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# Intelligent Agents in a Trust Environment

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## ABSTRACT

*Intelligent agents and multi-agent technologies are an emerging technology in computing and communications that hold much promise for a wide variety of applications in Information Technology. Agent based systems range from the simple, single agent system performing task such as email filtering, to very complex, distributed system of multiple agents each involved in individual and system wide goal oriented activity. With the tremendous growth in the Internet and Internet based computing and the explosion of commercial activity on the Internet in recent years, intelligent agent based systems are being applied in a wide variety of electronic commerce applications. In order to be able to act autonomously in a market environment, agents must be able to establish and maintain trust relationships. Without trust, commerce will not take place. This research extends previous work in intelligent agents to include a mechanism for handling the trust relationship and shows how agents can be fully used as intermediaries in commerce.*

## INTRODUCTION

As we look towards the future of electronic commerce, one can see a world where intelligent agents will play a larger and increasingly more important role in day-to-day transactions between both businesses and people. These agents will be used in situations previously only addressed by humans. As more businesses move towards this point, agents must be able to address one of the most important parts of electronic commerce, the trust relationship. This research builds upon the prior work of Maes (1999) and Bakos (1998) to extend the notion of intelligent agents working in an electronic market to include the building and maintaining of trust relationships.

Bakos (1998) establishes a framework (see Figure 1) for both electronic and non-electronic markets identifying three main functions: matching buyers and sellers, facilitation of transactions and institutional infrastructure. Intermediaries usually provide the first two of these functions while the third is the domain of governmental agencies.

**Matching buyers and sellers**
- Determination of product offerings
- Search
- Price discovery

**Facilitation of transactions**
- Logistics
- Settlement
- Trust

**Institutional infrastructure**
- Legal
- Regulatory

Figure 1

Maes, et. al. (1999) argue that intelligent agents are well suited for the roles that intermediaries play in commerce. In an electronic environment, agents fill many roles involved in matching buyers with sellers. Maes et al. (1999) have shown the application of intelligent agents to brokering and negotiating purchases between buyer and seller in the Kasbah project. However, in this project, issues involving trust are identified as more limiting than the issues involving artificial intelligence. In order for these agents to be widely accepted, the user must understand and easily control the mechanisms the agent uses to determine its behavior (Moukas, forthcoming). In an extension of the framework built by Maes et al.(1999), we will show how agents can be built to include the trust relationship necessary to fulfill the requirements put forth in the market framework of Bakos (1998).

## INTELLIGENT AGENTS

Intelligent agents and multi-agent technologies are an emerging technology in computing and communications that hold much promise for a wide variety of applications in Information Technology. An intelligent agent is "*a computer system situated in some environment and that is capable of flexible autonomous action in this environment in order to meet its design objectives* (Jennings and Wooldridge 1998). Agent based systems range from the simple, single agent system performing task such as email filtering, to very complex, distributed system of multiple agents each involved in individual and system wide goal oriented activity. With the tremendous growth in the Internet and Internet based computing and the explosion of commercial activity on the Internet in recent years, intelligent agent based systems are being applied in a wide variety of electronic commerce applications including on-line consumer purchasing, network management, supply chain systems, information retrieval, Internet based auctions, on-line negotiations.

Agent based systems may consist of a single agent engaged in autonomous goal-oriented behavior, or multiple agents that work together to exhibit granular as well as overall goal directed behavior. The general multi-agent system is one in which the interoperation of separately developed and self-interested agents provide a service beyond the capability of any single agent model. Such mutli-agent systems provide a powerful abstraction that can be used to model systems where multiple entities, exhibiting self directed behaviors must coexist in an environment and achieve the system wide objective of the environment. It is clear that agents are a powerful abstraction to model and design systems that require independent action at various levels of granularity of the system.

In the past few years, the Internet and the World Wide Web have become major vehicles for the growth of on-line commerce. The Census Bureau of the Department of Commerce estimated of U.S. retail e-commerce sales for second quarter 2000, not adjusted for seasonal, holiday, and trading-day differences, was $5.518 billion, an increase of 5.3 percent from the revised first quarter 2000

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level. The first quarter estimate was revised from $5.26 billion to $5.24 billion (US Department of Commerce, 2000). The department of commerce measures E-commerce sales as the sales of goods and services over the Internet, an extranet, Electronic Data Interchange (EDI), or other online system, where payments may or may not be made online. A recent report on the Digital Economy attributes the recent rapid growth of the Internet to its strength as a medium of communication, education and entertainment, and as a tool for electronic commerce. It is clear from all sources that advances in Information Technology and Electronic Commerce have been a significant contributor to the recent success and growth in the national economy.

