

A Trust Model for Supply Chain Management

Yasaman Haghpanah* and Marie desJardins†

Department of Computer Science and Electrical Engineering

University of Maryland Baltimore County‡

{yasamanhj, mariedj}@umbc.edu

<http://www.csee.umbc.edu/~yashagh1/>

Abstract

Many real-world applications, such as Supply Chain Management (SCM), can be modeled using multi-agent systems. One shortcoming of current SCM models is that their trust models are ad hoc and do not have a strong theoretical basis. We propose a trust model for SCM that is grounded in probabilistic game theory. In this model, trust can be gained through direct interactions, and/or by asking for information from other trustworthy agents. We will use this model to simulate and study supply chain market behavior.

Supply chain networks have often been modeled in the research literature with multi-agent systems in which the agents need to collaborate with one or more partners. This collaboration becomes more effective when agents have the ability to choose their partners based on the trustworthiness of the candidates. Trust is defined as the belief an agent has that the other party will fulfill its promises, given the possibility that the partner may defect to get higher benefits (Dasgupta 1998). A major shortcoming in previous research on trust in Supply Chain Management is that their trust-based decision making is not grounded in a formal trust model.

In this work, we propose a trust model for SCMs that incorporates trust factors specific to SCM, represented in probabilistic and utility-based terms. Our model also takes into account the effects of variable payoffs. We will investigate how market behavior is affected by different trust factors. We will identify optimal strategies for different situations; i.e., those strategies that result in the best performance and overall returns. This abstract describes our initial framework, which we are currently implementing.

Related Work

Trust has been used in all levels of multi-agent interactions, including individual-level and system-level trust. In individual-level trust, each agent has some beliefs about the honesty and reliability of its counterparts, which can

be formed through direct interaction with partners, by asking other agents about potential candidates (reputation exchange), and/or by forming and reasoning about beliefs of other agents' characteristics. System-level trust can be achieved when the rules that control the system force agents to be trustworthy (Ramchurn et al. 2004). Learning trust from direct experiences is advantageous when agents have repeated interactions. By contrast, reputation exchange is most useful for learning the trustworthiness of other agents quickly (Mui 2003).

There have been several proposed approaches for adding trust models into SCM. Centeno et al. (2009) propose a reputation mechanism based on organizational concepts and personal norms, with which agents define their preferences about potential interactions. However, this information is not sufficient for adaptively learning trust models, since agents do not model their confidence in the information they receive from other agents. Lin et al. (2005) build a trust model based on experiences with suppliers; trust is measured in terms of product quality, order-cycle time, and price. They generalize these factors to the abstract concepts of ability, integrity, and benevolence. This model does not use probabilistic decision theory. Other SCM trust factors have been studied as well, although many of them are focused on specific SCM industries. For example, Paterson et al. (2008) studied twelve trust factors, identifying three factors that are critical to the horticulture supply chain: shared values, point-of-sale information, and honesty and integrity.

The above trust frameworks categorize some aspects of trust, but most of them focus on producing a single metric for trust or reputation (Sabater and Sierra 2001, Mui 2003). In addition, many trust frameworks do not use probabilistic methods, preferring ad hoc valuation schemes (Sabater and Sierra 2001). Smith and desJardins (2009) proposed a probabilistic trust model grounded in decision theory; their model allows an agent to decide whether or not to interact with another agent by predicting the trustworthiness of the agent. This trust-based decision framework separately models *integrity* and *competence*, and can therefore handle environments where payoff varies. Competence is modeled as the probability that a given agent is able to execute an action in a particular situation. Integrity is an agent's attitude towards honoring its commitments, and is affected by the perceived probability that an interaction will be repeated.

*PhD student at UMBC, started in Spring 2009

†Associate Professor at UMBC

‡1000 Hilltop Circle, Baltimore MD 21250, 410-455-8894

Copyright © 2010, Association for the Advancement of Artificial Intelligence (www.aaai.org). All rights reserved.

Smith and desJardins's model uses applied probability in the context of IPD games, and does not include a reputation exchange model. We will combine this model with SCM-related trust factors and a reputation exchange mechanism to adapt it to real-world scenarios.

