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Towards pre-standardization of trust and reputation models for distributed and heterogeneous systems

Félix Gómez Mármol *, Gregorio Martínez Pérez

Departamento de Ingeniería de la Información y las Comunicaciones, University of Murcia, 30.071 Murcia, Spain

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ABSTRACT

Different trust and/or reputation models have arisen in the last few years. All of them have certain key processes in common such as scoring, ranking, rewarding, punishing or gathering behavioral information. However, there is not a standardization effort for these kinds of models. Such effort would be beneficial for distributed systems such as P2P, ad-hoc networks, multi-agent systems or Wireless Sensor Networks. In this paper we present a pre-standardization approach for trust and/or reputation models in distributed systems. A wide review of them has been carried out, extracting common properties and providing some pre-standardization recommendations. A global comparison has been done for the most relevant models against these conditions, and an interface proposal for trust and/or reputation models has been proposed.

1. Introduction

Designing an accurate and efficient trust and/or reputation model for distributed and heterogeneous environments is nowadays a research challenge. Different issues have to be taken into consideration when developing such models.

The problem to be solved here consists of deciding in a distributed environment which entity is the most reliable to interact with, in terms of confidence and reputation. That is, having a system where different entities offer some services or goods and other ones are requesting those services, the former will always look for the best self profit, while the latter will demand the best services with respect to some quality characteristics, properties or attributes.

Nevertheless, most of the times it is not feasible or realistic to assume the existence of service level agreements (SLA) or the presence of a centralized entity or architecture (such as a PKI), supplying reliable information regarding the actual and current behavior of every service provider in the system.

Hence, requesters have to determine on their own which service providers are the best ones according to certain criteria. Under these conditions, trust and/or reputation models are aimed to select the most trustworthy entity all over the system offering a certain service.

And although several authors have proposed different models in this way, there is a lack of standardization orientations when designing a trust and/or reputation model for distributed systems.

Many scenarios would benefit from the existence of some trust and/or reputation model standardization recommendations, such as P2P networks, multi-agent systems, ad-hoc networks, Wireless Sensor Networks, file-sharing systems, etc, since these scenarios already have standards in many other issues, but not in managing trust and/or reputation between different entities.

The rest of the paper is organized as follows: we present a review of the main existing trust and/or reputation models in Section 2. A classification of the studied models has been done in Section 3. Section 4 describes the components of a general trust and/or reputation model and gives some designing recommendations that might be considered as part of a pre-standardization approach. Finally, Section 5 exposes some conclusions and future work to be done towards pre-standardization of trust and/or reputation models.

2. Analysis of main trust and reputation models

Different trust and reputation model proposals have been suggested recently. In this section we will describe the most representative ones, exposing their main characteristics. Our intention will consist of extracting certain common features from them and providing a set of recommendations for a pre-standardization process.

2.1. Multi-agent system models

Multi-agent systems are supposed to reflect the collective behavior of human societies, since intelligent agents aim to represent human reasoning and behavior in electronic communities.

In such systems, individuals may collaboratively decide who to interact with, forming thus a social network which improves the quality of the decisions to be made.

Several trust and/or reputation models have been developed in this field in order to achieve those goals.

* Corresponding author. Tel.: +34 868 88 78 66; fax: +34 868 88 41 51.
E-mail addresses: felixgm@um.es (F. Gómez Mármol), gregorio@um.es (G. Martínez Pérez).

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2.1.1. Sporas

In [44], for instance, authors suggest *Sporas* as a reputation mechanism in agent systems where the reputation is computed recursively and where the more recent a rating is, the more weight it has.

Thus, the reputation rating at time i, R_i, is obtained recursively from the previous reputation R_{i-1} and the purchase rating W_i as

$$R_i = R_{i-1} + \frac{1}{\theta} \cdot \Phi(R_{i-1}) \cdot (W_i - R_{i-1}).$$

Where θ is the effective number of ratings taken into account in an evaluation ($\theta > 1$), W_i represents a rating given by user i, and function Φ is defined in order to slow down the incremental changes for very reputable users as follows:

$$\Phi(R_{i-1}) = 1 - \frac{1}{1 + e^{\frac{-(R_{i-1}-D)}{\sigma}}}.$$

Where D is the maximum possible reputation value and σ is the acceleration factor of the damping function Φ. Hence, the smaller the value of σ, the steeper the damping factor $\Phi(R)$.

2.1.2. Regret

The model proposed in [30], called *Regret* (one of the most representative trust and reputation models in multi-agent systems), manages the reputation from three different dimensions: the individual one, given from direct interactions with the agent; the social one, from previous experiences of group members with the agent and its acquaintances; and the ontological one, given by the combination of multiple aspects in order to build a reputation about complex concepts.

Authors define $\iota = (a, b, o, \varphi, t, W)$ as the impression of agent a about outcome o of agent b for a certain subject φ at time t, being $W \in [-1, 1]$ the subjective opinion of a.

Thus, an individual reputation at time t from agent a's point of view and satisfying pattern p, $R^t(IDB_p^a)$, is computed as

$$R^t\left(IDB_p^a\right) = \sum_{\iota_j \in IDB_p^a} \rho(t, t_i) \cdot W_i$$

where IDB_p^a is agent a's impressions database satisfying the pattern p, $\rho(t, t_i) = \frac{f(t_i, t)}{\sum_{\iota_j \in IDB_p^a} f(t_j, t)}$, and $f(t_i, t)$ is a time dependent function that gives higher values to values closer to t.

