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Agent-Mediated Electronic Commerce: Issues, Challenges and some Viewpoints

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&
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Abstract

Electronic commerce is set to be a major application area of agent technology, yet it is not very clear from our published agents literature what the core research issues that we need to address in this area are. In this paper, we examine this important domain of agent-mediated electronic commerce highlighting in particular some of its key issues and challenges. It strongly takes the view that a research area is defined by its problems, not its methods, and hence we try and tease out some of the problems/sub-problems that define agent-mediated electronic commerce. We present them as a list of open questions. Next, the authors propound their viewpoints on these issues in the hope that it stimulates and influences the research that need to be carried out in order to realise truly usable, agent-mediated or agent-enhanced electronic commerce. This paper is a part summary of the views propounded by some of the panelists at a panel session on agent-mediated electronic commerce at the 2nd International Conference on Autonomous Agents held in Minneapolis, May 1998.

1 Introduction (Hyacinth S. Nwana, BT Labs)

Agents are software entities that have been given sufficient autonomy and 'intelligence' to enable them to carry out specified tasks with little or no human supervision. An agent interacts with an ever-changing environment whilst representing the interests of a particular owner. The convergence of computing and telecommunications is radically changing the future of traditional commerce, e.g. via the Internet. Indeed, electronic commerce is already considered to be a multi-billion dollar industry, and many researchers/analysts predict that agent-mediated electronic commerce would revolutionise Internet Commerce even more. However, traditional buying/selling of products will be only one of many services which customers will get on the Internet including entertainment, education, health and other seamless end-to-end services which would be available to Internet users from a myriad of service providers. Therefore, electronic commerce will cover a much broader scope than current traditional offerings.

Customers, we are told, will be able to delegate to agents the responsibility of accessing many service providers in just the...
same way we now access search engines, in order select and procure particular products and services. The wide variety of services on offer will mean that making the best choice will involve balancing factors such as price, availability, brand, quality, locality, etc. before committing to any particular vendor or service provider. It has been claimed that agent technology may be the only way that customers will be able to cope with the complexity and sheer volume of future commerce service offerings, particular on mediums like the Internet.

In order to allow new electronic commerce services to be created and brought to market quickly, the information systems of many companies will be required to interact flexibly, and perhaps in ways not foreseen in their original designs. Here as well, agents may provide a way for corporate electronic commerce service providers to facilitate information flows between their respective management systems.

If this projection is valid, then we might foresee the following uses for agent technology in commerce:

- Customers will employ software agents to help them identify, locate and procure the products and services that they require;
- Customers will empower and trust their agents (to varying degrees) to negotiate electronically with other customers and/or their agents in order to buy and sell products and services within a complex multimedia information trading system.

These raise example issues for discussion such as the following:

- What are the properties of agents and agent systems that are useful in commerce applications?
- What particular challenges does electronic commerce pose to agent technology?
- What requirements must be met before we can expect to see fielded systems?
- In what specific contexts might agents be trusted and empowered to conduct negotiations and make agreements? What are the implications of this?
- Indeed, how do we build trust and reputation into agent-mediated commerce systems?
- What kind of warranty has to be provided to customers in order to engage them to delegate to their agents everyday commerce tasks? How do we develop software that provides these warranties?
- What will be the marketing or economic consequences of the automation of commerce services and transactions using agent technology?
- What standards need to be in place for agent-mediated electronic commerce to be a reality?
- What roles will certification authorities, trusted third parties and security/authentication functions play in agent-mediated electronic commerce?
- How do we ensure our agent-mediated electronic commerce systems are stable, scalable and have adequate performance times?
- What state of the art technologies are available to allow agents to "understand" multimedia information like sounds, images, video and text in order to facilitate commerce within a complex multimedia information system?

The aim of this paper is to define the domain of agent-mediated electronic commerce by asking such questions as these above. We identify such goals and challenges for agent-mediated electronic commerce with a view to informing and influencing future research to facilitate its realisation. We hope the views propounded below also highlight the opportunities agent-based commerce creates, what some of their threats, strengths and weaknesses are. What lessons are there to be learnt from current fledgling attempts to deliver agent-based commerce? What are the key barriers to the uptake of this technology?