Approach

Our SCM model consists of several layers in a supply network, where each layer contains a number of agents. The layers can correspond to suppliers, producers, distributors, or retailers. Each agent in each level connects to some of the agents in neighboring levels to obtain or provide services and ultimately form a team or a "supply chain." In general, upstream agents provide services (or deliver goods) to adjacent downstream agents, and downstream agents ask for services (or bid on goods) from adjacent upstream agents. In this model, we also use variable payoffs for different services in different environments. Agents in this framework use a utility function to estimate the future reward that would result from working with a potential partner.

Each downstream agent has a list of criteria and preferences for the services or goods that it needs. For example, one downstream agent might need a high-quality material from an upstream agent, with three weighted criteria: quality 70%, price 20%, and time 10%. In this case, the most important factor for the agent is quality. Downstream agents ask for goods from upstream agents, or bid for the services of those agents. The downstream agents will select the closest match of possible offers based on their criteria and preferences in such a way that the selected offer maximizes the agent's return utility.

In our model, trust by downstream agents in upstream agents is maximized when the latter agents provide goods and services with low prices and good quality in a timely manner. To model trust in this case, we define the two components of competence and integrity for each factor (e.g., quality, price, and time). The competence for each of these factors is the probability that the upstream agent is able to fulfill the commitment. Integrity is modeled as the degree to which the agent keeps the same behavior in the long term and in variable-payoff situations. For example, the upstream agent might offer the desired service for two rounds, but after gaining the trust of the downstream agent, the agent might betray in the third round, if they have low integrity for that service. On the other hand, trust of an upstream agent in a downstream agent is affected by the number of times that the downstream agent has accepted the upstream agent's offer, the payoff level for each interaction, and the frequency of on-time payments. Each of these factors is also modeled using competence and integrity. The combination of these factors will yield an overall trust level of an upstream agent in a downstream agent.

We propose to add another individual-level trust mechanism—namely, reputation exchange—into our model. Agents might have different opinions about the reputation provided by another agent, based on how well each agent knows that agent. To address this complexity, we propose to use a weighting factor for the exchanged information, taking into account the size of payoffs in the previous transactions

with that agent, how many interactions they have had, and for how long they have known each other.

Reputation can be exchanged as a bundle including trust factors (quality, price, time, and/or on-time payment), confidence in trust factors (competence and integrity), and personal criteria. To make our model more realistic, we will consider cost associated with reputation exchange, modeled as money, time, and/or a limitation on the number of messages each agent can send.

We have performed some preliminary experiments on a simplified general SCM based on direct experience only. Our preliminary results demonstrate improved performance in terms of overall return.

Conclusion

We propose to incorporate a trust model into a realistic SCM agent-based model, with a focus on modeling multiple factors that affect trust, and on incorporating indirect (reputation-based) trust. We will investigate how different trust factors affect the system in terms of the performance and stability in realistic markets under different conditions. We will evaluate the results with and without the proposed trust model, and will study the effect of different parameters on the market.

References

- Centeno, R., Silva, V., and Hermoso, R., 2009. "A reputation model for organisational supply chain formation," *COIN@AAMAS*.
- Dasgupta, P. 1998. "Trust as a commodity," *Trust: Making and Breaking Cooperative Relations*, chapter 4, 49-72.
- Lin, F., Sung, Y., and Lo, Y. 2005. "Effects of trust mechanisms on supply-chain performance: A multi-agent simulation study," *Int. J. Electron. Commerce* 9(4):9-112.
- Mui, L. 2003. "Computational models of trust and reputation: Agents, evolutionary games, and social networks," *PhD thesis*, Massachusetts Institute of Technology.
- Paterson, I., Maguire, H., and Al-Hakim, L. 2008. "Analysing trust as a means of improving the effectiveness of the virtual supply chain," *Int. J. Netw. Virtual Organ.* 5(3/4):325-348.
- Ramchurn, S. D., Huynh, T. D., and Jennings, N. R. 2004. "Trust in multi-agent systems," *The Knowledge Engineering Review* 19(1):1-25.
- Sabater, J., and Sierra, C. 2001. "Social regret, a reputation model based on social relations," In *ACM SIGecom Exchanges* 3.1:44-56.
- Smith, M. and desJardins, M. 2009. "Learning to trust in the competence and commitment of agents," *Autonomous Agents and Multi-Agent Systems* 18(1):36-82.