TRUST: DIFFERENT VIEWS, ONE GOAL

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ABSTRACT

A thorough review of trust models is carried out in this paper to reveal the key capabilities of existing trust models and compare how they differ among disciplines. Trust decisions are risky due to uncertainties and the loss of control. On the other hand, not trusting might mean giving up some potential benefits. Advances in electronic transactions, mutliagent systems, and decision support systems create a necessity to develop trust and reputation models. The development of such models will allow for trust reasoning and decisions to be made in situations with high risk and uncertainty. In recent years, several attempts have been made to model reputation and trust. However, perceiving trust differently and the lack of having a unified trust definition are among the main causes of the proliferation of many trust models across different disciplines.

1. INTRODUCTION

Despite its usefulness in both human and artificial societies, trust was and will continue to be a risky proposition. Trust has been always an integral component of human social life and actions. The advances in autonomous intelligent systems, communications, and electronic transactions motivated the execution of research regarding trust and reputation in order to span the spatial and temporal separation among the partners involved in a social interaction or an exchange of commodities or goods.

Reputation is used as a means to build and update trust after a certain number of successful transactions [3, 15, 28, 29, 34, 40, 102]. Anonymity, uncertainty, risk, lack of control, and potential opportunism are key elements in most online transactions. Using trust evaluation and models to compensate for the lack of information and control in online environments will allow one to make decisions in regard to whom to trust and engage within a transaction or cooperative action. Some of the associated risks with online transactions include the exchange of some personal information, the absence of the physical goods, the non-immediate exchange of goods and money, and how secure the transaction media is [8, 41, 42, 54].

Trust is inevitably involves uncertainty. In general, uncertainty is the absence of credible knowledge about future events. Trust is supposed to assure an agent that the desirable course of events will be realized in the unknowable future, as if being guaranteed from past knowledge. As Luhmann [81] wrote, “trust rests on illusion. In actuality, there is less information available than would be required to give assurance of success. The actor willingly surmounts this deficit of information”. A trustful person can comprehend new experiences and carry out actions that have been previously undesirable or unachievable. This is due to the fact that when trusting, in favour of an inner confidence, one simplifies the complexity of the outer world and removes any uncertainties.

When trusting, we allow ourselves to be vulnerable to others by depending on them to achieve or care for something we value. This interdependence relationship occurs when it is in the mutual benefit for both parties to fulfill their obligations towards the achievement of their common goal.

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In this case, no party has a dominant power over the other. While engaging in a dependence relationship, none of the parties is willing to exploit its situation. The realization of this dependency relationship by the trustee will put him or her in a relatively more powerful situation [81]. If properly used, this kind of power will strengthen the trust relationship. Some trustees might refrain from using this power to avoid the negative consequences associated with exploiting the dependent trustor.

Section 2 reviews trust definitions from different disciplines. In Section 3, different approaches to modeling trust are explained. Section 4 highlights the common shortcomings of the current approaches to modeling trust and suggests ways of improving them. Some concluding remarks and insights are given in Section 5.

2. TRUST DEFINITIONS FROM DIFFERENT DISCIPLINES

Different disciplines handle trust differently according to their own perceptions and what fits their specific goals. In order to consolidate sensible measures of trust, one needs to step back and analyze why different disciplines view trust differently. What follows is a thorough review of the existing trust definitions from different disciplines like, Psychology [9, 76, 80, 104, 105], Sociology [18, 48, 52, 78, 81, 118], Philosophy [6, 32, 63, 68, 101], Economics [25, 57, 85, 124, 130], Finance [45, 61], Marketing [39, 49, 50, 93, 117], Management [51, 69, 82, 88, 91, 123], E-Commerce [71, 89, 90], and Computer Science [8, 36, 44, 100, 112].

2.1. TRUST IN PSYCHOLOGY

In his 1973 book, M. Deutsch defines trust as confidence that one will find what is desired from another person rather than what is feared [37]. Many researchers find this definition to be a specific characteristic of a relationship. Deutsch, however, presents many other aspects of trust in his 1973 work. He presents trust as being connected to despair, innocence, social conformity, virtue, gambling, risk-taking and faith, among others.