The following several responses below are viewpoints to the above questions from notable agent researchers and developers from internationally renowned universities and companies. They constituted some of the panelists on a panel session on agent-mediated electronic commerce at Autonomous Agents '98. Not all viewpoints are included because of the 8-page limitation of this paper.

2. Some Viewpoints

2.1 Jeff Rosenschein, Hebrew University & AgentSoft (Israel)

What are the properties of agents and agent systems that are useful in commerce applications?

The biggest advantage that agents bring is simply their ability to automate previously manual operations. It seems simple in principle, but it makes an enormous impact on commerce, because it removes friction from the commercial environment, making more information available more widely. This is an issue of scale, of access, and of information. Agents can visit more sites, gather more information, let me know of commercial Web sites that I would never have found on my own---and even if I had, would not have had the time to explore. The number of things an agent can realistically do can be orders of magnitude beyond what a human can realistically do, and this can have a major impact, even when the agents themselves are relatively unsophisticated. Sophisticated agents bring another layer of capabilities to the tasks they carry out. The ability to do automated negotiation, automated planning and to learn are areas where sophisticated agents can leverage their strength in commerce applications. Unsophisticated agents can carry out plenty of useful commercial transactions. However, when the agents are able to interact with other agents and come to viable
agreements, plan for information gathering, and learn about the make-up of their user's preferences and the items available at specific sites, we will then be more properly exploiting Internet automation. In general, it's likely that real-world demands will drive the development of more sophisticated agents, as we struggle to deal with efficiency issues (handling such large amounts of information) and new opportunities for flexible communication (e.g., agent-to-agent).

What particular challenges does electronic commerce pose to agent technology?

Electronic commerce demands higher levels of security than simple information retrieval; many of these problems are already dealt with at lower network levels, such as through SSL and the SET initiative. Agents can and do simply leverage these lower-level protocols. The specific problems associated with agents revolve around our ability to rely on their sophistication when it involves real money, possibly large amounts of it. How much damage can my agent do when retrieving stock information for me? In contrast, my agent can do a *lot* of damage if it has my credit card and is empowered to buy stock for me, even if I have given it what I believe to be clear instructions; things sometimes go wrong. So we ultimately need to address these issues of high-level trust of our surrogate, if we're ever going to have it really act as our representative in non-trivial e-commerce settings.

What requirements must be met before we can expect to see fielded systems?

There are already many fielded systems for e-commerce, of various forms.

In what specific contexts might agents be trusted and empowered to conduct negotiations and make agreements? What are the implications of this? Indeed, how would we build trust and reputation into agent-mediated commerce systems?

The first step is probably to do our best to build reliable systems that don't act unreasonably (within the limits of current theory and technology), while insisting that humans remain in the loop. Within this model, a user would always have to approve the purchase or agreement that an agent initiated. There is an analogy here with medical expert systems, where the AI program might make a recommendation, but a doctor always had to sign off; you never had a chemotherapy advice system administering drugs on its own. Similarly, I will send my agent out to look for travel deals, and it might even do a good job, but at first, I will definitely want the final say on whether to buy the package. Or equivalently, the ability to cancel any deal that the agent made within some reasonable period of time. This introduces some inefficiency into the overall system, but people are likely to demand it for a long time. Someday, my own level of trust in the agent software may be great enough to remove this requirement, but it is only sometimes important to get humans out of the loop (in a time-critical domain, for example, like stock purchasing). If I am able to have veto power on any deals the agent makes, I will be much more willing to send the agent out on errands. Certainly simple e-commerce transactions like purchases of hardware, software, books, CDs, and travel are non-time-critical applications where my agent could easily work for me, and bring me back an agreement for approval (with supporting documentation, competitive prices, for example).

As for inter-agent trust, there are researchers working on such models, and they will be helpful for repeated interactions. In many cases, however, I think that agents will simply leverage external frameworks for trust that are already in place for humans (credit cards, for example). Between companies, this is even easier, as corporations often maintain lists of authorized suppliers with whom they are willing to work. Agents representing such a supplier would be assumed to be validly authorized.