Bakos (1998) points out that markets match buyers and sellers, facilitate transactions between them and provide and institutional infrastructure to support the transactions. In the contemporary marketplace, the first two of these three functions is conducted with intermediaries. In the electronic marketplace, these functions may be facilitated using electronic intermediaries by leveraging the efficiencies afforded by Information Technologies (Bakos, 1998). Intelligent agent technologies hold great promise for fulfilling the role of intermediary in the electronic marketplace and supporting, or conducting on behalf of the user, the processes involved in matching buyers and sellers and facilitating the transactions between them. The Internet is a large distributed environment platform where multiple agencies conduct commercial activity. This activity involves: the search for sellers with products to suit the buyers defined by price, quality, and other business considerations; the search for buyers who will buy the products of a seller; and the facilitation of such transactions. Intelligent agent technology has the technology to search through a large information space for specific needs and identify such sources. Intelligent agents can perform such searches within the parameters defined by the user and facilitate the transaction by bringing the resource to the user and act on behalf of the user to conduct transactions. Therefore, it is not surprising that significant attention is being paid to this technology for the facilitation and empowerment of electronic commerce by the academic and business communities.

Intelligent Agents that are primarily directed at Internet and Web-based activities are commonly referred to Internet Agents. There are many agent systems in the electronic commerce area, which perform limited functions to support users. Examples include Andersen Consulting's BargainFinder, which undertakes price comparison, as does Jango (see Doorenbos et al. 1997), and AuctionBot (see Wurman et al. 1998) and Kasbah (Chavez et al. 1997), which supports product transactions (Macredie, 2000). The Communications of the ACM ran a special issue in March 1999, which focused on how "software agents independently and through their interaction in multi-agent systems are transforming the Internet's character. Agents and the business performance they deliver will be involved in up to $327 billion worth of Net-based commerce in five years according to Forrester Research (Rosenbloom, 1999). Intelligent agents carry out activities in the electronic marketplace on behalf of the human user.

Maes et. al. (1999) present a model (Figure 2) for the behavior of intelligent agents over the web through traditional marketing consumer buying behavior models. The consumer buying behavior model illustrates the actions and decisions involved in the buying and using goods and services. This model is adapted in their research to consumer buying in the electronic marketplace and the use of intelligent agents in facilitating this activity. They present six states to categorize agent mediated electronic commerce.

1. Need Identification
2. Product Brokering
3. Merchant Brokering
4. Negotiation
5. Purchase and Delivery
6. Service and Evaluation

Figure 2

Intelligent agents may be used facilitate a number of these stages in the consumer buying model. The following table presents a summary of the activities involved in each of these stages and provides suggestions for the facilitating role agents may play in each of these stages.

| Consumer buying behavior model stage | Activities involved | Intelligent Agent Facilitation |
|---|---|---|
| Need Identification | Realization of unfulfilled needs by the consumer | Tools that alert the user to needs or opportunities based on knowledge of the user's preferences or business environment are useful in this regard. |
| Product Brokering | refers to retrieval of information about products. | In this stage, the agent is primarily involved in search activities to determine products and services to suit the consumer's needs. |
| Merchant Brokering | This stage provides a filtering of the information retrieved by the agents on the various products based on the criteria of the buyer. It results in the creation of a set of feasible sellers. | This stage is analogous to many traditional decision support activities that require choice on the part of the user. Agents may facilitate the ranking of alternatives thereby facilitating the generation of choice from the user. |
| Negotiation | This stage determines the terms of the transaction. It varies in duration based on a number of factors including the complexity of the marketplace, the number of feasible alternatives, the monetary and business value of the transaction. | This is a dynamic stage where the buyer and seller(s) agents communicate preferences to find a mutually agreeable set of terms for the transaction. This activity may be facilitated by agents through communication abilities and matching of the needs of the buyer with the capabilities of the seller. |

Table 1: The consumer buying behavior model and intelligent agent support.

The above model and the associated applications of intelligent agent technology provide a foundation for the analysis and development of intelligent agent based systems for Internet based application deployment. Individual components of the consumer behavior model's application to agent assisted electronic commerce may have greater significance than others based on the nature of application. Even with the completeness and wide scope of this model, there is a need to extend the model to account for trust. It is the one component of the Bakos (1998) framework for markets that is not addressed. In the absence of trust, agents will not be able to fully operate on behalf of their human masters, but instead can only provide basic data gathering functions or operate only under strict instructions. Barney wrote in 1995 that , "***Interpersonal and inter-organizational trust have been widely cited as important components of economics exchanges."*** For intelligent agents, trust is the missing piece to the puzzle.

