Agents and Electronic Commerce,

Hype and Reality

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1. Introduction

In recent years electronic commerce has been at the centre of interest of many companies and also of many researchers. See the International Journal on Electronic Commerce (IJEC) for current research topics and e.g. (Kalakota and Whinston 1996, Kalakota and Robinson 2001) for an overview. However, after a period of a growing world economy in which electronic commerce was advocated as one of the motors of the new economy, at the moment we experience a set back that makes many people doubt the true value of electronic commerce for the economy. In fact what we are experiencing is the maturing of a new way of doing business based on new paradigms. In order to assess the role of IT, and especially software agents, in this development it is paramount to have at least some understanding of this new way of doing business. If electronic commerce is seen only as a way to use the Internet as a new channel through which products can be traded then the role of IT is quite limited. It should provide efficient means to build websites that are secure and robust and that can be connected to the back-office in order to process the incoming orders.

The role of intelligent systems, such as software agents, in this scenario is usually limited to that of searching the Internet for the user in order to find the best bargain. Good examples of this use of agents are (Jango (http://www.jango.com/) (Doorenbos et.al., 1996) and Bargainfinder (http://bf.cstar.ac.com), etc.).

A more interesting way to employ agents, however, is to actually have them execute the transaction on electronic marketplaces where agents can buy and/or sell goods. Some good examples are Kasbah (Chavez & Maes 1996), the Fishmarket project (Rodriguez 1997) and AuctionBot (Wurman 1998). Although the agents in the first case play a role in electronic commerce their actual role is that of searching the Internet in an intelligent way. These types of agents are not supposed to interact with agents at the selling side and strike bargains with these agents. The scenario assumes that prices are fixed and can be found by searching the WWW.

In the scenario of the electronic marketplaces, both sides play an active role. This is a good example of current developments in business and also opens new perspectives for the use of agents. In most cases the selling agents advertise their products in the market. They indicate a price, but this price does not have to be the final selling price. In case of an auction model the price indicated by the seller is the reserved price. It will not sell its products for less than that price.

In these electronic marketplaces the agents have the task to "bargain" about the price of the products and try to find the best deal. An easy way to organize the bargaining is by way of auctioning the products. This way of bargaining is very structured and can easily be done automatically. Of course, the strategies of the participating agents are not trivial and much work is done in trying to find so-called "dominant" strategies for certain types of auctions (see e.g. Varian 1995; Huberman & Hogg, 1995; Rosenschein & Zlotkin 1994; Sandholm 1996). These strategies are guaranteed to give the best result no matter what the other agents do.

In this paper we will first discuss some of the more fundamental developments in electronic commerce and the consequences of these developments for electronic markets. In section 3 we will look at the role of electronic institutions in electronic commerce. The role of agents in electronic commerce and their interactions with electronic institutions will be discussed in section 4. Some examples of the current use of agents in electronic commerce are given here as well. In section 5 we will look at the future roles that agents can fulfil in electronic commerce transactions and which research questions are of interest in this context. Some conclusions will be presented in section 6.

2. Developments in Electronic Commerce

2.1 From operational excellence to customer intimacy

Although IT is an important component of electronic commerce, the biggest mistake that many companies have made is that they expected huge benefits from just implementing new IT components that support electronic commerce, without changing their organisational structure. A very similar situation is visible in traditional commerce already. There are mail-order companies that sell their products through the mail by means of (paper) catalogs. However, although this opportunity is open for every company, not all companies choose to use this selling channel. In order to reap full benefit of selling by mail the company has to have a certain structure and do business in a way that does not fit with all existing companies. For instance, these companies often give the possibility to pay for products, like clothes, in monthly installments. This is very unusual for companies that sell their clothes through shops. Also mail-order companies have a huge department that handles returns. Something that is of small importance to most companies that sell their products through shop outlets.

Electronic commerce (or electronic business as some now prefer to call it) should also be seen in this perspective. It is primarily a new way of relating to customers and suppliers. In general it means a transformation from a company that is geared towards production excellence or innovative excellence into a company that is geared towards customer intimacy. (See (Treacy and Wiersema, 1997) for a more thorough description of this development).