What kind of warranty has to be provided to customers in order to engage them to delegate their agents to do everyday commerce tasks? How do we develop software that provides these warranties?

The main kind of "warranty" is what I mentioned above: the ability to have final approval of what my agents are agreeing to in my name. A two-stage process, involving contingent commitment in the first stage, and final (human-approved) commitment in the second can handle everyday commerce tasks. This is not a complicated software engineering task. We might choose a more aggressive strategy, and warrant users against the misuse of their charge cards by misbehaving agents, the way we limit customer liability to $50 if a charge card is stolen. I'm not sure if creators of agents would be willing to provide this kind of insurance (unlikely for this to be economically feasible), but charge card companies may find it in their interest to do so, to encourage use of their cards by automated agents. There's also the issue of what constitutes misbehaviour. The agent may do something that provably follows from the instructions it was given, but that in no way reflect the common-sense element of what was intended (and unstated) by the user. If the user relates to the agent as he would relate to a human surrogate, there will be a lot that's left unspecified.

What will be the marketing or economic consequences of the automation of commerce services and transactions using agent technology?

Any mechanism that spreads information more widely will, from an economic theory point of view, make real markets correspond more closely to idealized markets. It increases efficiency of the marketplace, and will tend to provide goods at better prices for the consumer. We'll still be far from a perfect information market, and there are reasons why consumers may still stick to inefficient mechanisms of shopping or purchasing, but the more agents that are out there, the more downward price pressure there will be, and the more level the playing field.

What standards need to be in place for agent-mediated electronic commerce to be a reality?

I think most of the standards (e.g., for secure transmission of credit card numbers) are already in place for simple agent-mediated electronic commerce. We're mostly waiting for agents to develop more sophisticated systems. When we want to increase agent sophistication, and allow multiagent negotiation among consumer and provider agents, then we will
need appropriate higher-level languages and protocols by which to run these negotiations. Languages like KQML, for inter-agent communication are appropriate for holding conversations among agents, and the work on economic models and game theoretic protocols that Mike Wellman, Tuomas Sandholm, and myself have been involved with, will provide the agents a framework within which to hold their conversation.

What roles will certification authorities, trusted third parties and security authentication functions play in agent-mediated electronic commerce?

I think the role here will be very similar to the role they play in human-oriented electronic commerce. I want to have others be able to use a digital certificate to verify who I am, or analogously I want my agent to have a digital certificate so that people will know it is really representing me, and not someone else. I want to know that the Lands’ End Web site that I’m interacting with really belongs to Lands’ End, and not to some credit card number snatcher pretending to be Lands’ End (hence, things like the SET protocol, where the storefront’s credentials are backed up by a bank). In most of these areas, we’ll see a leveraging of human-oriented certification and security systems.

How do we ensure our electronic commerce systems are stable, scalable and have adequate performance times?

There are design issues that need to be addressed both at the implementation level and the theoretical level. We don’t want theories of agent interaction that don’t take into account agents’ limited computational resources—we’re going to have trouble implementing theories like that in the real world. But even with the appropriate theoretical treatment, we need to pay attention to the engineering details of the implementation. Scalability and response time are two issues that might argue, for example, for more work being done on the client side, rather than on the server side. This is not a theoretical issue, but rather a software engineering issue that will need to be taken into account by agent developers. It gets complicated, because there are so many other considerations that come into play when a piece of software is written and deployed. For example, will stores shut out a shopping agent that always originates from the same server? Could we get around this by deploying basically the same software on every user’s machine?

What state of the art technologies are available to allow agents to ‘understand’ multimedia information like sounds, images, video and text in order to facilitate commerce within a complex multimedia information system?

There’s already a lot of progress in recognition of images and of speech, and in understanding natural language. As that progress manifests itself in lower-cost, more widely deployed software, it’s natural that agents will start using it more routinely. I would love to be able to have my agent reliably summarise information at a Web site, right now, that demands expensive software to do well, but over time, summarisation will become a cheaper technology, and everyone will have greater access to it (including agent builders). Similarly, the big push in speech recognition that is underway will put this technology everywhere, in the operating system, and in hand-held PDAs. Agents will also get to leverage this progress, and retrieve voice data that has been appropriately parsed into a text format.

