Trust Based Prioritization of Quality Attributes

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Abstract: *Advances in network and distributed technology has revolutionized the advent of multi-agent systems. Nowadays, agent technology has been applied in revising and restructuring the complex software systems. Trust plays a key role in multi-agent systems as agents will be representing or acting on behalf of users or owners with different goals and motivations. Tasks are delegated to software agents that achieve their common goals based on interaction among themselves. Current trust models focus on the limited aspect of stakeholders trust in multi-agent systems; for example security issues of the entities involved in system while ignoring the other issues such as knowledgeability, usability, persistency, accessibility, performance, collaboration, realism and integrity. This paper identifies the quality attributes of Multi-agent system, which foster the stakeholders trust in the system and hence establishes the multifaceted definition of trust in MAS. Building trust from the quality attributes would encourage the developer to induce these quality attributes in the MAS development life cycle and produce a system whose foundation will be the stakeholders trust. This paper also prioritizes the quality attributes of MAS in order of their impact on stakeholders' trust.*

Keywords: *Multi-Agent Systems (MAS), Intuitionistic Fuzzy Sets (IFS), trust, quality attribute.*

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1. Introduction

Trust is a crucial factor for the successful introduction of new products and services, including agent technology. It enables people to believe in risky and uncertain situations. Software engineering community is becoming increasingly dependent on agent technology for engineering complex distributed systems. Software agents are enmeshed in various systems such as consumer shopping, monitoring complex chemical processes, aircraft maintenance, wireless collaboration, financial portfolio management etc. Trust plays a fundamental role in Multi-Agent Systems (MAS); therefore we need to identify quality attributes, which affect stakeholders trust the most. Few models have been proposed in literature to measure trust in these systems. Current trust models focus on limited aspects of quality such as security and privacy of agent's code while ignoring the other issues such as knowledgeability, persistency, accessibility, usability, performance, realism, collaboration and integrity. Although the list presented is not exhaustive, but it entails most of the significant quality attributes that cultivate stakeholders trust in MAS the most. This paper proposes a multifaceted definition of stakeholders' trust that incorporates broad aspects of quality in software agents.

Since the relationship between quality and trust is subjective in nature, Intuitionistic Fuzzy Sets (IFS) are most suited for capturing such subjectiveness. IFSs are one of the interesting and useful generalizations of fuzzy set theory, introduced by Atanassov [1] having membership, non-membership and hesitation part. An IFS based method has been proposed that captures the relationship between trust and quality of MAS in form of a triplet (μ, ν, π), where μ represents the degree of membership of relationship between trust and quality; ν represents the degree of nonmembership of relationship between trust and quality; π represents the degree of indecisiveness of relationship between trust and quality; such that $\mu + \nu + \pi = 1$. Then prioritization of quality attributes has been obtained based on their influence on stakeholders trust.

The paper is organized as follows. Section 2 defines MAS, quality in MAS and some basic definitions of intuitionistic fuzzy sets. Section 3 includes trust definition and need of trust in MAS. Section 4 establishes relationship between trust and quality and Section 5 prioritizes the quality attributes of MAS in order of their impact on stakeholders' trust. Section 6 concludes the paper.

2. Multi-Agent Systems

A Multi-Agent Systems (MAS) consists of an environment populated with a set of agents that cooperate to solve a complex problem in decentralized way. Software agents are autonomous program units that simulate human relationship on behalf of their users, across open and distributed environments, to solve a growing number of complex problems and can move throughout a network of agent aware computers [2]. Agents are characterized as autonomous, goal-oriented, situation aware and proactive as well as reactive. MAS models problems in terms of autonomous interacting component-agents, which is proving to be a more natural way of representing task

allocation, team planning, user preferences, open environments, and so on. MAS have been applied in a variety of domains including monitoring of complex chemical process [5], maintenance of cellular switching systems [13].

2.1. Quality in MAS

Quality in software systems is defined as the degree to which a system, a component or process conforms to specified requirement or fitness for use [6]. ISO Standard 8402 defines quality as: "The totality of features and characteristics of a product or service that bears on its ability to satisfy stated or implied needs". A quality based product results in better user satisfaction. Conventional software quality models such as McCall's [14], and ISO 9126 based on 6 factors: functionality, reliability, usability, maintainability, efficiency and portability. It addresses quality of software in terms of factors and criteria.

