Towards User Driven Trust Modeling and Management

Zheng Yan, and Valtteri Niemi

Nokia Research Center, Helsinki, Finland

{zheng.z.yan, valtteri.niemi}@nokia.com

Abstract. Trust management is emerging as a promising technology to facilitate collaboration among entities in an environment where traditional security paradigms cannot be enforced due to lack of centralized control and incomplete knowledge of the environment. However, prior art generally lack considerations on usable means to gather and disseminate experiential evidences, extract trust criteria from a system user for effective trust evaluation, as well as provide trust information to users. This could cause the trust management solution to be hard to understand, use, and thus accept by the users. This paper proposes a user driven trust modeling and management method in order to design and develop a usable trust management solution that could be easily accepted by the users towards practical deployment. We illustrate how to apply this method into the design of a mobile application's reputation system in order to demonstrate its effectiveness.

1 Introduction

The concept of trust has been studied in disciplines ranging from economic to psychology, from sociology to medicine, and to information science. It is hard to say what trust exactly is because it is a multidimensional, multidisciplinary and multifaceted concept [1]. We can find various definitions of trust in the literature. Common to these definitions are the notions of confidence, belief, faith, hope, expectation, dependence, and reliance on the goodness, strength, reliability, integrity, ability, or character of a person or thing [2]. Generally, a trust relationship involves two parties: a trustor and a trustee. The trustor is the person or entity who holds confidence, belief, etc. on the reliability, integrity, ability, etc. of another person or thing, which is the object of trust - the trustee.

Although trust has been recognized as a complicated concept hard to narrow down, the critical characteristics of trust can be summarized. Trust is subjective because the level of trust considered sufficient is different for each individual in a certain situation. It is the subjective expectation of the trustor on the trustee's behaviors that could influence the trustor's belief. Trust is also dynamic as it is affected by many factors. It can further develop and evolve due to good experiences about the trustee. It is sensitive to be decayed caused by bad experiences.

Recently, trust management has been emerging as a promising technology to facilitate collaboration among entities in a digital environment where traditional security paradigms cannot be enforced due to lack of centralized control and incomplete

knowledge of the environment. Trust management is concerned with: collecting the information required to make a trust relationship decision; evaluating the criteria related to the trust relationship as well as monitoring and re-evaluating existing trust relationships; and automating the process [3]. Various trust management systems have been described in the literature. One important category consists of reputation based trust management systems. Trust and reputation mechanisms have been proposed in various fields such as distributed computing, agent technology, GRID computing, and component software [4-7]. Recently, many mechanisms and methodologies have been developed for supporting trusted communications and collaborations among computing nodes in a distributed system [8-11]. These mechanisms and methodologies are based on digital modeling of trust for trust evaluation and management.

Due to the subjective characteristic of trust, trust management needs to take the trustor's criteria into consideration. For a digital system, it is essential for the user's device to understand the user's trust criteria in order to behave as her/his agent for trust management. However, most of today's digital systems are not designed to be configured by the users with regard to their trust criteria. Generally, it is not good to require a user to make a lot of trust related decisions because that would destroy usability. Also, the user may not be informed enough to make sound decisions. Thus, establishing trust is quite a complex task with many optional actions to take. Trust should rather be managed automatically following a high level policy established by the trustor [12]. Embedding the user's criteria/standard of trust in different contexts into the device requires interaction between the user and his/her device. This would require a friendly user interface to a) collect useful information (e.g. a user's trust criteria) for trust evaluation and management; b) present the evaluation results in a comprehensive manner to the user; c) disseminate individual experiences to other devices as recommendations or contribute to reputation generation. There could also be other novel approaches that can help us to make a usable trust management system.