2.2 Tuomas Sandholm, Washington University (USA)

[This is a very quickly written piece of text that requires much more polishing. However, it represents thoughts that have been generated over a long period of thinking. The text is for the purpose of the panel only, and may not be used for any other purpose. I am planning to write a journal article that will include this material and other related work].

Commerce, and electronic commerce in particular, has at least the following stages: interest generation, finding, negotiating, contract execution and after sales. In the following, I list some thoughts on what role I envision that software agents / MAS will play in these different phases.

Interest generation: A user’s agent will keep a profile of the user, and selectively choose which advertisements the user should read. Vendors will keep profiles of potential customers, and tailor their advertisements to the customers. People will not read spam. Instead, advertisements will come with payments (e.g. digital cash) on them. These “funded spamlets” can be viewed as agents that can negotiate with the user’s agent regarding whether the user will read them. Interesting questions include: how do we ensure that the user really reads the ad, and not just collects the money? How should these spamlets be co-ordinated? For example, a spamlet can change its negotiation strategy based on the results that other spamlets have had with other users. The spamlet could dynamically re-choose its target, or the amount of cash it offers.

Finding: This phase is where software agents have classically been deployed in e-commerce, e.g. BargainFinder and Jango. The idea is to find items that the user wants. This involves identifying appropriate vendors, comparing their products, etc. There is much more to this than just finding the cheapest price. Infrastructure needed include: web pages with meta-data, taxonomy of items, and agreement on feature lists for items so that comparison is possible. Interesting question: how do these feature lists get agreed on? How do they get updated while making sure that all agents understand the updated versions?

Negotiation: Negotiation will be a key component of electronic commerce. Fixed menu offers - these are currently prevalent in physical commerce – are likely to give way to agent-mediated negotiation. There are several reasons for this. While haggling is not the norm in real commerce due to the time that would be wasted, in e-commerce, software agents can do the negotiation. One of the reasons why commerce moved from bargaining to fixed menus was the advent of paper catalogues. Printing and delivering them was costly, so changes were made infrequently. On the other hand, electronic catalogues can be change quickly, and without cost. Giving a particular price to an agent does not imply that other agents will request the same. This is because the transaction can be kept out of the view of others. Negotiation is more than just bargaining over price. For example, users do not want to just buy a single item. They usually have preferences over bundles of items. At the same
time they have a limited budget. So, agents will help the users efficiently strike the tradeoffs between different items in a bundle, and price. The items of a bundle need not be purchased from one vendor. Automated negotiation is the main research focus of my group. There has also been a lot of other significant work on this in the MAS community. Some of the key techniques that we have developed for this are:

- Levelled commitment contracts: in automated negotiation systems consisting of self-interested agents, contracts have traditionally been binding. Such contracts do not allow agents to efficiently accommodate future events. Game theory has proposed contingency contracts to solve this problem. Among computational agents, contingency contracts are often impractical due to large numbers of interdependent and unanticipated future events to be contingent on, and because some events are not mutually observable. We propose a levelled commitment contracting protocol that allows self-interested agents to efficiently accommodate future events by having the possibility of unilaterally decommitting from a contract based on local reasoning. A decommitment penalty is assigned to both agents in a contract: to be freed from the contract, an agent only pays this penalty to the other party. There are two problems/doubts. First, the breacher’s gain may be smaller than the victim’s loss. Second, the agents do not want to decommit truthfully. Instead, they are somewhat reluctant in decommitting because there is a chance that the other party will decommit, in which case the former agent who gets freed from the contract does not have to pay a penalty, and will collect a penalty from the partner. We have shown that this protocol is desirable despite these issues. We have shown through formal analysis of several contracting settings that this levelled commitment feature in a contracting protocol increases Pareto efficiency of deals and can make contracts individually rational when no full commitment contract can. This advantage holds even if the agents decommit manipulatively (in Nash equilibrium).