Behrouz Homayoun Far defines quality in MAS from various viewpoints such as [8]:

- Conformance: conformance to customer's requirements; conformance to standards.
- Development process quality: requirement, design, implementation, test and maintenance quality.
- End-product quality: reliability, usability and availability.
- Relativity: advantage over similar products.

For this study we define *Quality* as the characteristic of MAS that bears on its ability to achieve stated goals. Quality in MAS can be addressed in terms of attributes such as knowledgeability, persistency, accessibility, usability, performance, realism, integrity, and performance.

2.2. Basics of Intuitionistic Fuzzy Sets

Below some basic definitions are given [1], which are used in the next section.

Definition 1: Consider a set *E*. An *IFS* A in E is defined as an object of the following form

$$A = \{(x, \mu_A(x), \nu_A(x)) \mid x \in E\} \quad (1)$$

where the functions

$$\mu_A: E \rightarrow [0,1] \quad (2)$$

and

$$\nu_A: E \rightarrow [0,1] \quad (3)$$

define the degree of membership and the degree of non-membership of the element $x \in E$, respectively, and for every $x \in E$,

$$0 \leq \mu_A + \nu_A \leq 1 \quad (4)$$

Obviously, each ordinary fuzzy set may be written as

$$\{(x, \mu_A(x), 1-\mu_A(x)) \mid x \in E\} \quad (5)$$

Definition 2: The value of

$$\Pi_A(x) = 1 - \mu_A(x) - \nu_A(x) \quad (6)$$

is called the *degree of non-determinacy* (or *uncertainty*) of the element $x \in E$ to the intuitionistic fuzzy set *A*. This may cater to either membership value or non-membership value or both.

Intuitionistic fuzzy sets based models may be adequate in situations where we face human testimonies, opinions, etc. involving two (or more) answers of the type:

- Yes
- No
- I am not sure

Voting may be a good example [19] of such a situation as the human voters may be divided into three groups of those who:

- Vote for
- Vote against
- Abstain or giving invalid votes.

This third area is of a great interest from voter behavior analysis because people from this third undecided group after proper enhancement (e.g., different activities) can finally become sure; i.e., become persons voting for against.

3. Trust in Multi-Agent Systems

Trust has been studied in variety of fields including philosophy, sociology, psychology, management, marketing, ergonomics, human-computer interaction and e-commerce [7]. The challenge for exploiting trust in computing lies in extending the use of trust based solutions, first to artificial entities such as software agents or subsystems, then to human users' subconscious choices. Trust enables people to believe in risky and uncertain situations. Lewis and Weigert define trust as 'observation that indicate that members of a system act according to and are secure in the expected futures constituted by the presence of each other for their symbolic representations' [12]. They characterize trust in terms of actions that conforms to expectations. Morris Sloman defines Trust as " the quantified belief by a trustor with respect to the competence, honesty, security, and dependability of a trustee within a specified context" [18]. Barber and Kim describe trust as confidence in the ability and intention of an agent to provide correct information or perform promised actions [2]. Trust modeling derives the components of trust model as follows:

- *Intent:* An agent's tendency toward honest behavior [3]. Examples of honest behavior include an agent providing information it believes to be truthful.

- *Competence:* An agent's raw ability to accomplish a task, such as performing a desired action [3].
- *Credibility:* Fogg and Tseng define credibility as believability [9]. A system's professional design, ease of use increases the credibility of users in the system.
- *Reputation:* Robinson states reputation as "one builds probabilistic beliefs about the [other] party based on rational reasons, such as the past behavior of or experience with that other party" [16]. It may be defined as the extent to which customers believe a system is honest and concerned about them. In the context of MAS, *Trust* can be defined as the expectation that reflects that system will be able to achieve goals as intended.

3.1. Need for Trust Model

MAS, in which tasks are delegated to software agents that simulate human relationship on behalf of their users; an agent often achieves the goals through gaining information from other agents. So agents may risk their ability to accomplish the intended goal, since the requesting agent cannot be guaranteed that the responding agent will be able to fulfill the request. However, cooperation in uncertain environments exposes agent to risk. Trust model serve as decision criteria for whether to trust the MAS that is being modeled. From a stakeholder's point of view, trust is extremely important which safeguards the commitments that software agents have made. Various trust models have been proposed in the literature that incorporates aspects of security of agent's code or protection against its malicious behavior and hence restrict the definition of trust. Kristian Schelderup discuss trust models that raises several issues related to the security of agent systems, notably with respect to trust modeling and procedures for authentication, access control, integrity, and confidentiality [17]. [11] views security as a mechanism to transfer trust, e.g., as a certificate, between where it is held and where it is needed. In [15], a security model has been presented which allows the management of security policies on the basis of trust relations among autonomous software agents and emphasize that to allow the development of useful trust relations, agent systems should provide proper security framework. However, attributes other than security can be as important to the stakeholders. [10] incorporates aspects of system security, usability, reliability, availability, audit and verification mechanisms as well as user privacy concerns, user experience, and user knowledge in their expanded model of trust. This paper identifies quality attributes of MAS that arouse the stakeholders trust and then prioritize them in order of their influence. Comprehensives trust model of MAS must predict how other attributes of quality affect stakeholders trust.