## ELECTRONIC TRUST

Trust is perhaps the most important aspect of electronic commerce. It is at the very heart of its foundation. In the absence of trust, commerce usually breaks down. (Keen, 2000) The current use of intelligent agents in the electronic environment does not explicitly account for this necessary ingredient for success. This is a modification needed in the model proposed by Maes to enable agents to fully function in the current electronic marketplace. While it is true that we can program agents to buy and sell things, in order to become autonomous, we need to account for trust relationships. In the current literature, electronic trust is gaining importance and garnering much attention. Studies about trust can be found in many diverse disciplines such as: anthropology, economics, organization behavior, psychology and sociology. Bhattacharya et. al.(1998) attempt to synthesize several many different definitions of the construct to develop a research framework for this area. They define different criteria that a definition must include to truly represent the richness of it meaning. First, trust exists in an environment that includes uncertainty. Kollock (1999) and others (Deutsch, 1958, Sheppard, 1998) view trust as existing only in an uncertain and risky arena. In commerce, there is an exchange of information. Whether it is electronic or face-to-face, there is a sharing of personal information such as credit card numbers, addresses, phone numbers and other such information. The concept of sharing this information places the parties involved at risk. This places a price or value for the consumer on the presence of trust in a transaction. The second aspect of trust is that it can be predicted to exist. One can count on its presence. This could also be looked at as dependability (Sitkin, 1993). This really should be considered a distribution of the expectancy. At any given time, there is a percentage chance that the trust one has in a company will fail (Bhattacharya et al., 1998). Two other aspects to be considered are the strength and importance of the trust relationship. If the purchase is something of great importance or cost, the importance of the relationship will be heightened. If it were a minor purchase, the reverse would be true. The importance of trust in these relationships can be seen in the work of Zucker (1986) and others (Arrow, 1974, and Williamson, 1974) who claim that the basis for stability in markets is trust. The final aspect of the trust framework is that trust is good (Bhattacharya, 1998, Lewicki, 1998). It is to be considered a positive outcome. In the absence of trust, we have distrust, which will inhibit the growth of the online relationship. This research will show how this framework is used to explain behavior in markets that take place in a virtual space and how intelligent agents can build and maintain a trust relationship.

Given the range of disciplines that trust entails, it is important to clearly define the aspects of trust that are in the working definitions for this research. That definition is as follows:

> *Trust is an expectancy of positive (or nonnegative) outcomes that one can receive based on the expected action of another party in an interaction characterized by uncertainty.* (Bhattacharya, 1998)

Mayer et al. (1995) synthesizes multiple disciplines with the definition of trust as:

> "the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party."

To put it succinctly, Barney and Hansen (1994) describe trust as the avoidance of bad outcomes.

## AGENTS THAT TRUST

Having established the importance of trust in commerce, we now turn to how agents can carry out this most human of functions. This research presents a model for the application of intelligent agents in the implementation of electronic trust to facilitate electronic commerce. Using the framework defined by Bahattacharya et al. (1998), we will show that intelligent agents can be used to build and maintain trust relationships on behalf of the human owner that the agent is acting on the behalf of. The first requirement is that the agent can handle uncertainty and risk. These elements will be present in any transaction. For the agent to be successful at brokering a deal to the satisfaction of its owner, it must first know something about the preferences of that person. This information will be stored in a profile that the intelligent agent maintains and modifies over time. Much like profiling techniques that currently are employed on the Internet, information about buying preferences and approved vendors can be entered. This information gives the agent a starting point as it begins buying and selling activities. As transactions take place, the agent can modify its behavior based on the response from the user. For example, initially when trust in the agent is low, the user may wish the agent to search for prices, but not complete the transaction until authorization is approved. Through a series of acceptance or denials of suggestions, the agent can build a better profile about the buying and selling patterns of its users that later lead the user to allow the agent to complete the transaction without interacting with the user.

Two other important aspects of trust identified by Bhattacharya are the notions of importance and strength. As agents negotiate on our behalf, the items being considered for sale are important. If the transaction involves a small amount of money it may not be critical that the best price be found or that the transaction involves a certain vendor. As the importance of the transaction grows, the behavior of the agent will be modified. As an example, the agent's owner may have one set of preferences when the transaction cost is below a certain threshold, but require additional step for the agent to complete a transaction involving high price items. What is considered the threshold is something that will be set by the user and can be modified over time as the agent obtains a greater case history of transactions to search when making a decision. The strength of the trust relationship may be used to decide which vendors or buyers an agent will deal with. The agent can store a database of trust ratings for trading partners that it has previous experience with. In certain transactions, the agent can be required by its user to only interact with vendors or buyers that have the desired trust rating. These ratings could be obtained through experience or the agent could use an outside source such as a trust assurance service that is provided through a third party.

One final consideration in the trust relationship that can be programmed into the agent is the ability to store and utilize the rating of risk for its user. Some people will be more risk seeking than others. The intelligent agent will need to reflect this characteristic in order to be used without constant supervision. The agent will need to know in what types of situations a person is risk seeking and when they are risk adverse. For instance, when buying commodities, an individual may be indifferent between vendors and want to search for the best price. In other cases, the vendor may play a large role and the person is willing to accept a higher price in order to transact business with the particular company.

All of these considerations can be built into the next generation of intelligent agents. The end result is that agents will be able to reflect the characteristics that a person maintains and modifies in their trust relationships as they transact business. When we have agents that can account for trust, we have agents that can act as intermediaries and fulfill the first two roles identified in the framework by Bakos (1998).

## CONTRIBUTION

Intelligent agents have matured a great deal from the filter email and find information agents of a short time ago, but they still have more growing to do before they will be able to act on our behalf in a commercial situation. In this research we have outlined how an extension of the model by Maes et al. can allow for trust to be represented. By having agents that can build and maintain trust relationships, we are able to build agents that can operate in the market framework identified by Bakos. Intelligent agents can take the place of human intermediaries that previously have acted on our behalf. These agents can be flexible and can adjust their profile of the user based on user input and market interaction. Most importantly, this next generation of intelligent agents will be able to provide a mechanism for operationalizing trust, the cornerstone of commerce.

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