- Powerful combinatorial contract types: we have analyzed task (or items in general) allocation where individually rational (IR) agents contract tasks among themselves based on marginal costs. A task allocation graph was introduced as a tool for analysing contract types. Traditional single task contracts always have a short path (sequence of contracts) to the optimal task allocation but an IR path may not exist, or it may not be short. We have analyzed an algorithm for finding the shortest IR path. Next we introduced cluster contracts, swaps, and multiagent contracts. Each of the four contract types avoids some local optima that the others do not. Even if the protocol is equipped with all four types, local optima exist. To attack this problem, we introduce OCSM-contracts, which combine the ideas behind the four earlier types into an atomic contract type. If the protocol is equipped with OCSM-contracts, any sequence of IR contracts leads to the optimal task allocation in a finite number of steps: an oracle—or speculation—is not needed for choosing the path (no subset of OCSM-contracts suffices even with an oracle). This is a powerful result for small problem instances. For large ones, the anytime feature of our multi-

contract-type algorithm, with provably monotonic improvement of each agent’s solution— is more important.

- Coalition formation: Coalition formation will be a key issue in electronic commerce. Parties that collude can gain by using the greater market power that collusion provides. The colluders can be consumers, providers, or a combination of both. Coalition formation has traditionally been studied in game theory without regard of computational complexity. Recent results from our group and other DAI researchers have helped reduce complexity in all three activities of coalition formation: coalition structure generation, solution optimization within each coalition, and payoff division.

Contract execution: Contract execution is trickier in e-commerce than normal commerce because the parties may be anonymous. There has been a lot of work on secure digital payment mechanisms, and some are being used already. Another (not exclusive) option is to split the exchange into chunks, where each party delivers a little bit at a time, and the exchange proceeds with such alternation. We have developed two algorithms for dividing exchanges into chunks, and have devised a nontrivial, quadratic chunk sequencing algorithm that is guaranteed to find a safe sequence of delivering the chunks if one exists. (We call a sequence safe if each party is motivated to follow the exchange at every step instead of vanishing with what the other party has delivered so far.)

After sales: While there has been little attention on using agents for after sales, this is an important part of commerce, and e-commerce, and should receive attention from the agents research community.

2.3 Carles Sierra (IIIA, CSIC-Spanish Scientific Research Council, Spain)

What are the properties of agents and agent systems that are useful in commerce applications?

The basic one is trust. A user must trust in the actions that an agent will make on its behalf. Moreover, users will like to have clear means of enforcing particular rules of behaviour into the agents acting on their behalf. It will be argued later on that Electronic Institutions can act as the certification organisations that guarantee that a particular agent satisfies particular rules of behaviour and protocols. A step forward would be that these institutions ‘enforce’ particular rules of behaviour on an agent not only to prevent the agent from damaging the reputation of the institution, but also to prevent the agent to damage its own owner’s reputation. Also, users must trust the other parties in the negotiation - this second type of trust can also be guaranteed by the mediation of well-recognised and prestigious institutions.

What particular challenges does electronic commerce pose to agent technology?

Among others I would stress two: scalability and equal opportunities guarantee. Agent-mediated Electronic commerce may require thousands of agents dialoguing over Internet. No real experiment has been done up to date in which a huge
amount of agents work together. The guarantee of equal opportunities means that everybody should be equal, so no one with better equipment or transmission lines, for instance, can make the others die by starvation. Protocols should be carefully defined as well as to avoid/pre-empt procrastination and lies. The definition of such protocols will be an important matter of discussion in the definition of standards for Electronic Commerce.

What requirements must be met before we can expect to see fielded systems?

Currently there are several electronic commerce activities around retailing via catalogues (take-it-or-leave-it) that have no special differences with the already time-honoured commerce where the catalogue is printed on paper and not published electronically. For the agent-mediated electronic commerce to appear two independent phenomena should happen. First, the creation of Electronic Institutions which provide the necessary trust on the electronic transactions between agents, that supervise their commitments and that backup/support those users whose agents are damaged by others. Second, the emergence of enterprises that manufacture, distribute and sell agents which are able to trade inside one or several electronic institutions. These two activities should ideally be carried out by separate companies to further increase users' trust in the multi-agent systems derived from them - in a similar way as cable owners and cable service providers must be, by law, different companies in some countries. However, if this separation of activities represents a bootstrap problem, a similar approach to the one taken by Phillips on video discs could be taken. (Given that no one wanted to produce video discs before video disc players were sold and widespread, and no one wanted to buy a video disc equipment if there were no video disc films on the shelves, Phillips bought film distribution companies to produce video discs, and in this way sell its video laser disc equipment). That is, an already existing institution (e.g. an auction house) could create an electronic auction house and provide users with electronic agents or agent templates to participate inside the institution. These agents could be manufactured by the same auction house or developed by some third party for the auction house.