3.2. Establishing Trust from Quality

Trust and quality are inter dependent terms. As quality instill trust in the users of the system and likewise if a user trusts a system, the system is more likely to satisfy quality parameters of user interest. In literature, effect of comprehensive quality on stakeholders trust has not been explored much. This paper identifies the attributes of quality that foster stakeholders trust.

When agents operate over an extended period of time, they can earn a reputation based on credibility and its intentions to provide correct information and perform promised actions, which is further determined by its qualitative characteristics such as knowledgeability, collaboration, persistency, accessibility, usability, performance and integrity. For example, *knowledgeability* in MAS is the extent to which it acquires knowledge from its environment, peer agents and users to achieve the goals. A software agent performs a task that requires particularly large amount of knowledge and reasoning using that knowledge. For example, it may be required to have knowledge of daily routines, habits and preference of the users on behalf of whom it is simulating the behavior. Clearly, an agent that deemed knowledgeable will find it easier to establish trust relationship with its users and peer agents. *Usability* deals with interaction issues of agents with users. Usability is the ease with which the users can utilize the services of MAS and hence nurture trust of users in MAS. *Persistency* is the consistency with which an agent achieves its goals. Persistency designates identity to software agents and in turn helps in establishing relationship with other agents that can result in mutual assistance in achieving the goals. An *accessibility* characteristic of software agents prompts other agents to approach it whenever they need its service. It ensures the robustness of internet connection and use of fault tolerance platform techniques. *Performance* in agents system has multi facets e.g. response time, quality of service, value of response etc. Clearly, Performance of MAS affects the user trust directly. *Collaboration* is the extent to which agents in MAS communicate, interact and exchange messages to negotiate or share the information with other agents for achieving their goals. They perform the tasks in coordination with other agents. *Realism* is the capability of MAS to simulate a human behavior in terms of performance and goal achievement. An *integrity* characteristic deals with the authentication, security and privacy issues of parties involved in online transaction.

This paper maps the qualitative attributes to the parameters of trust and hence establishes relationship between trust and quality. Although the list of quality attributes that foster stakeholder trust in MAS is not exhaustive but it includes most of them. The quality attributes described above influence all the factors of stakeholders' trust but Table 1 below maps the quality

Table 1. Mapping of quality attributes to trust factors in MAS.

MAS Quality Attributes	Parameters of Quality Attributes	Correspondence to Trust Factor
Usability deals with interaction issues of agents with users.	• Interface design issues • Proper navigational links • Comfortable system's dialogue with users • Ease to Learn	Usability is the ease with which user utilizes the system. Clearly, if a system is appreciated and accepted by users, it establishes the *Credibility* of that system.
Knowledgeability in MAS is the extent to which it acquires knowledge from its environment, peer agents and users to achieve the goals.	• Use of most recent, concise, complete, relevant, consistent knowledge in achievement of goals	Knowledgeability characterizes the *Competence* of agents in achieving the goals. More knowledgeable an agent is, more capable it is in achieving the goals.
Persistency is the consistency with which an agent achieves its goals.	• Stability of system with respect to changes in environment, faults • Consistency of results	Persistency of MAS defines its ability to retain knowledge and its state that ensures consistent goal achievement. It helps in building the *Reputation* of users in MAS.
Accessibility is the extent to which software agents can approach peer agents to request its service whenever they need it.	• Robust Connection to Internet • Compatibility of agents with peer agents and technology • Information availability •	Accessibility affects availability of MAS to its peer agent's and users and develops the *Reputation* of the system.
Performance in agents system has multi facets e.g. response time, quality of service, value of response etc	• Resource Management • Quality of Service • Response Time • Turn-around Time • Efficiency in goal achievement	Performance of MAS characterizes its promptness towards achieving goals, efficiency with respect to resources and notifies the *Competence* of system.
Collaboration is the extent to which agents in MAS communicate, interact and exchange messages to negotiate or share the information with other agents.	• Cooperation and coordination in achieving the goals • Use of Up-to-date and relevant Information • Benevolence attitude toward cooperation	In Multi-agent system, an agent often achieves the goals through gaining information from other agents. Collaboration promotes socialism in MAS and characterizes the *Intent* of agents in the system.
Realism is the extent to which the performance of MAS matches with that of human agent in terms of problem solving and hence achievement of goals.	• Correctness • Self-descriptiveness • Cost effective • Professional Design	Realism of MAS certainly captures the believability of users in the system and hence encourages *Credibility*.
Integrity characteristic deals with the authentication, security and privacy issues of parties involved in online transaction.	• Data confidentiality of MAS • Recovery procedure for loss of data • Authentication of parties involved in transaction • Fault tolerance • Availability	Integrity of Multi-agent system ensures the confidentiality of the parties involved in the transaction with cryptographic methods and affects the *Credibility* of users in MAS.