A company, that is operational excellent, tries to organize its production process as efficient as possible. This has been the case since the 19^{th} century when Taylor proposed the division of the production process into simple tasks, each performed by a different person. The latest developments on Enterprise Resource Planning and Just In Time production are also part of this strive for operational excellence. Operational excellent companies usually focus on the product that the company delivers. The contacts with the customers are mainly through the sales department. That is where the orders come in and where payments are received. The contacts with the suppliers are mainly through the purchasing department that sends orders based on the current production planning.

In a company, that strives for customer intimacy, the focus shifts from the product delivered by the company towards the customers of the company. The company tries to find out as good as possible what the wishes are of its customers. Knowing your customers and producing those products that have the highest added value for the customers is the most important. One of the consequences of this shift is that the company has to have close contacts with its customer base. Contacts do not only go through the sales department, but customers also have direct access to data concerning the production planning in order to find out the status of their order. They might have contacts with the R&D department to influence the design of new products, etc.

Most of these customer contacts can all be directed through the website of the company. However, the website is no longer just connected with the ordering system, but should be connected to various systems of different departments. As a consequence, these systems should also be integrated in order to have a consistent contact with the customer. One of the main consequences of this development is that several heterogeneous IT systems throughout the organization should be coupled and a secure customer view on the data should be available. I.e. the customer should be able to check the data on production planning, but in only in so-far it pertains to its own order and only the information that is necessary to check its status. Also the communication channels between the departments should be shortened in order to update information about the customers. Usually this is established by using an intranet.

On the supplier side the organization also usually tightens its relations in order to adapt as quick as possible to demands of the customer.

In general, the above developments lead to tighter relations with a fixed number of suppliers and a relative fixed customer base. For the IT support it means loosely coupling many heterogeneous systems, which also become more “open” (i.e. are coupled with systems outside the organization and can be inspected and/or updated from outside the organization).

2.2. Transaction costs theory

A second perspective on developments in commerce and the role of IT comes from the theory on transaction costs. Economic transactions can be organized through two mechanisms: hierarchy or market (see also (Malone 1987) for an analysis). In the hierarchical mechanism the buying and selling party have a "special" (usually longstanding) relationship. This can be because they are part of the same company or because they have a frame contract that covers the transaction. In this situation the negotiation phase (price discovery) can be skipped during the individual transaction. All negotiation is done at the time the parties enter into the frame contract. The situation is relatively static and most suitable for EDI applications. One of the big advantages of this mechanism is that it is possible to make a tight integration between the production processes of the buyer and seller. Something that is very important in just-in-time production in e.g. the car manufacturing industry. A disadvantage is the dependence on a few suppliers and/or buyers. If one of the suppliers fails to deliver (or goes bankrupt) it immediately creates a problem in the production line.

The second mechanism to organize transactions is the market mechanism. The main idea is that there are many providers of a product and many clients that want to purchase the product. The parameters of the transaction (like the price of the product) are not fixed for a long period of time, but determined for each single transaction. In general it holds that the coordination costs for this mechanism are higher than that of the hierarchy mechanism. However, because of the economy of scale and growing competition the production costs are usually lower. Tight coupling of production processes is harder using the market mechanism, because of the fact that suppliers will change regularly.

In general one could say that there is a trade-of between the coordination costs and the production costs (see table 1). If a complete product is manufactured within one company the coordination costs are very small and optimal logistics can be achieved because all is under control of one party. However, the production itself is more expensive because some parts could be produced much more efficient by other parties. If on the other hand the manufacturing and assembly of all parts of a product are out-sourced then maximal efficiency can be achieved in the production processes. However, the costs of coordinating these different parties are much higher.

	Production costs	Coordination costs
Markets	low	high
Hierarchy	high	low

Table 1. trade-of between production and coordination costs

The introduction of ICT support in performing business transactions (introducing electronic commerce) seems to favour the use of the market mechanism for the transactions. The use of ICT can reduce the coordination costs drastically (easy search, comparison, etc.). Therefore both the production costs as well as the coordination costs will be low and the overall costs will be lower than when a hierarchical mechanism is used. Of course, this is a generalization, but the overall feeling is that the introduction of electronic commerce in a certain industry area will favour the use of markets as a means to coordinate.