In what specific contexts might agents be trusted and empowered to conduct negotiations and make agreements? What are the implications of this? Indeed, how would we build trust and reputation into agent-mediated commerce systems?

Again, via Electronic Institutions. Traditionally trade has been made under theegis of reputable institutions: the stock market, an auction house, and chambers of commerce. Commitments including mortgages, contracts, etc., have been mediated by third parties. The natural way of introducing agent-mediated electronic commerce is by the extension of these already existing institutions. The trust on the existing institutions will in this way be naturally extended to their electronic counterpart. The creation of new electronic institutions will be then possible, as the culture of electronic trading matures.

What kind of warranty has to be provided to customers in order to engage them to delegate to their agents everyday commerce tasks? How do we develop software that provides these warranties?

Security and Privacy. Security, so that agents fulfill their commitments or otherwise their users receive the appropriate penalty. That is why it is so important that the protocols and the rules of the game are clear and shared by everybody, and the reason why electronic institutions seem to be the adequate context to make trade. And privacy, so users have complete control on who knows what about their electronic trade transactions. Security is an indirect consequence from the fact that agents do not surpass the goals they are instructed to fulfill. Privacy is related to protocol: who is an agent permitted to talk to and what is it permitted to say and hear. In order to guarantee that some software abides by a particular standard of security and privacy, independent organisations should certify it. A chamber of commerce seems a natural place to do so. Chambers should be authorised by the agent manufacturers to make as many tests as necessary on top of their products in order to certify its characteristics. This certification could be forced to be prior to any commercialisation of agent products.

What will be the marketing or economic consequences of the automation of commerce services and transactions using agent technology?

First of all it will be the biggest accountable field test for economists ever designed. Theories would be tested, controlled experiments designed and contrived. A second, the inherent globality of electronic markets will have a very strong impact on the marketing techniques: potential customers are already at hand. Even new jobs will appear to give service, information and software development to new users and to adapt old commerce practices into new ones.

What standards need to be in place for agent-mediated electronic commerce to be a reality?

The basic standard pertaining to negotiation protocols or, more generally, about dialogue protocols. The safest and most transportable type of agents for agent-mediated trading will be dialogue agents, that is, agents whose only interaction with the other agents is based on illocution exchanges. Hence, protocol standards must be in place in order to define the communication components of agents in order for them to successfully participate in a given dialogue. The contents of the agents will be the added value of different software companies and the concrete instructions and goals given by their users.

What roles will certification authorities, trusted third parties and security/authentication functions play in agent-mediated electronic commerce?

To certify that an agent complies with a particular standard to operate within an institution. Institutions should provide agents with the means to identify themselves, and to guarantee that its integrity and identity is preserved within a particular dialogue. That is, that no supplantation or take over. As argued before, chambers of commerce seem appropriate to do this job.

How do we ensure our electronic commerce systems are stable, scalable and have adequate performance times?
I have participated during the last three years in an electronic fish market experience, which has shown us that the way to scalability should probably follow the same way followed in real life, i.e. by structuring markets into hierarchies. That is, by introducing secondary markets, tertiary markets, etc., where bigger specialised transactions are performed. There could be a pyramid of markets depending on the amount of goods/services being transacted. The performance times we obtained for a Dutch auction, which was very lively, were quite acceptable. However, these issues should be treated on a case by case basis.

What state of the art technologies are available to allow agents to ‘understand’ multimedia information like sounds, images, video and text in order to facilitate commerce within a complex multimedia information system?