In this paper, we propose a user driven trust modeling and management method in order to design and develop a usable trust management solution that can be easily accepted by the users towards practical deployment. Our motivation rose from a weakness encountered in our past work about autonomic trust management [12]. We met some practical issues during the trust management system deployment. Concretely, how to extract user's trust criteria in a dynamically changed environment, how to disseminate users' past experiences in a friendly approach and how to inform the user trust information in an understandable and comprehensive measure are what we confront in practice, especially in a mobile system. We focus on supporting trust between a user and a digital system, which is either a device or a digital service or a software application consumed by the user.

The rest of the paper is organized as follows. Section 2 gives a brief overview of the literature background. Section 3 proposes the method of user driven trust modelling and management. In Section 4, we illustrate how to apply this method by taking the design and development of a mobile application's reputation system as an example. We further discuss the advantages of our method in Section 5. Finally, conclusions and future work are presented in the last section.

2 Background

In this part, we briefly review the methods used in the literature regarding trust management for digital systems. Generally, there are two main categories. One is psychological and sociological study on trust in the area of trustworthy interaction with digital systems. The other is engineering study on trust in a computational way or for the purpose of trusted computing. We aim to study different methods applied in the literature in order to propose a feasible approach that can be adopted in practice towards usable trust management for mobile systems.

2.1 Psychological and Sociological Study on a Trustworthy System

In [13], the early formation of trust and the likelihood that a shopper will return to a website for subsequent purchases were examined. Two hypotheses were proposed in the study and corresponding experiments were conducted to prove them. The first hypothesis is that the presence of voice and interactivity should each lead to higher ratings on trustworthiness and other positive attributions. The second hypothesis assumed that trust in a store's reliability and the ability of the user interface to engage the user should significantly predict purchase intent. Based on the hypothesis, the authors studied user's behavior after first impression – an initial trust behavior, and after real experience based on initial trust. Results indicate that real-time interactivity, but not voice, increased judgments of friendliness and of the trustworthiness of the salesperson. The research method applied in this paper is worth referring to in order to design a trustworthy user interface.

Lumsden and MacKay presented and discussed the results of a study which took an initial look at whether consumers with different personality types (a) are generally more trusting and (b) rely on different trust cues during their assessment of first impression vendor trustworthiness in B2C E-commerce [14]. They developed a questionnaire-based survey to serve as an initial investigation into the effect of personality type on consumers' trust and perception of importance of trust triggers. A five-point Likert scale was applied to let respondents respond their feedback of each questionnaire item. The method used in this study is helpful to investigate the trust influencing factors and user's opinion on user-device interaction designs.

Li, Valacich and Hess made use of a survey instrument to measure the trusting constructs and sub-constructs in two initial trust models: McKnight, Choudhury and Kacmar's trust model in e-commerce [15] and TTFM (Technology Trust Formation Model) model in information systems [16]. A number of measurement scales were developed to conduct an experimental study regarding these two models on the basis of large number of participants. This kind of measurement scale based study could help us to work out the trust constructs regarding a specific system or scenario. The result could instruct the design of a trust management system. Unfortunately, it is impossible to apply the graphic or linguistic trust constructs directly for digital trust evaluation and management.

Herlocker, Konstan and Riedl studied explanation's influence on user's acceptance of ACF (Automated Collaborative Filtering) systems [17]. They addressed explana-

tion interfaces for ACF systems – *how* they should be implemented and *why* they should be implemented. A model for explanations based on the user's conceptual model of the recommendation process was proposed. User experimental results demonstrated what components of an explanation are the most compelling. To address *why*, experimental evidence was presented to show that providing explanations can improve the acceptance of ACF systems. It has been accepted that user experiment study can greatly help designing a trustworthy system user interface.

Pu and Chen used a qualitative survey to find research focus – explanation interface and the related design issues [18]. They further used pilot study and interview; post-survey discussion/interview; significant scale empirical study; paired samples, t-test, and five-point Likert scale to conduct continuous research.

An integrated model of trust in electronic commerce was proposed in [19]. This model serves as the theoretical foundation to study the impact of trust on the success of electronic commerce. The model was developed by studying existing research in diverse fields such as psychology, social psychology, relationship theory, and human machine interaction, then integrated all valuable results into a comprehensive model. This method is beneficial for us in order to propose a new method built upon the advantages of previous work.

