

Uncertainty and Trust

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1 Introduction

This report summarizes the findings of a working group on "Uncertainty and Trust" which met during Dagstuhl Seminar 08421 "Uncertainty Management in Information Systems". All participants of the working group are co-authors of this report. The aim of the working group was to analyse the relationship between trust and uncertainty in distributed reputation systems. We started by identifying sources and types of uncertainty in this context and investigated their relation to trust. After that we compiled a list of desirable properties of trust representations and finally determined open research challenges in the area.

2 Scenario

We consider decentralized systems, e.g., multi-agent systems, where autonomous entities, e.g., agents, have to perform individual tasks, either for themselves or on behalf of a human principal. Since those entities are restricted in terms of their capabilities, they have to delegate some of their tasks. Obviously, cooperation among entities is crucial in such systems. However, agents have restricted resources and may have conflicting goals. Since they are autonomous, i.e., a central authority controlling interactions between system participants is missing, non-cooperative behavior is likely, as in the absence of incentives, the best response for rational agents is to defect. Consequently, an agent interacting with another one cannot be sure about the outcome of this interaction. An undesirable interaction outcome is coupled to some kind of loss (negative utility) and thus interacting with another party is associated with a certain risk. Hence, selecting an agent from a number of possible interaction partners requires decision-making under uncertainty. Trust and reputation systems assist in this process by utilizing

experiences made in former interactions to assess the degree of uncertainty that is associated with a specific transaction partner, i.e., the subjective probability that a transaction with this partner will be successful. Jøsang et al. [1] refer to this kind of trust as *reliability trust*. Finally, trust or *decision trust* as referred to in [1] denotes the extent to which an entity is willing to enter into a transaction with another one. It depends on the degree of uncertainty and the risk associated with a selection decision as well as on the personal and situation-dependent risk attitude of the decision maker.

3 Sources of Uncertainty

As already seen, trust is tightly coupled to uncertainty. We identified various sources of this uncertainty, which require different treatment.

- uncertainty about the identity
- uncertainty in the behavior of the interaction partner (this includes intended (cheating) and unintended misbehavior (system crash, ...))
- uncertainty in observation (even if an interaction partner cooperates, we may observe misbehavior due to noisy "sensors" and "channels")
- second-hand experiences reduce uncertainty, but also introduce additional uncertainty:
 - uncertainty about the reliability of an experience provider
 - uncertainty about the interpretation of an experience (due to different system models, subjective world view)
 - uncertainty about the transferability/applicability of an experience (also think about the context of an experience)
 - uncertainty about the temporal accuracy, and therefore the predictive power, of an experience (since the behavior of a transaction partner may change over time)

Ideally, a trust system can represent trust in a meaningful way despite these uncertainties by taking them into account when calculating or estimating trust values.

4 Desirable Properties of Trust Representations

Trust is coupled to the notion of both risk and uncertainty, meaning if there is no risk, i.e., nothing to win or to lose by entering into a transaction, there is no need to trust. Therefore, to allow for decision making we require two components: first, a representation of uncertainty and, second, a representation describing the risk related to a given choice. In the following we determined desirable properties of trust/uncertainty representations. We omitted the problem of representing the risk associated with an interaction as an orthogonal issue.

1. **A trust representation should reflect/integrate different "uncertainties"**.
 - We identified two main types of uncertainty: "natural" uncertainty about the outcome of a transaction and "artificial" uncertainty resulting from the fact that we use second-hand experiences.
 - We thus require two uncertainty measures, one capturing the "natural" uncertainty predicted from the second-hand information and one characterizing the "artificial" uncertainty, i.e. the confidence of this prediction.
2. **A trust representation should allow for decision making** and should have the following properties:
 - enable ranking of alternatives,
 - allow to compare with own standards,
 - enable to calculate expected risk.
3. **Scalar vs. complex trust representation**, e.g., whole explanation
 - Explanations/interaction context are helpful in reducing the uncertainty resulting from using second-hand experiences.
 - But: we have to consider privacy issues (Open Issue: How can we transmit explanations/interaction context without harming privacy?) as making sure the explanations are not forged (i.e., evidence or non-repudiation).

5 Research Challenges

Given the desirable properties of trust values and the different sources of uncertainties we listed in the previous sections, a main research challenge is how to represent trust accordingly - both for a single agent and for meaningful exchange between agents in order to benefit from second-hand information.

The following are research questions we would like to see answered:

- Can explanations help to generate trust?
- Can context help to generate trust?
- Can second-order prediction/trust help?
- How should initial trust be represented, bootstrapped?
- What are the dynamics of trust systems?
- What is the relation between Byzantine agreement and trust?
- Do we need trust strategies?
- How do different trust systems with their representations compare qualitatively and quantitatively?

References

1. Jøsang, A., Presti, S.L.: Analysing the relationship between risk and trust. In: Proceedings of the Second International Conference on Trust Management (iTrust, Springer-Verlag (2004) 135–145