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Design of Fuzzy Rule Base for Trust Model Optimizing the Cloud Services

Jaishree S
PG Student, Computer Science and Engineering
Bharath Institute of Science and Technology
Chennai, India

Dr. Kumaravel A
Dean, Computer Science and Engineering
Bharath Institute of Science and Technology
Chennai, India

Abstract

Cloud computing with its inherent advantages draws attention for business critical applications, but high level of trust is concurrently expected in cloud service providers. The evaluation of the trustworthiness is a challenge in current research. We contribute to this field by providing a novel model for the evaluation of propositional logic terms under uncertainty that is compliant with the subjective logic. The model uses the concept of fuzzy logic to add fuzziness with certainty and average rating to calculate the trustworthiness more accurately. We represent the trustworthiness of evidence value using Fuzzy Associative Memory (FAM).

Keywords-*Cloud; Trust; Uncertainty; Certain trust; Fuzzy Logic; FAM rule.*

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1. Introduction

Cloud computing has been recognised as an important new paradigm to support small and medium size businesses and general IT applications. The main advantage of Cloud computing is access to several services. However, despite the advantages and rapid growth of Cloud computing, it brings several security, privacy and trust issues that need immediate action.

The issue of trust is also important for service providers to verify if the infrastructure providers maintain their agreements during service deployment.

The main goal is to design a trust model for optimizing the cloud services based on different aspects, namely *trust*, *risk*, *eco-efficiency*, and *cost*. This paper describes a trust model to support service providers (SP) to verify trustworthiness of infrastructure providers (IP) during deployment and operational phases of the services supplied by the service providers

The aim of the Service Provider (SP) is to offer efficient services to its customers using resources of the Infrastructure Provider (IP). The IP aims to maximize its profit by efficient use of its infrastructure resources ensuring that it provides good service to the SP and meeting all its requirements. The trust framework is active during the two phases of service life cycle. The trustworthiness of the IP and the SP are monitored during these two phases of the service life cycle.

The trust model described in this paper calculates trust values based on three different parameters, namely (i) *compliance of SLA parameters* (e.g., when the IP fulfils the quality aspect specified in the SLA between an SP and the IP), (ii) *service and infrastructure providers satisfaction ratings* (e.g., when SP supplies a rating for the IP where the SP is being deployed), and (iii) *service and infrastructure provider behaviour* (e.g., if the SP continues to choose the same IP independent of the rating that it has supplied for the IP).

For each of the different parameters above, trust values are calculated based on Certain Logic [12].Our model is based on an extension of Trust Model [1], mainly the representation portion based on fuzzy logic.

2. Related Work

Following the day by day improvements of the internet of services, the future internet based on Cloud computing IT systems will become highly distributed, dynamically composed and will be hosted and managed by multiple parties. But it is sorry to say at present people, enterprises, officials, organizations and corporate farms are still hesitating and feeling less of security and safety to move to the Cloud [4-6]. The reasons behind this are missing transparency, security concerns. So, both the users and providers and accreditation authorities are interested in evaluating the trustworthiness of cloud services.

Trust is an important concept for cloud computing given the need for consumers in the cloud to select cost effective, trustworthy, and less risky services [2]. There is a lack of models that provide means for deriving the trustworthiness of the overall system considering (1) the trustworthiness of the subsystems and atomic components (independently from how these trust values are assessed), (2) the uncertainty associated to this information. For example, reputation values might be based on insufficient information and current solutions from the field of trusted computing cannot effectively capture dynamic changes in trust [3].

It is evident that the evaluation of the trustworthiness of complex systems is one of the major challenges in current IT research. Different trust models are now present in the world, which are dependent on uncertainty [7-11].

Although, there are researchers in the field of trust focusing on modelling (un-)certainty [9, 11, 13], they do not provide operators for the evaluation of propositional logic terms, except for subjective logic" [10, 11]. Furthermore, there are well-known approaches for modeling uncertainty outside the trust field. The probabilistic approach allows to deal with the uncertainty of the outcome of the next event, but it is assumed that probabilities are to be known.

Fuzzy logic [14] seems to be related, however, it models another type of uncertainty, which could be typed as linguistical uncertainty or fuzzyness.