The above described pieces of work aim to conceptualize trust based on user studies through a psychological or sociological approach (e.g. a measurement scale, interview, focus group, etc.). This kind of research aims to prove the complicated relationships among trust and other multiple factors in different facets. The trust models generated based on this approach are generally linguistic or graphic [1]. They do not quantify trust for machine processing purposes. Therefore, the achieved results could only help people understanding trust more precisely and generally work as a design guideline or an organizational policy towards a trustworthy digital system or a trustworthy user interface. Although little work has been conducted to integrate psychological, sociological and technological theories together, we believe, however, that the psychological and sociological study results could further play as practical foundations of computational trust – modeling trust for a digital processing purpose.

2.2 Computational Trust

The method to specify, evaluate, set up and ensure trust relationships is referred to as a trust model [2]. Computational trust is a technical approach applied to represent trust for the purpose of trust calculation and digital processing. Regarding computational trust, we found quite a number of studies in the literature [1]. One of the earliest formalizations of trust in computing systems was done by Marsh in 1994 [20]. In his approach, he integrated the various facets of trust from the disciplines of economics, psychology, philosophy and sociology. Since then, many trust models have been constructed for various computing paradigms such as ubiquitous computing, peer-to-peer (P2P) networks, and multi-agent systems. For example, Abdul-Rahman and Hailes used discrete integer numbers to describe the degree of trust in virtual communities [22]. Then, simple mathematic, such as minimum, maximum, and weighted average, is used to calculate unknown trust values through concatenation and multi-path trust

propagation. Buchegger and Le Boudec designed a distributed reputation system using a Bayesian approach for P2P and mobile ad-hoc networks, in which the second-hand reputation rating is accepted only when it is not incompatible with the primary rating [23]. In almost all of these studies, trust is accepted as a subjective notion by all researchers, which brings us to a problem: how to measure trust? Translation of this subjective concept into a machine readable language becomes a main objective. However, most of above studies focus on computational trust expression and calculation. Some subjective parameters or subjective policies (e.g. weighting) used in the models were generally hidden in the system without any confirmation from the users if they were the trustors.

Sun, Yu, Han and Liu presented an information theoretic framework to quantitatively measure trust and model trust propagation in ad hoc networks [8]. In the proposed framework, trust is a measure of uncertainty with its value represented by entropy. The authors develop four axioms that address the basic understanding of trust and the rules for trust propagation. Based on these axioms two trust models are introduced: entropy- based model and probability-based model, which satisfy all the axioms. The only doubt of this work is whether the fundamental axioms could be accepted by normal users, which could be an issue in practical deployment.

Xiong and Liu presented five trust parameters used in PeerTrust, namely, feedback a peer receives from other peers, the total number of transactions a peer performs, the credibility of the feedback sources, a transaction context factor, and a community context factor [5]. By formalizing these parameters, a general trust metric is presented. It combines these parameters in a coherent scheme. This model can be applied into a decentralized P2P environment. It is effective against dynamic personality of peers and malicious behaviors of peers. This work did not consider P2P system users' concern regarding feedback distribution and collection. It applied a laboratory simulation to prove trust evaluation metric and its efficiency against malicious peers.

2.3 Applied Methods

The study of a trustworthy system is wide. We briefly summarize some methods applied in the related work in Table 1.