characteristics of agents to the trust factor that it affects the most.

4. Association Between Trust and Quality

Trust modeling defines Trust (T) as a function of combined attributes Reputation (R), Intention (I), creDibility (D) and competeNce (N) plus an error term $\in$ (that can't be defined in terms of these attributes). Thus,

$$T = f(N, R, D, I) + \in \quad (7)$$

In light of trust redefinition in section 2, Trust (T) is affected by key attributes of quality which we believe, are Knowledgeability (K), Persistency (P), acessiBility (B), Usability (U), perforMance (M), Collaboration (C), realism (L) and inteGrity (G). Now, from Table 1, it was found that competence is a function (g) of *K* and *M*. So

$$N = g(K, M) \quad (8)$$

R is a function (h) of *P* and *B*

$$R = h((P, B)) \quad (9)$$

D is a function (i) of *G*, *U* and *L*

$$D = i(G, U, L) \quad (10)$$

And I is a function (j) of *C*

$$I = j(C) \quad (11)$$

Substituting the values of *R*, *I*, *D*, *N* in equation 1, we obtain

$$T = f(g(K, M), h(P, B), i(L, G, U), j(C)) + \in \quad (12)$$

$$T = Fq(K, M, P, B, L, G, U, C) + \in \quad (13)$$

Hence T is a function (*Fq*) of quality attributes knowledgeability, persistency, accessibility, usability, performance, collaboration, realism and integrity.

5. Prioritizatizing Quality Attributes Based on Stakeholders Trust

Trust and *quality* are inter dependent terms. If quality of MAS is high; it foster stakeholders trust in the system and if users of system trust it then it is more likely to satisfy quality parameters of their interest. Since association of quality attributes to trust factors is subjective in nature, the IFS are most suited for correlation of quality with trust. IFS captures the association of quality attribute (q) to trust factor (t) in the form of a triplet ($\mu_q(t)$, $\nu_q(t)$, $\pi_q(t)$), where $\mu_q(t)$ represents the degree of membership of quality attribute to trust factor; $\nu_q(t)$ represents the degree of nonmembership of quality attribute to trust factor; and $\pi_q(t)$ represents the degree of uncertainty of quality attribute to trust factor.

An algorithm to prioritize the quality attributes based on stakeholders' trust is as follows:

Step 1: Identify the quality attributes that affect the stakeholders trust in MAS.
Step 2: Obtain the association of quality attributes to trust factors from the stakeholders in the form of recommendations using IFS.
Step 3: Compute the effective contribution (without hesitation) of quality attributes to trust factors by subtracting the product of nonmembership and uncertainty part from the membership part ($\mu(x) - \nu(x) * \pi(x)$) [4].
Step 4: Obtain the effect of quality attribute on comprehensive trust by taking the Σ of memberships of quality attributes to trust factors.
Step 5: Quality attributes have been prioritized on the basis of their affect on trust.

The algorithm can be used to encourage the developer to induce these quality attributes in the MAS development life cycle right from beginning and would result in a system, which will be based on stakeholders' trust.