There is the field of (Dempster-Shafer) belief theory, which again leads to subjective logic" [11]. The main drawback of this model is that the parameters for belief, disbelief, and uncertainty are dependent on each other, which introduces an unnecessary redundancy from the perspective of modeling and prevents one from re-assign just a single parameter.

Beyond subjective logic there are numerous other approaches for probabilistic reasoning, see e.g. [15]. However, as we argue for the mathematical validity of our model based on its compliance to subjective logic and the standard probabilistic approach, we do not provide a discussion of probabilistic reasoning in general.

[12] defines operators for AND, OR, and NOT for the evaluation of propositional logic terms under uncertainty and we give the properties of these operators. The operators have been designed to be compliant to the standard probabilistic approach and subjective logic [10, 11], which also provides the justification for the mathematical validity of the model.

3. Trust model

The SP verifies the trust of an IP using the opinion obtained from three different computations, namely (i)compliance of SLA parameters (SLA monitoring), (ii)service provider satisfaction ratings (SP ratings), and (iii)service provider behavior(SP behavior).

3.1 SLA Monitoring

The SLA monitoring determines the opinion about an IP from the SLAs that the IP have established with the SPs for their services. The SP for each of its service has a single SLA that includes several indicators. For each indicator of an SLA, there is an associated monitor that evaluates the compliance/non-compliance of the indicator.

3.2 SP Behavior

The SP behavior is defined in terms of the number of times the SP has used the infrastructure of an IP against the SPs total usage. An SP using a single IP for the majority of the times indicates the SPs good behavior towards an IP. The SP may use the infrastructure of an IP for one or more indicators specified in the SLA.

3.3 SP Ratings

The service provider satisfaction rating is calculated based on the rates of the services given by an SP using an IP and these ratings are used to form an opinion about an IP.

We use the following three parameters used in certain logic: average rating t, certainty c, initial expectation f. The average rating t indicates the degree to which past observations support the truth of the proposition. The certainty c indicates the degree to which the average rating is assumed to be representative for the future. The initial expectation f expresses the assumption about the truth of a proposition in absence of evidence.

The equations for these parameters are given below:-

- Equation for average rating,

$$t = \begin{cases} 0.5 \text{ if } r + s = 0 \\ r / (r + s) \text{ else} \end{cases} \quad \text{.... (1)}$$

Here, r represents number of positive evidence and s represents number of negative evidence defined by the users or third person review system.

- Equation for certainty,

$$c = \frac{N.(r + s)}{2.w.(N-(r + s))+N.(r + s)} \quad \text{.... (2)}$$

Here, w represents dispositional trust which influences how quickly the final trust value of an entity shifts from base trust value to the relative frequency of positive outcomes and N represents the maximum number of evidence for modeling trust. Using these parameters the expectation value of an opinion can be defined as follows:

- Expectation value of an opinion,

$$E(t,c,f) = t * c + (1-c) * f \quad \text{.... (3)}$$

The parameters for an opinion o = (t, c, f) can be assessed in the following two ways: direct access and Indirect access. Certain Trust evaluates the logical operators of propositional logic that is AND, OR and NOT. In this model these operators are defined in a way that they are compliant with the evaluation of propositional logic terms in the standard probabilistic approach. In order to combine the opinions, those operators will especially take care of the (un)certainty that is assigned to its input parameters and reflect this (un)certainty in the result.

With the help of these parameters and operators derived from certain trust, Trust T is calculated from certainty c and average rating t. the equation is:

$$\text{Trust, } T = \frac{c*t}{\text{Highscalingvalueofrating}} * 100\% \quad \text{.... (4)}$$

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Here, High scaling value of rating means the upper value of the range of rating.
Calculating T, we have applied FAM rule of fuzzy logic for creating a relation between certainty c and average rating t. Trust T represents this relation in percentage such a way that the quality of the product can easily be understood.

4. Evaluation

For evaluating our proposed model we consider that an SP hosts the application with its multiple components either at one IP or at multiple IPs. According to CTM's operators, we know that, the input for this model is r, s, f and w. We use MATLAB tool for designing our proposed trust model using fuzzy logic.