Table 1: Research methods for establishing a trustworthy system

Examples	Research Methods
Basso, Goldberg, Greenspan and Weimer [13]	Hypothesis based initial study; trust model design based on experimental results on users
Lumsden and MacKay [14]	Questionnaire-based survey with five-point Likert measurement scale
Li, Valacich and Hess [16]	A number of measurement scales developed to conduct an experimental study regarding two initial trust models; comparison of two models
Herlocker, Konstan and Riedl [17]	Research questions based exploration; user experimental study to prove hypothesis
Pu and Chen [18]	Qualitative survey; pilot study and interview; post-

	survey discussion/interview; significant scale empirical study; paired samples, t-test, and five-point Likert scale
Kini and Choobineh [19]	Integration of previous research results
Abdul-Rahman and Hailes [22]	A discrete trust model for supporting trust in virtual communities, which is based on experience and reputation. An example application was given for illustration
Buchegger and Le Boudec [23]	A continuous trust model based on a modified Bayesian estimation approach. Simulation proof on its performance
Sun, Yu, Han and Liu [8]	Axiom based trust modeling and evaluation; laboratory simulation proof
Xiong and Liu [5]	Laboratory simulation proof on the proposed trust metric

Obviously, a thorough understanding of both the psychological and engineering aspects of trust is necessary in order to develop a usable trust management solution. However, psychological and sociological trust study lacks a way towards digital trust management, while engineering study lacks a basic sociological and psychological foundation in order to convince normal user for easy acceptance. Current computational trust study generally lacks sociological and psychological support. Therefore, it is hard to predict if a trust management system built upon it could be easily accepted and widely used. A gap exists between these two categories of trust research. The reason could be they are solving different research issues. But for developing a practical trust management system, we need to apply the advances of both researches and make the computational trust derived from social trust finally benefit the users.

3 A Method of User Driven Trust Modeling and Management

To overcome the above gap, we propose a user driven trust modeling and management method. We aim to design and develop a usable trust management solution that can be easily accepted by the users towards practical deployment. Our focus is to support user-device and user-system trust. For low level trust management (e.g. trustworthy network routing) without any concern and involvement of users, this method may not applicable since it only treats the cases with the user as the trustor. Herein, the term "user-driven" means that user study is applied in every step of our research in order to prove users' acceptance of our proposal, design and development. A user-driven computational trust model will play as the core of the trust management system achieved through applying this method. Additional user experimental studies will be further conducted in order to design trustworthy human-device interaction required in the trust management system.

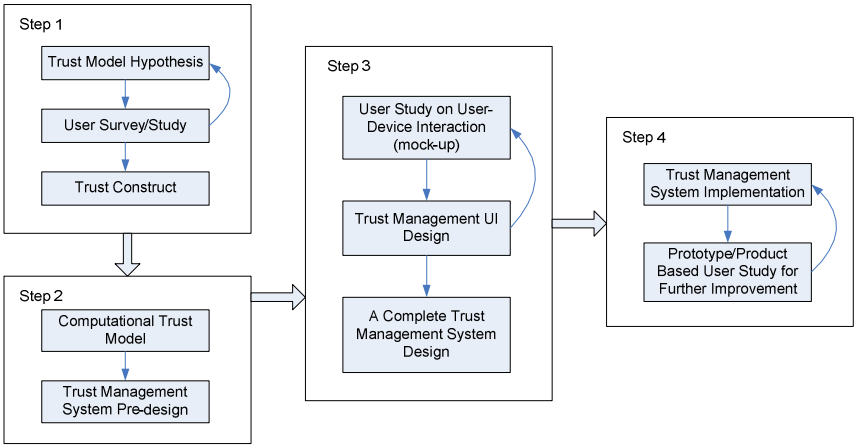

Figure 1: A procedure of user driven trust modeling and management

Figure 1 presents our research method with four steps.

Step 1 aims to figure out trust constructs for trust modeling. Firstly, we propose a number of hypotheses. We then design a measurement scale to conduct user experiments on a suitable number of users. We further apply a psychometric method to analyze the experimental results in order to find out the constructs and sub-constructs of a trust model. The above procedure could be repeated in order to achieve a convinced trust construct. For example, the user experiments should be conducted at least twice in order to extract principle factors of trust construct, optimize the measurement scale and study the causal relationships among those factors [15]. This is the psychological and sociological study of trust model. The result is a clear construct of trust based on users' feedback.

