving in this case equal importance to each expertW^c =[(0.64, 0.246, 0.377),(0.591,0.303, 0.427), (0.437,0.492, 0.578), (0.62, 0.287,0.416), (0.428, 0.495, 0.587)]

Proximity vectors are calculated PP^k:
PP^1= [0.944, 0.68, 0.817, 0.916, 0.823]
PP^2= [0.852, 0.801, 0.942, 0.916, 0.632]
PP^3=[0.944,0.899, 0.739, 0.916, 0.632]

After that preference to change (CC) are identified (11).

$$CC = \{W_i | cv_i < 0.9\} = \{w_2, w_3, w_5\}$$

Average proximity for this value is computed as follows:

$(pp_2^A = 0.793, pp_3^A = 0.833, pp_5^A = 0.696)$

Proximity values for each expert in preferences $\{w_2, w_3, w_5\}$ is as follows:

$(pp_2^1 = 0.68, pp_3^1 = 0.817\ pp_5^1 = 0.823)$

$(pp_2^2 = 0.81, pp_3^2 = 0.942, pp_5^2 = 0.632))$

$(pp_2^3 = 0.899, pp_3^3 = 0.739, pp_5^3 = 0.632)$

The sets of preferences to change ($pp_i^k < pp_i^A$) are:

$$\{v_2^1, v_3^1, v_5^2, v_3^3, v_5^3\}$$

According to rule DR1, the experts are required to increase the following relations:

$$\{v_3^1, v_5^2\}$$

According to rule DR2, the experts are required to decrease the following relations:

$$\{v_3^3, v_5^3\}$$

And According to rule DR3 this relations should not be changed:

$$\{v_2^1\}$$

Second Round

According to the previous advices, the experts implemented changes, and the new elicited preferences

	A	B	C	D	E
E1	G	M	M	G	B
E2	VG	VG	M	G	B
E3	G	G	M	G	B

Table 4. Preferences Round 2.

Similarity vector are obtained again:

S^{12}=[0.9, 0.682, 1, 1,1]

S^{13}=[1, 0.782, 1, 1,1]

S^{23}=[0.9, 0.9, 1, 1,1]

The consensus vector CV=[0.933, 0.676, 1, 1, 1]

Finally, an overall consensus degree is computed:

$$cg = 0.922$$

Because cg=0.93>$\mu = 0.9$ the desired level of consensus is achieved.

5 Conclusions.

The fast expansion of cloud computinghas caused the development of many cloud services. Given the diversity of cloud service offerings, an important challenge for customers is to discover who are the ‘‘right’’ cloud providers that can satisfy their requirements with numerous criteria that should be counted in the selection process and diverse stakeholders involved. Therefore, the selection process of cloud services can be considered as a type of multi-criteria multi-expert decision analysis problems.A consensus process allows developing a better group decision process.

Recently, neutrosophic sets and its application to multiple attribute decision making have become a topic of great importance for researchers and practitioners alike. In this paper a new framework for selecting cloud services taking into account consensus and using single valued neutrosophic numbers for indeterminacy representation is presented.

The proposed framework is composed of five activities: framework, gathering parameters, eliciting preferences, computing consensus degree, advice generation, rating alternatives and cloud service selection. The model includes automatic search mechanisms for conflict areas and recommendations to the experts to bring closer their preferences. To demonstrate the applicability of the proposed model and illustrative example ispresented.

Further works will concentrate in extending the model for dealing with heterogeneous information and the development of a software tool. New measures of consensus based on neutrosophic theory will be additionally developed.

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