The social reputation of agent b's group, $\mathcal{B}$, from the point of view of agent a, about subject φ at current time, $R_{a \to \mathcal{B}}(\varphi)$, is

$$R_{a \to \mathcal{B}}(\varphi) = \sum_{b_i \in \mathcal{B}} \omega^{ab_i} \cdot R_{a \to b_i}(\varphi)$$

where $\sum_{b_i \in \mathcal{B}} \omega^{ab_i} = 1$. Social reputations $R_{\mathcal{A} \to b}$ and $R_{\mathcal{A} \to \mathcal{B}}$ are also computed in a similar way. And finally, a reputation measure that combines both individual reputation and social one is defined as follows:

$$SR_{a \to b}(\varphi) = \xi_{ab} \cdot R_{a \to b}(\varphi) + \xi_{a\mathcal{B}} \cdot R_{a \to \mathcal{B}}(\varphi) + \xi_{\mathcal{A}b} \cdot R_{\mathcal{A} \to b}(\varphi) + \xi_{\mathcal{A}\mathcal{B}} \cdot R_{\mathcal{A} \to \mathcal{B}}(\varphi)$$

where $\xi_{ab} + \xi_{a\mathcal{B}} + \xi_{\mathcal{A}b} + \xi_{\mathcal{A}\mathcal{B}} = 1$.

At last, being $C_\varphi = children(\varphi)$, the reputation of node φ in an ontological graph is defined as

$$OR_{a \to b}(\varphi) = \begin{cases} \sum_{\phi \in C_\varphi} w_{ij} \cdot OR_{a \to b}(\phi) & \text{if } C_\varphi \neq \varnothing \\ SR_{a \to b}(\varphi) & \text{otherwise.} \end{cases}$$

2.1.3. AFRAS

Authors of *AFRAS* [7] propose a reputation mechanism in multi-agent systems whose main characteristic is the modelling of an agent reputation and the interaction rating as fuzzy sets.

Thus, the reputation fuzzy set of an agent at time i, R_i, is computed from the i-th satisfaction fuzzy set, S_i, as follows:

$$R_i = R_{i-1} \cdot W_2 + S_i \cdot W_1$$

where W_1 and W_2 weights determine how much the last reputation value, R_{i-1}, and the satisfaction, S_i, respectively contribute; and both are defined from a sole weight $W \in [0, 1]$ as follows:

$$W_1 = 1 - \frac{W}{2} \; W_2 = \frac{W}{2}$$

So, the reputation R_i can be expressed as

$$R_i = R_{i-1} + \frac{(S_i - R_{i-1}) \cdot (1 - W)}{2} = R_{i-1} + \frac{(S_i - R_{i-1}) \cdot (1 - \rho_i)}{2}$$

where ρ_i may be understood as a function based on historic transactions indicating the weight of past reputation values at time i, and can be recursively computed as follows

$$\rho_i = \frac{\rho_{i-1} + \Delta(R_{i-1}, S_i)}{2}$$

where $\Delta(R_{i-1}, S_i) \in [0, 1]$ measures the similarity between the two fuzzy sets R_{i-1} and S_i. Having this, we can deduce that, if the prediction was right (i.e. $\Delta \approx 1$), then memory at time i, ρ_i, is increased by $1/2 + \rho_{i-1}/2$. Otherwise ($\Delta \approx 0$), the memory at time i is halved.

2.1.4. MTrust

In MTrust [33], authors use a Bayesian network in order to compute the trust value among entities in the network. It is focused on a mobile agent system, where the cooperative interactions among these agents and their respective visited hosts is ensured.

Therefore, $T^M_{O_i^T \to vh_l} \in [0, 1]$ is defined as a trust value between a truster owner of agents O_i^T (that is, a node who generates a set of mobile agents $A^{O_i} = ma_1^{O_i}, \ldots, ma_j^{O_i}$) and a visited host vh_l, computed using a method from set M, where $M \in \{$predefined trust value, general trust value, Feedback Aggregation method for inexperienced truster (FA_{IN}), Feedback Aggregation method for experienced truster (FA_{EX}), Bayesian Network (BN), a combination of FA_{EX} and $BN\}$.

A predefined trust value is a trust value deduced from a truster's behavior. A general trust value is computed from an averaging of all trustees' trust values. If a BN is used, every owner develops a simple BN model which is updated with every received feedback.

FA_{IN}: A truster computes each trustee's reputation perceived by each rater O_i^R as an expectation of beta distribution as follows

$$Rep_{O_i^R \to vh_l} = \frac{\alpha}{\alpha + \beta}$$

where $\alpha = N_P + 1$, $\beta = N_N + 1$ and N_P and N_N are the number of positive and negative consistent feedbacks, respectively. A general form of a trustee's trust value is presented next:

$$T^{FA_{IN}}_{O_i^T \to vh_l} = \sum_{k=1}^{Num} w_k \cdot \frac{\sum_{i=1}^{N_k} Rep_{O_i^R \to vh_l}}{N_k}$$

where Num is the number of ranges, w_k is the weight of range k and N_k is the number of raters in range k.

To use FA_{EX} there are three situations a truster must consider. The first, if all raters are unknown, then the truster applies FA_{IN} with a