Step 2 aims to work out a user driven trust model and the pre-design of trust management system. In the way towards digital management of trust, we should further work out a computational trust model on the basis of the trust construct achieved in the first step. The computational trust model should reflect the principle factors of trust construct and their causal relationships. Laboratory simulation based proof is essential since users' feedback itself may not help to overcome a number of malicious behaviors or serious attacks. The computational trust model proposed based on the user study should be further improved and optimized according to the simulation results. We call what we achieve as a user driven trust model. At this time, the trust management system can be pre-designed according to the achieved model.

In Step 3, we conduct relevant user study about the pre-designed trust management system. User's feedback should be collected and analyzed regarding user-device or user-system interaction for trust management. The user experiment could be mockup based and repeated several times in order to improve/optimize and pre-prove the user-device interaction design for trust management. After this, a complete trust management system design (i.e. both backend design and front end design) can be achieved.

In Step 4, a prototype or a trial product implementation is conducted. Based on it, real system usage experiences are collected from the users for further improvement.

The improved system could be further studied through real usage for next round of optimization.

We summarize the above procedures with the listed steps below:

Step 1:

a) Propose research questions and hypothesis towards a trust model for the underlying trust management system;
b) Prove hypothesis through user study (a) and b) could be repeated);
c) Extract trust constructs based on psychometric analysis;

Step 2:

d) Propose a computational trust model based on the trust constructs;
e) Conduct laboratory experiment to optimize and improve the proposed computational trust model;
f) Pre-design the trust management system based on the user-driven computational trust model;

Step 3:

g) Mockup based user study regarding user-device interaction design for trust management;
h) Design user interfaces for trust management (g) and h) could be repeated);
i) Do a complete system design based on the pre-design and UI design;

Step 4:

j) Implement the trust management system design;
k) Prototype/product trail based user study and further improvement of the design (j) and k) could be repeated).

It is important to note that some sub-steps listed above are iterative in order to achieve either a good model or a usable design. The purpose is to concern the users' preference and considerations as early as possible, thus effectively save the cost of the system development and enhance the users' acceptance.

4 Applicability Study

In this section, we take the design of a mobile application reputation system as an example to illustrate how to apply the proposed method into practice. A mobile application is a software package that can be installed and executed in a mobile device, for example, a mobile email client that can help a mobile user to check and manage his/her email using a mobile phone. Generally, the mobile applications developed by various vendors can be downloaded from a web site or received from another device for installation. The trustworthiness of a mobile application influences the user's purchase and usage and thus becomes a crucial issue that impacts its final success.

We aim to design and develop a common and usable reputation system for various mobile applications that could help the mobile users' purchase and usage. We hope to achieve sound usability; otherwise the users could not accept the system. This means user-device interaction for trust management should be designed in a usable way. Additionally, the system can be easily followed and accepted by mobile users. It is ideal that the users feel very natural and normal with regard to data extraction and dissemi-

nation for trust/reputation evaluation, trust criteria input and trust/reputation information presentation.

4.1 Trust Construct Analysis

In order to collect users' usage experiences in an easy and usable way for trust and reputation evaluation, we propose a hypothesis: a user's trust in a mobile application can be reflected through his/her usage behavior. Then, we design a questionnaire with seven-point Likert measurement scale to conduct a user survey. Based on the survey results, we can analyse and achieve the detailed construct of trust behaviors regarding mobile application usage [21]. Those trust behaviors can be automatically monitored and thus recorded when the mobile user is using the application. Therefore, the mobile device can automatically collect useful information for trust/reputation evaluation without bothering the user.

4.2 Computational Trust Model and Trust Management Design

A computational trust model can be further proposed based on the trust construct achieved from the Step 1. It reflects the principle factors related to trust and their causal relationships with a mathematical measure. We should further conduct laboratory simulations to optimize and improve the computational model. Target is to make it robust against various malicious behaviors and attacks. This model can be used to calculate each user's trust in a mobile application. It can also be used to combine trust values from a number of users together in order to achieve a reputation value of the mobile application. Based on the above achieved model, a reputation trust management system can be pre-designed.