5.1. Experimental Study

An experimental study of Online Stock Market (OSM) was performed to assess the relationship of quality and trust. OSM is an open system that we model as MAS, with traders, brokers, buyers, sellers, price analyzers and negotiators are software entities (agents) that act on behalf of their human owners by autonomously carrying out the negotiation and the exchange of stocks. All the entities are distributed, each connecting to Internet from a different location, with agents entering and leaving the system as they wish. For an intelligent seller agent to return the most relevant stocks, it must understand the nature of order placed by buyer agent and the context of the search. It must also understand the content of web search it indexed, and be able to reason what lead it to serve the order in this way. Knowledgeability of software agents will identify which of stocks are in demand while persistent identity of software agents will help in establishing relationship with other agents and can result in increased turnover of MAS application.

Integrity authenticates the parties involved in transaction and protects the software agents against the alteration in code or its malicious behavior. Usability of MAS signifies ease to use, easy to learn system for users and realism emphasizes the performance of trading system as if it is being performed by human agents.

In order to prioritize the quality attributes which influence the stakeholders trust, three groups each for the academicians (who are working in the areas of software quality, agent oriented software engineering, trust, web engineering), practitioners (that are practicing as quality engineers, members of SQA team and testing professionals) and users of stock market were formed. Eight quality attributes namely knowledgeability, usability, accessibility, performance, collaboration, realism and integrity are selected for this study; that have been found to affect the trust most. Each group of members were requested to give their opinion about affect of quality characteristics on trust factors using IFS that captures their opinion in form of presence, absence and hesitation.

The contribution of quality attributes to trust factors has been presented in form of membership, nonmembership (Table 2) using IFS. The effective contribution (without hesitation) of quality attributes to trust factors has been obtained in table 3 (using step 3 of Algorithm). Summation of membership of quality attributes to trust factors is obtained in Table 4 and it has been found from the above study that *realism* affect the trust most and *accessibility* affects the least among all the quality attributes that were surveyed and results are presented in Table 5. This study could be effective while designing and implementation of MAS as the quality attributes that foster the stakeholders trust in MAS can be induced right from beginning of development process till the last stages of maintenance. Prioritization of quality attributes on trust emphasizes that more attention to be paid to those attributes which affect the stakeholders trust more than those which are comparatively low in priority.

6. Conclusions

Trust and quality are inter dependent terms. If quality of MAS is high; it foster stakeholders trust in the system and if users of system trust it then it is more likely to satisfy quality parameters of their interest. Our research indicates that stakeholders trust can be improved by improving the quality of MAS. This paper prioritizes the quality improved by improving the quality of MAS. These paper priorities the quality attributes of MAS in order of their impact on trust

building. Since the association of quality and trust is subjective in nature and there is a chance of hesitation with each observation made by stakeholders, so IFS are most suited here, having membership, nonmembership and hesitation values. The significant quality attributes that encourage the trust can be induced in MAS right from its design and implementation as this would result in useful and trustworthy MAS.

Table 2. Association of quality attributes to trust factors in MAS using IFS.

R	Competence	Credibility	Intention	Reputation
Knowledgeability	0.79	0.46	0.08	0.46
Usability	0.44	0.79	0.57	0.56
Persistency	0.20	0.57	0.05	0.68
Accessibility	0.20	0.32	0.05	0.80
Performance	0.79	0.46	0.05	0.68
Collaboration	0.2	0.44	0.68	0.44
Realism	0.68	0.90	0.79	0.80
Integrity	0.05	0.90	0.18	0.46

Table 3. Effective contribution of quality attributes to trust factors in MAS.

S	Affect on Trust
Knowledgeability	1.79
Usability	2.36
Persistency	1.50
Accessibility	1.37
Performance	1.98
Collaboration	1.76
Realism	3.17
Integrity	1.59

Table 4. Association of quality attributes to stakholders' trust using Table 2 and Table 3.

S	Affect on Trust
Knowledgeability	1.79
Usability	2.36
Persistency	1.50
Accessibility	1.37
Performance	1.98
Collaboration	1.76
Realism	3.17
Integrity	1.59

Table 5. Prioritization of quality attributes on the basis of their influence on trust in MAS.

Rank	Quality Attributes
1	Realism
2	Usability
3	Performance
4	Knowledgeability
5	Collaboration
6	Integrity
7	Persistency
8	Accessibility

References

[1] Atanassov K., *Intuitionistic Fuzzy Sets: Theory and Applications*, Studies in Fuzziness and Soft Computing, Springer Verlag Company, 1999.

[2] Atanassov K., Pasi G., Yager R., "Intuitionistic Fuzzy Interpretations of Multi-Person Multi-Criteria decision Making," *First International IEEE Symposium on Intelligent Systems*, no. 1, pp. 115-119, 2002.