From a psychological perspective, risk in trust is approached as one of the characteristics of individuals. While some people are willing to take risks, there are some who are too cautious and distrustful to take any chances. Trusting behavior depends on how individuals perceive an ambiguous path or unclear situation. In such cases, the occurrence of a good or bad result is dependent on other's actions. Knowing that a negative result is more harmful than a good one, a trusting decision should be made.

The use of the word "perceive" in the previous paragraph is to emphasize the subjective nature of trust. If trust is based on individual perception, it is likely that the same situation will be seen differently by different individuals. Estimates of chances and expected gains or losses are subjective. Thus, some individuals might make unwise risks, thereby acting as if they are taking chances while, in fact, they are trusting unwisely.

2.2. TRUST IN SOCIOLOGY

The sociology of trust has been investigated from different angles: rational choices, culture, functionality, symbolic interaction, and others. Trust is a social relationship subject to its own special system of rules [81]. Trust occurs within interactions that are influenced by both personality and social systems [78]. Most sociologists agree with: "the clear and simple fact that, without trust, the everyday social life which we take for granted is simply not possible" [52, p. 32]. We always find ourselves in a condition of uncertainty about and uncontrollability of future

actions. We have no way of knowing and controlling what others will do independently of our own actions and we are not even sure how they will react to ours. In general, uncertainty and risk are integral components of human interactions that can't be ignored or avoided.

In situations in which we have to act in spite of uncertainty and risk, the third factor that comes to the fore is that of trust [118]. Trusting becomes a crucial strategy for dealing with an uncertain and uncontrollable future. Since there is no way of knowing what is in the minds of others, we need trust to deal with an unknown future and others' uncontrollable actions.

When participating in uncertain and uncontrollable conditions, we take risks, we gamble, and we make bets about the future and the actions of the others. A simple and general definition of trust is: "trust is a bet about the future contingent actions of others" [118, p. 25]. In this sense, trust consists of two main components: beliefs and commitments. First, it involves specific expectations: "trust is based on an individual's theory as to how another person will perform on some future occasion" [52, p. 33]. When placing trust, we behave as if we know the future. Second, trust involves commitment through action or roughly speaking, placing a bet. Thus: "trust is the correct expectations about the actions of other people that have a bearing on one's own choice of action when that action must be chosen before one can monitor the actions of those others" [48, p. 51]. In order to have a better and deeper understanding of trust, we need to pay attention to the mental and subjective attitudes of the trusting person. It is important to focus on what happens in an individual's mind when trusting someone else.

2.3. TRUST IN PHILOSOPHY

Trust and distrust are subjective attitudes that affect our thinking and feelings [63]. When trusting, we are more likely to let ourselves be vulnerable to others and allow ourselves to depend on others. Trust is a cooperative activity in which we engage so that we can assist one another in the care of goods [6]. We trust others when we afford them the opportunity to care for something we value. We trust things as well as people. While trusting things is based on the properties of the things that we know in advance, trusting people is based on past experiences. When we trust, we hold expectations toward another person. To expect is to look forward to something without anticipating disappointment. When holding expectations of another, we project into the future, making an inference about the sort of person someone is going to be in the future. When trusting, the expectations alone are not enough but we must anticipate that the other has good intentions and the ability to carry out what is expected of him or her.

In order to trust someone, we need to have a sense of his or her values. A person who lacks commitment to any values or principles doesn't give us the ability to predict either good or bad intentions or treatment. Knowing the other's values, commitments, and loyalty will help us to decide to what extent risk would be involved if we count on that person. We trust others more fully when we believe that they have positive feelings towards us personally and not just as members of some group. Trust is a risky business because people whom we trust can let us down and we are vulnerable to harm when they do so. It is important to accept the risks of trust and try to handle them rather than taking the simplistic view that trust is always good. Sometimes we trust too easily and risk a great deal in doing so [32, 63]. Our trust is generally based on experiences with other people. On the basis of those experiences, we construct a characterization or picture of them but in reality they are free agents with different characterizations that go beyond our beliefs about them.