This is related to which degree of intelligence an agent must have in order to make electronic commerce. The intelligent interpretation of video images or natural language texts are still research, and hence I presume they will not appear in the first generation of agents in agent-mediated electronic commerce. The commerce will be brokered. That is, agents will talk to agents and will negotiate with agents following shared protocols and ontologies. If commitments are to be in place there is no room for ambiguities in the interpretation of a particular piece of text or image. The use of all such mentioned information types by an agent is, basically, the ultimate goal of artificial intelligence research. During second-generation work, some emotional content knowledge might be needed. So human-like expressions/emotions, or other cues may be needed.

2.4 Pattie Maes & Robert Gottman (MIT Media Laboratory)

What are the properties of agents and agent systems that are useful in commerce applications?

Software agents are programs to which one can delegate (aspects of) a task. They differ from “traditional” software in that they are personalised, continuously running and semi-autonomous. These properties make agents useful for a wide variety of information and process management tasks. It should come as no surprise that these same qualities are particularly useful for the information-rich and process-rich environment of electronic commerce.

What particular challenges does electronic commerce pose to agent technology?

Electronic commerce poses a diverse array of challenges and opportunities for agent systems. From a consumer buying behaviour (CBB) perspective, we see agents playing roles in three primary CBB stages: product brokering, merchant brokering, and negotiation corresponding to what to buy, who to buy it from, and how to determine the terms of the transaction respectively. It is in these roles that agent system designers have the challenge to accurately identify opportunities to prescribe innovative ways of doing business. Of course, there are other opportunities for agents in e-commerce such as helping automate supply chain management and numerous other back-office tasks.

What requirements must be met before we can expect to see fielded systems?

The answer depends on the problem and market, of course. We already see agent systems playing visible roles in retail markets (e.g. Firefly, Jango, Dell’s computer configurators, etc.) as well as stock markets (e.g. OptiMark Technologies, E-Trade, etc.) However, for agent systems really to become ubiquitous, some pieces need to be in place first. The two general goals of e-commerce in business are interoperability and automation. In many cases, there is a dependency of automation upon interoperability. For example, in order to help automate the management of supply chains, there needs to be a semantically interoperable language and protocol for co-ordinating the parties involved. Unfortunately, there is currently a lack of common languages and ontologies for inter-business interoperability. Although HTML web scraping may get us by for certain problems (e.g. product information retrieval in retail markets), it is not sufficiently robust to base important business processes on. As a community with a long history of language and protocol design, we have the opportunity to help define such languages and protocols for e-commerce systems. OPS and ICE are two such examples of this. Related to this is the need for an open (distributed) registry mechanism which helps tie businesses together. If not EDI Value-Added Networks (VANs), then we need to find another avenue for managing the evolution of these registries - e.g. CommerceNet.

In what specific contexts might agents be trusted and empowered to conduct negotiations and make agreements? What are the implications of this? Indeed, how would trust and reputation into agent-mediated commerce systems?

We already see agent systems being used to negotiate and make agreements in consumer-to-consumer (e.g., eBay's AuctionWeb) and business-to-business (e.g., FairMarket) and stock markets (e.g., E-Trade and OptiMark Technologies). In order to trust such systems, the agent owners must be assured that the agent will not compromise private information and deviate beyond its constraints. This can occur in the form of insured guarantees (e.g., E-Trade), audits (e.g., TRUSTe), clear controls of strategic and other private information (e.g., OPS/P3P), as well as reputation services (e.g., BizRate and Kasbah's Better Business Bureau). The implications of agents helping automate negotiations among numerous parties are profound. The first wave will substantially help streamline business-to-business transactions, reducing transaction costs at every stage of the supply chain. At some critical threshold, new types of transactions will emerge in the form of dynamic relationships among previously unknown parties. In this next wave, agents will strategically form and reform coalitions to bid on contracts and leverage economics of scale - in essence, creating dynamic business partnerships that exist only as long as necessary. The potential is an environment where companies will be at their most agile and marketplaces will approach perfect efficiency.
What kind of warranty has to be provided to customers in order to engage them to delegate to their agents everyday commerce tasks? How do we develop software that provides these warranties?