2.2. Electronic markets

The developments sketched in the previous two sections seem to point in opposite directions. According to section 2.1 the industry should move to tight connections with long lasting relations, while according to section 2.2 companies should perform their transactions through markets where relations can change for each transaction. In this section we will discuss some more points that are of influence on the use of transaction mechanisms and conclude with the current trend for electronic markets as seen in practice.

Some characteristics of products also influence the decision on whether the products should be traded through a hierarchy mechanism or through a market mechanism. The first characteristic is the asset specificity of a product. For instance, if a product is very location specific (i.e. produced only at a specific place and relatively difficult to transport) then it will be more difficult to trade the product through a market mechanism because it is more difficult to choose freely between different producers (or consumers). A good example is the car manufacturing industry. Because this industry is very competitive they try to lower costs as much as possible. One way to achieve this is by reducing stocks. In order to accomplish this the factories only start manufacturing a car after it has been ordered. Moreover they only want the parts to arrive when they are needed in the production process. As a consequence the factories depend on the fact that their suppliers are located in the vicinity of the manufacturing plant such that parts can be reliably delivered just-in-time. In this situation a hierarchy mechanism is more efficient than a market mechanism. The extra costs that are incurred because the company is tied to a few suppliers are easily outweighed by the benefits of the just-in-time delivery.

Another example of asset specificity is the fact that a product can be related to a specific type of customers and/or producers. For example, if a symphony orchestra is needed for a concert than the quality of the orchestra is very dependant of the people playing in it. One cannot easily substitute one orchestra for another. On the other hand some products are completely geared towards a small market, like operation tools for surgeons. Also for these types of products a hierarchical model is usually preferable to a market model.

Also products that are difficult to specify are not so easily traded through a market mechanism, because it is hard to compare products from different producers. So, it is not about the complexity of a product but about how easy it is to specify. E.g. a car is very complex, but is relatively easy to specify, because most parts are standardized. However, a business insurance policy is very difficult to describe accurately, because there are no standards at all.

Other characteristics of products that determine how they are purchased are: the impact of the product on the company result, the supply risk for the product, whether the product is used in control and management or for production, and the way the products are sourced (systematic vs. spot sourcing). The so-called routine products (see (Kraljic, 1983)) are products with a low supply risk and little impact on the financial result of a company . Office supplies form a good example. These products only account for a small part of the purchase value, but usually cause a major part of the procurement costs. The main goal in electronic procurement for these products will therefore be cost reduction of the procurement process. So, they can best be traded through electronic purchasing tools with a few fixed suppliers. For the products that have a low risk in supply but a high impact on company results, the so-called leverage products, a company might look at using electronic markets. For these products price/quality ratio is more important than transaction costs. Good examples of these products are commodities that are part of the end product of a company. E.g. most of the components of PC's are of this type. The products that carry both a high risk in supply and have a high impact on the company results (the strategic products) can also be purchased electronically. However, these products are usually purchased directly through an EDI connection from the ERP system. Good examples are the car parts for a car manufacturer. The delivery of these parts has to be in line with the own production, while there is only one (or a few) possible suppliers of that part.

The last type of products are the bottleneck products that have a low impact on company results and a high supply risk. The fastening products of e.g. Borstlap are a good example of this category. There are only a few suppliers in this market, but the products have a low impact on the end product of the customers (like car manufacturers). For this type of products no readily available solutions are on the market. Most companies experiment with combinations of EDI and web-based ordering.

To conclude, it can be said that there are products for which the market mechanism is the obvious choice. E.g. commodities like books and CD's. There are also products and markets where the hierarchical mechanism seems natural. E.g. specialized tools for industries with only a few (but large) companies. However, there is also a whole range of products and markets for which the choice is not obvious. For this area it can be said that the use of information technology reduces the coordination costs in all cases and therefore more products in these markets will be traded through some form of market mechanism.

The effect of the development sketched in section 2.1. (towards customer intimacy) is that the markets will not be completely open. Although a market mechanism is used to perform the transactions the players on the market are fixed and usually known to each other. A good example is the market organized for the automotive industry. All suppliers for the major car manufacturers have to compete through this market, but only a limited number of companies qualify as supplier and can enter the market. The latter ensures that suppliers and manufacturers still know each other (and each other's requirements) quite well.