4.1 *Fuzzy Inputs*

In designing fuzzy inference system, it is easy to understand that membership functions are associated with term sets, which normally appears in the antecedent or consequent of rules. We have divided parameter certainty c into five categories according to its values in table I:-

Table I: Ranges of certainty

Class Name	Certainty Range Value	Symbols
Very Low	0.0-0.2	VLc
Low	0.1-0.4	Lc
Average	0.3-0.7	Avg.c
High	0.6-0.9	Hc
Very High	0.8-1.0	VHc

Following the same way, we have divided parameter average rating t into five categories according to its values shown in table II and fig.1 shows the fuzzy input and output sets.

Table II: Ranges of average rating

Class Name	Avg. Rating Range Value	Symbols
Very Low	1.0-2.0	VLt
Low	1.5-3.0	Lt
Average	2.0-4.0	Avg.t
High	3.0-4.5	Ht
Very High	4.25-5.0	VHt

4.2 *Inference Rules*

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made, or patterns discerned. According to our inputs, there are 25 rules designed for formulating the trust model as shown in table III and fig. 2

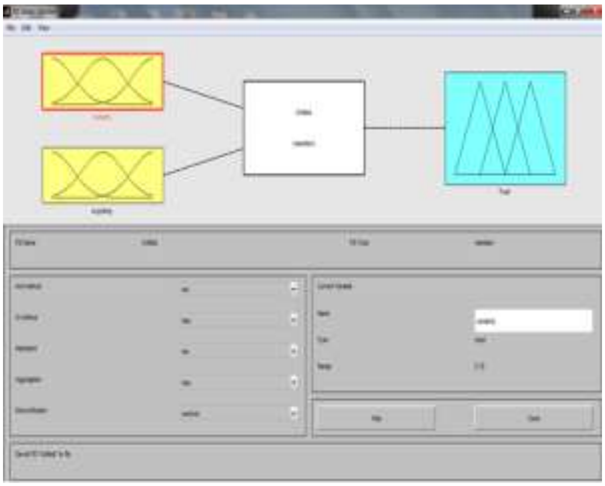

Figure 1. Fuzzy Inputs and Output

Table III: FAM for representing trust

c/t	VLt	Lt	Avgt	Ht	VHt
VLc	VLT	VLT	VLT	VLT	VLT
Lc	VLT	LT	LT	LT	LT
Avgc	VLT	LT	AvgT	AvgT	AvgT
Hc	VLT	AvgT	AvgT	HT	HT
VHc	VLT	AvgT	HT	HT	VHT

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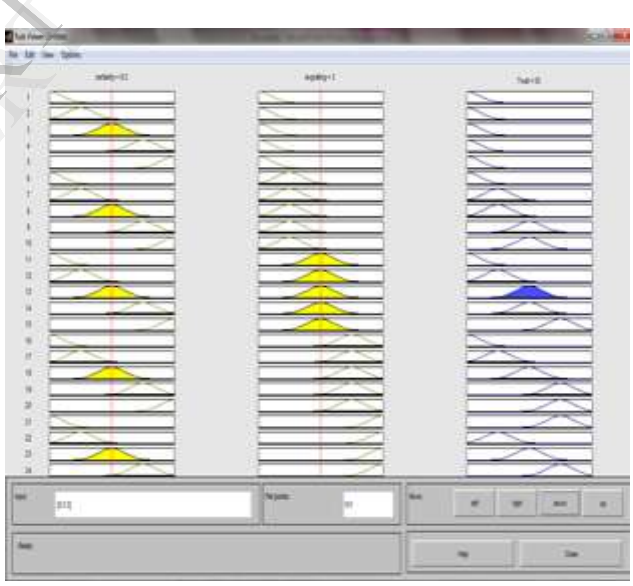

Figure 2. Rule View of Aggregating all outputs

4.3 *Fuzzy Outputs*

From the input fuzzy sets described above, passing those fuzzy sets through inference rules and fuzzy base rules, we get crisp values for our new parameter trust T. Plotting those values according to Gaussian membership function equation we have got the figure… for Trust T parameter. It can also be classified into five categories after finding out and plotting as shown in table IV and Fig 2.