2.4. TRUST IN ECONOMICS

The study of trust and reputation in a free economy tries to address the relationship between trust and competition. By supplying quality goods at competitive prices, firms are building good reputations in order to secure their future market position and share. Firms will refrain from being concerned about the short-term profits when compared to building a good reputation and long-term profits thereafter.

In free-markets economy, consumers are faced with the dilemma of getting quality good for the least prices from profit-maximizing entities (firms). The trade-off between the price of goods and their quality is bridged by means of good reputation and trust between the consumer and the goods' providers. Some of the pioneers in this field are [26, 27, 47, 65, 66, 77, 103, 114, 116, 120, 121].

2.5. TRUST IN FINANCE

The allocation of financial resources to certain activities includes buying assets, investments, and loans. These activities, and all financial activities, in general, are associated with some risk and uncertainty due to one of the involved parties not honoring his or her obligations. For example, borrowing money for a specific investment is highly related to the future ability of the borrower to pay back the loan. This highly depends on the trustworthiness and the associated evaluation of risks. Jensen and Meckling [70] strongly believe that trust, reputation, and social bonds will always be present in such interactions. The formation of trust and what factors would affect it were a topic for research in finance. Hart [64] studied trust within agency theory. Others, like Shapiro and Stiglitz [115], investigated the ethical side of trust in terms of the reliability of one of the parties. This required importing some of the sociological concepts such as social capital and social networks [55, 56, 57, 58]. Guth and Kliemt [62] analyzed the evolution of trust in a simple game of trust between a buyer and a seller.

2.6. TRUST IN MARKETING

Studying trust relationship between a marketer and a customer is a key factor in the relationship between the two. Most of the research in this area focuses on the customer's trust [93]. The research of trust in marketing dates back to the 1970s. Establishing a high level of trust in a marketing relationship allows the two parties to focus more on long lasting term benefits [49]. Some of the developed marketing theories are based on trust [93]. Trust could assume different phases like, the trust between the firm and its marketers [119], the marketers and the customers, and the customers and the firm [113]. These three trust phases interact and affect each other one way or another [93]. This explains why most marketing researchers have included trust in their relationships channel models where a vendor provides a service or a good to a distributor who resells it to the end user [50].

2.7. TRUST IN MANAGEMENT

Different parties within an organization need to work together to accomplish specific goals at both the personal and the organizational levels. This often requires some teamwork and dependence on others to execute certain assigned tasks. Risk will be always present in such relationships due to a lack of knowledge to do a specific task or the unwillingness to do it [88]. The presence of trust will reduce the risks associated with group interactions. However, some of the problems associated with trust in such environments are: lack of a specific definition of trust, difficulties of defining the boundaries of each task, lack of well defined regulations governing the

interactions between the different inter-organization parties, and the unclear relationship between trust antecedents and consequences. There are some studies suggesting that trust is highly influenced by factors of which some are individual and others are organizational. In his 1998 work, Doney and Cannon [39] suggested that social values and norms, besides behavioral attitudes, are key factors in trust. The length and the type of the relationship between the different parties within an organization and between the different organizations, the presence of previous interactions, and the interpersonal relations, if any, are other factors suggested by Inkpen and Currall [69]. Gill and Butler [51] focused on the presence of some personal knowledge or quality for fulfilling some delegated tasks. Therefore, they define trust as an elaboration from current qualities as the most reliable for attaining a future goal. Some hidden factors or mental processes could be accounted for in explaining the high levels of trust for entities interacting for the first time [91]. Trust leads to some interdependencies which will eventually involve some sort of sharing of the control and management of things we care for [69]. Nevertheless, trust has not been appreciated enough within the management field. This is in part because managers didn't devote sufficient time, energy, or resources to creating it within their organizations or because they look at it as a matter of strategic choice [123].