[3] Barber K. and Kim J., "Belief Revision Process Based on Trust: Agent Evaluating Reputation of Information Sources," *in Proceedings of the Workshop on Deception, Fraud, and Trust in Agent Societies-Autonomous Agents Conference*, Montreal, Canada, pp. 73-82, 2002

[4] Barber K., Kim J., and Fullam K., "Challenges for Trust, Fraud and Deception Research in Multi-agent Systems," *Lecture Notes in Artificial Intelligence*, *Falcone R., Barber K., Korba L., and Singh M. (eds.)*, Springer Press, pp. 8-14, 2003.

[5] Bedi P. and Kaur H., "Trust Based Personalized Recommender System," *INFOCOMP-Journal of Computer Science*, vol. 5, no. 1, pp. 19-26, 2006.

[6] Bunch L., Breedy M., Bradshaw J., Carvalho M., Suri N., Uszok A., Hansen J., Pechoucek M., and Marik V., "Agents, Interactions, Mobility, And Systems (AIMS): Software Agents for Process Monitoring and Notification," *in Proceedings of the 2004 ACM Symposium on Applied Computing,* Nicosia, Cyprus, pp. 94-100, 2004.

[7] Conrath D., Sharma W., and Sharma R., "Toward a Diagnostics Instrument for Assessing the Quality of Expert Systems," *in Proceedings of the ACM SIGBDP Conference on Trends and Directions in Expert Systems,* Orlando, United States, pp. 72-87, 1990.

[8] Corritore C., Kracher B., and Wiedenbeck S., "On-Line Trust: Concepts, Evolving Themes, A Model," *International Journal Human-Computer Studies*, vol. 58, no. 6, pp. 737-758, 2003.

[9] Egger F., "Trust Me, I'm an Online Vendor: Towards a Model of Trust for e-Commerce System Design," *in Proceedings of the Conference of Human Factors in Computing Systems*, The Hague, The Netherlands, pp. 101-102, 2000.

[10] Far B., "Software Agents: Quality, Complexity and Uncertainty Issues," *in Proceedings of the 1st IEEE International Conference on Cognitive Informatics (ICCI'02)*, Canada, pp. 122-132, 2002.

[11] Fogg B. and Tseng H., "The Elements of Computer Credibility," *in Proceedings of Conference on Human Factors in Computing Systems (CHI'99)*, ACM Press, USA, pp. 80-87, 1999.

[12] Hoffman J., Blum J., and Jenkins L., "Trust Beyond Security an Expanded Trust Model," *Communications of the ACM*, vol. 49, no. 7, pp. 94-101, 2006.

[13] Josang A., "The Right Type of Trust for Distributed Systems," *in Proceedings of the 1996*

New Security Paradigms Workshop, ACM, Lake Arrowhead, United States, pp. 119-131, 1996.

[14] Lewis D. and Weigert A., "Social Atomism, Holism and Trust," *Sociological Quarterly*, no. 4, pp. 455-471, 1985.

[15] Guiagoussou M. and Soulhi S., "Implementation of a Diagnostic and Troubleshooting Multi-Agent System for Cellular Networks," *International Journal of Network Management*, vol. 9, no. 4, pp. 221-237, 1999.

[16] McCallJ., Richards P. , and Walters G., "Factors in Software Quality", *RADC Reports*, vol . 1-3, 1977.

[17] Poggi A., Vitaglione G, and Tomaiuolo M., "A Security Infrastructure for Trust Management in Multi-Agent Systems," *Lecture Notes in Computer Science*, vol. 3577, pp. 162-179, 2005.

[18] Robinson S., "Trust and Breach of the Psychological Contract," *Administrative Science Quarterly*, vol. 41, pp. 574-599, 1996.

[19] Schelderup K., lnes J., "Mobile Agent Security-Issues and Directions," *Lecture Notes in Computer Science*, Springer, vol. 1597, pp. 155-167, 1999.

[20] Sloman M., "Trust Management in Internet and Pervasive Systems," *IEEE Intelligent Systems*, vol. 19, pp. 77-79, 2004.

[21] Szmidt E. and Kacprzyk J., "Evaluation of Agreement in a Group of Experts via Distances Between Intuitionistic Fuzzy Preferences," *First International IEEE Symposium Intelligent Systems*, vol. 1, pp. 166-170, 2002.

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