4.3 User Study on Pre-designed Trust Management System

At this point, we make clear what user-device interactions are needed in the underlying system pre-design. Clearly, data extraction for trust management can be conducted automatically with few user interactions (e.g. allowing the device to monitor personal usage behavior). What we need to study is why, how, what and when to show trust/reputation information to the user and the corresponding design for trustworthy user-device interaction (e.g. how to make user feel convenient to share his personal usage experiences and trust information). A practical strategy could be that the user is asked to agree sharing his/her personal trust information in order to retrieve the reputation information of a mobile application.

For each required user-device interaction in the pre-designed system, we should conduct corresponding user study in order to design an easily accepted user interface with the users' considerations kept in mind. In this case, we need to study the following:

a) Whether it is helpful to provide trust or reputation information to the users when they are using a mobile application. This study aims to solve the issue why interaction between user and device is needed.

b) How to display the trust/reputation information and what contents should be provided to the users and in which way. This study aims to solve the issues how to interact and what to be interacted.

c) At which moment is user-device interaction required, (e.g. whether user's confirmation is needed for sharing his usage history with others or a reputation service provider). This study aims to answer the question when interaction is required.

According to the above user study results, the system user interface design can be worked out to satisfy users' preferences and considerations. We can then work out a complete reputation system design for implementation.

4.4 Prototype Based User Study for Further Improvement

A prototype/product trial could now be implemented on the basis of the user driven trust modeling and management system design. Based on the prototype or trial system, real system usage experiences can be collected from the system users for further improvement.

5 Discussions

We believe our method hold a number of advantages over existing methods. Firstly, the user driven trust model is proposed based on a wide user survey. Statistical data analysis plays as the foundation that could help us generate a trust model easily accepted by the users. Thus our method overcomes the weakness of current computational trust models that were built beyond any considerations of users.

Secondly, the computational trust model is proposed on the basis of trust constructs achieved from the user study. It is further improved and optimized based on laboratory experiments in order to overcome malicious behaviors and attacks. This compensates the problem of linguistic or graphic trust models generated purely from the user study and its hardness to be directly applied into trust management for a digital system.

Thirdly, sound usability could be easily achieved if applying our method. Based on the user driven trust modeling and management system design, we can study why, when, how and what should be interacted between the users and their devices. These user studies play as the basis for designing a trustworthy system, including user interface design. In addition, the method itself could study the applicability of a system design that aims to release the burden of user-device interaction.

6 Conclusions and Future Work

In this paper, we presented our motivations for developing a usable trust management solution. We briefly overviewed the literature and research methods applied for establishing a trustworthy system. We found that it lacks a practical approach that could help us design and develop a usable trust management system. Furthermore, we proposed a method called user driven trust modeling and management to overcome the weakness of existing methods. We illustrated its applicability through applying it into the design and development of a reputation system for mobile applications. Although our work is still at the initial stage, this paper contributes on two folds. Firstly, it motivated to drive trust modeling and management from the users' points of view towards practical deployment and usage. Secondly, it proposed an applicable and cross-disciplinary method to design and develop a usable trust management system through integrating the advances of both psychological and sociological trust study and computational trust study.

At present, we are developing a reputation system for mobile application using the proposed method. Our current working status is that we are conducting a large-scale user survey in order to work out a detailed trust construct based on user behaviors. The early results are presented in [21]. Based on the achieved trust construct, we have proposed a computational trust model and a reputation system for mobile applications. Meanwhile, we have designed and are conducting a mock up user study to figure out why and how trust/reputation information should be presented to the mobile users when they are using a mobile application. We still have a lot of future work to perform. We will further prove and improve the user driven computational trust model through laboratory experiments. We will conduct other user studies that could help us to design a trustworthy user-device interaction interface based on the predesigned system. Further proof and improvement of our method should be based on the real usage experiences of the prototype system and/or real product.

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