2.8. TRUST IN E-COMMERCE

Trust in electronic transactions goes beyond risk and uncertainty to include other factors like lack of information, lack of control, ease of use, privacy and security issues [13, 31]. On-line transactions and exchange relationships are not only characterized by uncertainty, but also by secrecy, lack of control and potential fraud, thereby making risk and trust crucial elements of electronic commerce [21].

The process of buying over the internet being perceived as risky, presents numerous risks for consumers during and after the transaction itself. Online firms may be located in different locations of the country or even in different countries. This requires a non-immediate exchange of information, goods, and money. As a result, some sensitive information is exchanged online like, personal and financial information. The limited history about the seller prior to the interaction adds to the risk and uncertainty involved in this transaction [8].

Some of the system-dependent uncertainties go beyond the control of the parties involved in the transaction. These are environment related uncertainties which could be characterized as exogenous. Generally speaking, the concept of exogenous uncertainties refers to the uncertainties of the world [67]. The environment dynamics and system complexity are two main factors when considering exogenous uncertainties. In the context of electronic commerce, exogenous uncertainty relates to the potential technological errors or security gaps that can't be avoided [10, 11, 12]. The utilization of encrypted transactions, firewalls, authentication mechanisms and privacy seals are means of reducing the effects of system uncertainties [100]. Transaction-specific uncertainties are caused by decisions of parties exchanging information over the transaction media. The consumer may interpret the uncertainties as seller's potential behavior in the transaction process. In computer mediated transactions, element of personal interaction like body language, gestures, and facial expressions are eliminated.

In general, the more trust present in a given situation, the less additional information is needed to make a certain decision. On the other hand, if there is little or no trust, there will be a need for complete information in order to reduce system-dependent and transaction-specific uncertainties. Uncertainties are perceived differently and, hence, the level of the perceived uncertainties influences the needed balance between trust and information [122]. Trust and additional information could be seen as means to reduce uncertainties [81, 123].

2.9. TRUST IN COMPUTER SCIENCE AND INFORMATION SYSTEMS

Computer scientists tried to formalize the measures of knowledge derived from sociology and psychology into agents' architectures. One can understand trust as an attitude of an agent who believes that another agent has a given property. Therefore, one can analyze the meaning of trust as a function of the attributed properties [46]. For instance, the property may be that the agent one trusts fulfills his obligations, like the case of a buying agent. Properties one considers are the ability of the agent to do the job, to make decisions, or just to deliver information [36].

With the emergence of electronic commerce, trust issues became important for many people. Generally speaking, it is agreed that in order for electronic commerce to become successful, most people have to trust it. The person's trust in a transaction is determined by the trust in the counter party and the trust in the transaction media based on the assumption that party and media trust supplement each other. If there is not sufficient party trust, then the media trust and its control protocols should be brought in to supplement the party trust [38]. Trust in the counter party can be defined as "The subjective probability by which an individual A expects that another individual B performs a given action on which its welfare depends" [45, p. 56]. According to this definition, it could be argued that trust has both objective and subjective attributes. The first depends on the media structure, such as the functionality of the control mechanisms in place. The second depends on personal experiences in dealing with a specific party, or with specific procedures and control protocols.

2.10. TRUST AS A GLOBAL VIEW

Gambetta (2000) attempted to gather different thoughts regarding trust from many areas [5, 48]. The most important aspect of their work is the use of values. On the other hand, using explicit values for trust can be problematic due to the subjectivity of trust in which the same value could be seen differently by different agents. Yet the use of values for measuring trust allows one to talk more precisely about certain circumstances or behaviors concerning trust. Also, it permits a straightforward implementation of the formulation.