Table IV: Ranges of output trust

Class Name	Trust Range Value	Symbols
Very Low	0%-20%	VLT
Low	10%-40%	LT
Average	30%-70%	Avg.T
High	60-90%	HT
Very High	80%-100%	VHT

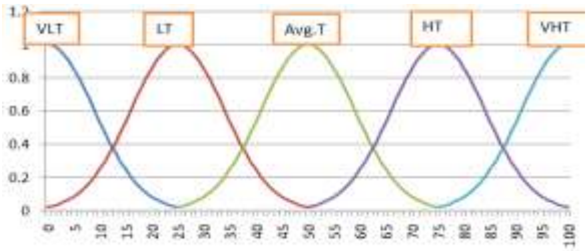

Figure 3. Membership Functions for Output Trust

4.4 *Mapping Surface*

In this map, we plot certainty, c and average rating, t and Trust, T. after plotting this, we get the following surface as shown in Fig. 4

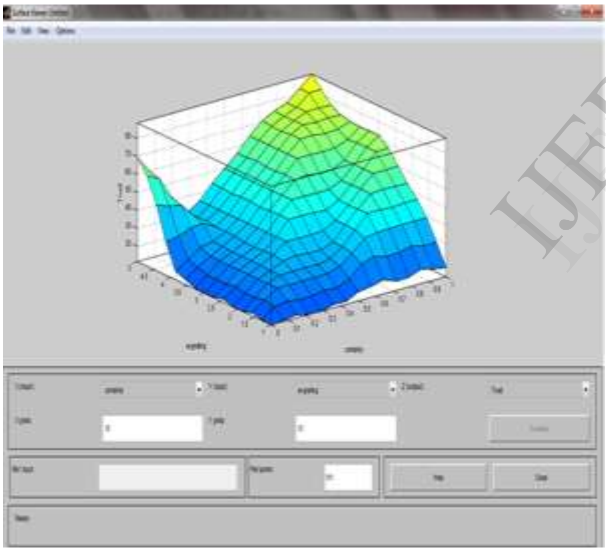

Figure 4. Surface View of Aggregating all outputs

A. SLA Monitoring

Let, each of the monitors associated with the indicators provides information about the compliance of the respective indicator for an IP. If we consider that monitors indicated 150 compliances and 10 non-compliance (150 positive evidence and 10 negative evidence) for IP, i.e., r=150, s=10, f=0.5 and w=1. Here, no of evidences are N=160.Then, the output values are:- t = 0.9313 and c=0.9413. Hence o_{SLA} = (0.9313, 0.9413, 0.5)

B. SP Behavior

Suppose that monitor associated with SP, records that SP have opted to use IP for 200 times against SP's 250 times total cpu usage. The opinion for the behavior of SP towards IP is calculated as: r=200, s=50, f=0.5 and w=1. Here, no of evidences are N=250.Then, the output values are:- t = 0.8 and c=0.9. Hence o_{SPB} = (0.8, 0.9, 0.5)

C. SP Ratings

Suppose that SP has provided 100 excellent and 5 worst ratings for each indicator. These ratings are transformed into 100 positive and 5 negative evidences for each of these indicators, as per the mapping described above. Based on the evidence of ratings for IP, the opinion that SP has about IP for its indicators is given as: t = 0.9523 and c=0.9623. Hence o_{SPR} = (0.9523, 0.9623, 0.5)

When combining the opinions, it is represented by using associative property as:

$(o_{SLA} \wedge o_{SPB}) \wedge o_{SPR} = o_{SLA} \wedge (o_{SPB} \wedge o_{SPR})$=(0.7052, 0.9093, 0.125)

Now, for mapping it to our proposed model, we need to modify t. Here,

t' = t*scale of rating

Usually, the scale of rating is 5. Now, the new average rating is t = 0.7052 = 3.526. Then, the value of parameter Trust, T = ((3.526*0.9093)/5)*100 = 64.12%. From fig…, we see that, it is an average situation of Trust.

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5. Conclusion and Future Work:

In this paper, we have proposed a new extension of representational model of certain trust for the evaluation of propositional logic terms, probability and fuzziness under uncertainty. It develops the representational model of the certain trust logic. Our proposed model is more expressive and useful than certain logic because it works both for machine and human beings.

The parameters of the proposed model directly show how much the infrastructure provider can be trusted by the service provider in cloud computing field. At present, this parameter works indirectly with security options. Last of all, we want to establish a newer trust model with a combination of certainty, fuzzy logic, evolutionary algorithm and so on for ubiquitous computing system.

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