For certain, consumers must be assured that their agents will not compromise private information and deviate beyond their constraints. This includes account numbers for payment mechanisms. Essentially, consumers must trust their agents and the environment in which agents carry out their tasks. As agent designers, we can help instil trust in our agents by having them exhibit (mostly) predictable behaviours and having them being able to clearly explain their actions and decisions. In addition, we must be careful not to inflate the users’ expectations beyond our agents’ capabilities as this can lead to a lack of trust in our systems.

What will be the marketing or economic consequences of the automation of commerce services and transactions using agent technology?

Thanks to agents such as Andersen Consulting’s BargainFinder and NetBots’ (now Excite) Jango, we see the threat of agent technologies to traditional business models. An important question is how to balance the needs of both consumers and merchants so that we do not turn markets into ineffective arms races of blocking and anti-blocking devices? Is it enough to say “deal with it” or is there also an opportunity to provide smarter tools to balance both sides of the equation? Our Tête-à-Tête system, for example, is helping to differentiate merchant offerings while still providing powerful cross-merchant product comparison tools to consumers. From a marketing perspective, agent technologies can help realise the elusive one-to-one marketing. Personalisation technologies such as automated collaborative filtering and other learning methods can (passively) help consumers identify their needs (stage 1 of the CBB). This can take the form of well-selected banner ads, or better yet, via more innovative means – e.g., personalised shopping catalogues, effective cross-sale and up-sale offers, etc. Agents will also have a large impact economically. Agents will likely help shape the new economy by taking over the roles of some traditional intermediaries (e.g., discount stock brokers) as well as reduce the need of other positions (e.g., customer service and sales). However, agents will also be instrumental in creating new markets (more viable consumer-to-consumer and B2G).

Most importantly, agents will help increase sales through the better matching of consumer needs with merchant offerings as well as reduce transaction costs through the semi-automation of business (and inter-business) processes.

What standards need to be in place for agent-mediated electronic commerce to be a reality?

Security, privacy, communication, and ontology standards need to exist for agents to be most effective. What is also important are processes for distributively managing and evolving these standards. Standards-by-committee will surely be too slow for the potential dizzying pace of e-commerce. There is also a need of clear legal jurisdiction on agent-mediated business deals and contracts. For example, what audit trails must agents leave in their digital wakes?

What roles will certification authorities, trusted third parties and security/authorization functions play in agent-mediated electronic commerce?

Cryptography and related certification and authentication services will play vital roles in agent-mediated e-commerce. Trusted third-parties will be used as market-makers (e.g., auction “houses”) as well as provide related services such as reputation brokering, financial services, escrow services, etc.

How do we ensure our electronic commerce systems are stable, scalable and have adequate performance times?

This is where software engineering skills come into play. However, ensuring all of these is obviously impossible in an environment as diverse, unpredictable, and unstable as the Internet (as we know it today). (This is one argument in favour of secure EDI VANs.)

What state of the art technologies are available to allow agents to ‘understand’ multimedia information like sounds, images, video and text in order to facilitate commerce within a complex multimedia information system?

Image processing, speech recognition, information filtering and retrieval, and other content-based technologies are slowly making progress to help extract semantics from multimedia. These may one day help agents find items of interest to their owners or to help accomplish a task. An alternative approach is to build statistical models of the relationships among multimedia objects (as opposed to their contents). Automated collaborative filtering, for example, enables the recommendation of previously unknown products – e.g., songs, movies, etc. – to a consumer through the aggregated ratings of numerous respondents.

3. Conclusions

The goals of this paper were threefold. Firstly, to provide a part summary of the proceedings of the panel on agent-mediated electronic commerce which took place at Autonomous Agents ’98. Secondly, and perhaps most importantly, to begin defining the essential core research issues required to make agent-mediated commerce truly a reality. In this vein, we believe we have posed a set of open questions that we hope will facilitate the definition of the domain. Our key assumption here is that a domain is defined by its problems, not its techniques. Thirdly, we have presented several responses and viewpoints to these open questions from some leading researchers in the field. They are not meant to be complete in the sense that detailed views reflected by the panelists are contained in this paper. Rather, they should be read as varied viewpoints which we hope will stimulate more debate beyond the proceedings of this conference, not least because a well-motivated electronic commerce may be about to become one of the most important applications of agent technology in particular, and artificial intelligence in general.