In his research, Gambetta [48, p. 217] defines trust as "a particular level of subjective probability with which an agent assesses that another agent or group of agents will perform a particular action both before he can monitor such action or independently of his capacity ever to be able to monitor it and in a context in which it affects his own action". This definition excludes certain aspects which are important to trust like referring only to the trust relationship between the agents themselves and not, for example, the agents and the environment. It also excludes those agents whose actions have no effect on the decision of the truster, despite the fact that trust is present. An interesting point in Gambetta's work is the concern regarding competition and cooperation. In some cases, cooperation is not good, such as the cooperation among thieves or drug dealers, while it is very desirable among policemen. Then, it is beneficial to find "the optimal mixture of cooperation and competition rather than deciding at which extreme to converge" [48, p. 215]. In competitive situations, cooperation is of great importance since "even to compete in a mutually non-destructive way one needs at some level to trust one's competitors to comply with certain rules" [48, p. 215]. Despite the importance of using values for trust, Gambetta didn't develop the idea in any concrete fashion [86].

3. APPROACHES TO MODELING TRUST

Different approaches have been used in an attempt to model trust, of which some have commercial applications and others are only meant for academic purposes. Some of these

modeling attempts are only informative while others are conceptual. In the following sections, different approaches for modeling trust are classified based on their underlying methodologies.

3.1. SIMPLE SCORING

Considered a relatively simple approach, some basic mathematical operators like, multiplication and addition, are used to compute trust values. The average and the weighted average are the two most common methods in this category. Getting direct ranking or feedback from the users and then averaging all the responses is a simple and intuitive way of the many techniques used in e-commerce [3]. A slightly modified version of this technique is being used in e-Bay [40]. Both positive and negative scores are summed separately and then subtracting the total negatives from the total positives to get the overall score. The values often used are 1, 0, and -1 for the positive, neutral, and negative ratings, respectively. In some cases, the weighted average is being implemented to put more emphases on the most recent transactions or to highlight some factors more than others.

3.2. STATISTICAL

When using this technique, a history of all previous interactions is maintained. This history is combined with the new interactions to compute the overall trust value using statistical approaches. The most common approach is Bayesian. The Bayesian system takes a binary input and utilizes the beta-Probability Density Function (PDF) to compute the updating. Within the PDF distribution, the two parameters (α, β) refer to the positive and negative ratings, respectively [72, 74, 95, 97, 125].

The Bayesian system starts with 1 assigned to both parameters and keeps updating after each interaction. While this provides a sound theoretical basis for computing a trust value, it might not be easily understood by average users.

3.3. LINGUISTIC

Sometimes, it is easier describing the level of trust using some linguistic terms rather than numerical values. Using fuzzy or probabilistic approaches, those linguistic terms could be matched with appropriate or approximated numerical values that are easy to calculate and program. Al-Mutairi et al. [2] used the linguistic terms absolutely low, very low, low, fairly low, medium, fairly high, high, very high, and absolutely high to describe the trust level. This enables the agent to calculate the trustworthiness of another agent before engaging with it in an interaction. Fuzzy logic is used to match those linguistic terms with approximated values to carry on some computations and obtain the overall expected trust value. This also depends on some other factors like the importance of the interaction for a specific agent, the expected value, the availability of other alternatives, and the risk attitudes of the agent.

3.4. COGNITIVE

This technique tries to mimic the human way of thinking and reasoning about trust. It attempts to go beyond sensible things and explore what transpires in the mind of one when trusting [7]. This is highly linked to one's belief and social community. For an inner feeling or confidence one may or may not trust another person. The thresholds of what is trustworthy or not will be different for different agents. Some authors [73] use the belief theory to predict a trust value. Belief theory is a framework based on probability theory where the total of the probabilities doesn't necessarily add up to 1. This is in part due to the presence of some uncertainties. It is important to mention that

transitivity is an underlying assumption in most of the models in this category where an agent is considered as trustworthy if referred to as trustworthy by other agent or agents.

3.5. FUZZY

When using fuzzy logic to evaluate trust, it is possible to refer to trust using a linguistic label that describes a specific fuzzy function rather than using numerical values. The trust level can have different memberships to different fuzzy sets like belonging to trustworthy and very trustworthy with memberships of 0.4 and 0.6, respectively. The models proposed by Al-Mutairi et al. [2], Manchala [84], and Sabater and Sierra [106, 107, 108] are good examples of this type of modeling.

3.6. FLOW CHAINS

The main assumption underlying in this category of models is transitivity. By that, one means that if agent a trusts agent b, agent b trusts agent c, then agent a must trust agent c. It could be as simple as an interaction between three agents or through long chains and loops of iterative deals. However, it could be the case that trust values from different agents are assigned different weights depending on the previous history of that particular agent. More interaction chains through a particular agent means higher trust value and vice versa [4]. In web semantics, the more hyperlinks to a site the higher its rank and more hyperlinks out of that page the less its rank [14, 99]. Makino [83] used the same concept to calculate the reputation based on the number of citations in a research environment.

4. DISCUSSION

Table 1 shows a chronological summary of some of the existing work in trust modeling. From this extensive review, one can highlight the following issues for further investigation when modeling trust.

4.1. UNRATED TRANSACTIONS

Though sighted as one of the most common ways of evaluating the rules of trust, feedback is not always given for all transactions [102]. This is in part due to the following:

- Lack of incentive (no direct benefits of providing feedback).
- Retaliation from the seller or service provider in response to negative feedback.
- Competition for a limited service or commodity.
- Feedback mechanism is lengthy or not easy to use.
- Ignorance.

Thinking of feedback as only being important in case it is negative (a way of warning others) while neglecting the positive ones could give a misleading trust value. For example, on e-Bay, assume that only 50 out 1000 transactions are assigned a negative feedback (the remaining 950 are positive). The score will be 950 when all transactions are given a feedback while the score for the same seller will be 750 if only 800 out of the 950 positive transactions are reported. This will cause the positive feedback ranking for this seller to drop from 0.95% in the first case to only 0.75% in the second case.

4.2. MISLEADING FEEDBACK

Feedback could be misleading when, for some reason, it is unfair or not justified whether they are positive or negative [34]. Some of the sited reasons for having a false positive feedback are:

- Reciprocation: a positive feedback for a positive feedback in return.
- Being rewarded with a discounted price.
- Building a good reputation through prearranged fake interactions.
- In contrast, false negative feedback could be due to:
- Based on a specific identity of a specific agent whether it is because of a previous interaction history or personal reasons.
- Blaming the seller or the service provider for a shortcoming on behalf of the buyer or the service recipient.
- Reasons that are beyond the control of the seller which could be related to the transaction media or the delivery system.

The process of providing feedback is a very subjective issue that is hard to monitor and control [92].

4.3. IDENTITY VERIFICATION

One of the risks associated with electronic environments is verifying that an agent is what he or she is claiming to be [128]. Some of the identity associated risks are:

- Stolen verification information (username and passwords).
- Identity change to escape from a past transaction history.
- Validating the information supplied during the registration process.

Based on the assumption that trust is the result of acquired cumulative reputation over a period of time through a number of interactions, not being able to verify the agents' identities will give a misleading trust index [23].

4.4. BEHAVIORAL CHANGES

When showing good intentions, regardless of the current low trust index, agents need to be given a chance to recover and start a corrective process [74]. An agent might start with a low trust index for one or more of the following reasons:

- Focusing on the short term benefits and not worrying about a long lasting one.
- Lack of knowledge about the importance of building a good reputation on the virtual environments.
- Reasons that are related to the transaction media which is beyond the control of the agent.
- Change of the service provider' management in order to recover from the current situation.
- Change of the service type or product.
- Behavioral changes over time.

Giving more weight on the most recent transactions, like for the past six months or last year without entirely neglecting the past interactions [16, 17], will give a more reflective index of the

agent's current situation. This will also allow one to analyze any behavioral trends over a period of time.

5. SUMMARY

From this extensive review, one can appreciate the importance of trust across many disciplines. However, trust research is still in its early stages and varies greatly depending on the trust context and use. Most of the models are based on feedback through direct interactions or conveyed through a third party. Though agreeing on the importance of direct experiences, there are more factors that contribute to trust that should be taken into consideration. By its nature, trust is complex, multidimensional, and subjective. It might be time to merge traditional game theoretic approaches with cognitive, sociological, and psychological ones in order to better understand and model trust. Due to the variations in defining and using trust, as of now, there is no single set of unified trust data that could be tested and compared among the different trust models. Testing and comparing trust models are still an arbitrary issue. Developing test data sets and general test frameworks will enable fine tuning and improving some of the proposed models. It will also allow researchers to examine which model works better for which uses.

Table 1. Chronological Summary Of Existing Trust Models.

Year	Author(s)	Domain	Methodology	Remarks
1994	S. Marsh	Computer Science	Simple Scoring	Simple mathematical formulation for multiagent systems.
1998	C. Castelfranchi and R. Falcone	Multiagent Systems	Cognitive	Based on goals, mental states, and beliefs.
1998	D. Manchala	Electronic Commerce	Fuzzy	Focuses on the relationship between trust and risk
1998	L. Page et al.	Electronic Commerce	Flow Chains	Transitivity through loops or long chains of interactions
1999	G. Zacharia	Electronic Commerce	Simple Scoring	Sporas and Histos are two modified models for online reputation systems with a focus on recent ratings.
1999	A. Josang	Electronic Commerce	Statistical	Based on statistically updating Beta probability density functions
2000	M. Schillo et al.	Multiagent Systems	Statistical	Boolean logic where it is either strictly good or bad.

2000	A. Abdul-Rahman and S. Hailes	Multiagent Systems	Linguistic	Based on witness information with some adjustments
2000	J. Schneider et al.	Electronic Commerce	Simple Scoring	Averaging all ratings (both positive and negative)
2001	B. Esfandiary and S. Chandrasekharan	Multiagent Systems	Statistical	Trust acquisition using Bayesian learning
2001	L. Mui and M. Mohtashemi	Electronic Commerce	Statistical	Based on statistically updating Beta probability density functions
2001	A. Josang	Electronic Commerce	Cognitive	Based on belief theory where the probabilities don't necessarily add up to 1.
2001,2002	B. Yu and M. Singh	Multiagent Systems	Statistical	Only most recent information is considered for calculation
2001,2002	J. Sabater and C. Seirra	Electronic Commerce	Fuzzy	Aggregated information from direct and indirect interactions.

Table 1. (*continued*)

2002	S. Sen and N. Sajja	Multiagent Systems	Statistical	Both direct interactions and observed ones are considered.
2002	eBay, Amazon, OnSale	Electronic Commerce	Simple Scoring	Online reputation models through direct feedback.
2002	J. Carbo et al.	Multiagent Systems	Fuzzy	Uses weighted aggregation to combine old and new reputation values.
2002	J. Carter et al.	Multiagent Systems	Cognitive	Uses weighted aggregation but the values used are different for different societies.
2002	A. Josang and R. Ismail	Electronic Commerce	Statistical	Based on statistically updating Beta probability density functions
2002	L. Mui et al.	Electronic Commerce	Statistical	Based on statistically updating Beta probability density functions
2003	V. Cahill et al.	Electronic Commerce	Linguistic	Some heuristics are needed to associate linguistic labels to values
2003	M. Carbone et al.	Electronic Commerce	Linguistic	Some heuristics are needed to associate linguistic labels to values
2003	S. Kamvar	Electronic Commerce	Flow Chains	Transitivity through loops or long chains of interactions
2004	A. Withby	Electronic Commerce	Statistical	Based on statistically updating Beta probability density functions
2004	C. Zeigler	Electronic Commerce	Flow Chains	Transitivity through loops or long chains of interactions
2004	R. Levien	Electronic Commerce	Flow Chains	Transitivity through loops or long chains of interactions
2005	E. Maximilien and M. Singh	Multiagent Systems	Statistical	Aggregate different scores for multiple attributes and choose the agent with the highest score
2006	N. Griffiths et al.	Peer-to-Peer Systems	Fuzzy	Combine a set of rules to represent and reason about others' trustworthiness

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