3. Markets and institutions

In this section we will look at the role of institutions in (electronic) transactions. Although the transactions can have many different forms, in general they all follow the following pattern (see also e.g. Kalakota & Whinston, 1996)):

- determine needs
- exchange information on products and companies
- negotiation / price discovery
- establish (legal) contract
- contract fulfillment
- guarantee and feedback

Depending on the type of market (product and participants) there will be more emphasis on one or the other phase. The role of institutions is to facilitate the transactions. An institution only is useful if it improves the performance or quality of the transactions in some sense. In (van Heck 1997) it is argued that an (electronic) institution is only viable if the stakeholders have converging interests in using the institution. I.e. if both buyers and sellers have some advantage in using the institution and the intermediary that manages the institution also has some benefit. This can be the quick fixing of decent prices, enhancing trust in partners (through securities), opening new markets, preventing information asymmetry, etc.

Our main interest lays in how the transactions can be supported when they are performed electronically. Especially of interest is the role of (electronic) institutions to support the transactions. In general one might say that institutions play two roles in this context:

1. They enhance the efficiency of the transaction between the partners
2. They enhance the trust that the parties have in a proper performance of the transaction.

The efficiency of the transaction is enhanced by providing e.g. an efficient price discovery mechanism and a standard transaction protocol.

The role of enhancing trust in the transaction is often underestimated. In many cases though institutions have evolved from in order to remedy a lack of trust in the market. The institution can enhance trust e.g. by providing trusted information on potential partners (Like Chambers of Commerce). They can also provide regulations for the behaviour of the parties during the transactions and ways to enforce that behaviour. They can enforce for instance guarantees of the parties on payment and/or credit. Often the institutions also provide a legal back up for the contracts that are closed within the institution. E.g. in the form of standard legal contracts that cover all transactions within the institution.

The emphasis on which role is played will be different when market transactions are supported and when hierarchical transactions are supported. In case of hierarchical transactions the institution can play a role in establishing a relationship between the parties (the contracting phase), but usually the negotiation phase is far more complicated and involves much more than just price discovery. During the fulfillment phase of the contract, the role might be in monitoring the workflow and assisting in case of disputes. In case of the use of a market mechanism for the transaction the role of the institution will be to structure the way buyers and sellers can interact on the market. E.g. by providing an efficient means for price discovery (like an auction mechanism).

Institutions are determined by two things. First the infrastructure that they provide and secondly the type of interactions that are supported by the institution (see also (Tsvetovatyy 1997)). E.g. an institution might provide both an auction as well as a shopping mall.

3.1 Infrastructure

The infrastructure for electronic institutions should at least contain banking facilities, communication facilities and an ontology. In any transaction at some stage one party has to pay the other party. This can be done very simple by giving a credit card number or very complicated by setting up some letter of credit or other financial security. An institution should provide different ways of payment such that the parties can always find a common way to pay. It is very awkward if a whole transaction is concluded but a payment cannot be made because one side can only pay with a Visa card and the other party only accepts Digital cash. Preferably the institution has some back-up such that it can convert itself between different methods of payment.

Of course the payment should be safe and guaranteed. This means e.g. that credit cards should be checked but also that the communication of the credit card number is encrypted in a secure way.

The communication facilities have two aspects. The first is that the communication should be confidential, integrity should be guaranteed, authentication of messages possible and repudiation of messages impossible. These are all measures of security that should be taken such that parties that do business through the institution can communicate in a secure and reliable way. The second aspect of the communication facilities is the provision of protocols and languages that can be used during the (formal) interaction between the parties. A good example is an auction protocol like the descending bids protocol. Finally there should be a common ontology available for the parties in the institution. This is needed such that they can check whether they are referring to the same objects when they use specific terms. E.g. it might state that a "monitor" refers to a 14" color monitor unless specifically stated otherwise. Also it might state that a "contract" refers to a legally binding contract according to a certain statute of the law.

3.2 Transaction types

The transactions that are performed between two parties can be performed either directly or through some broker. In the case that the transaction takes place through the hierarchy mechanism the transaction is almost always performed direct. This means that the contacts are between the parties themselves directly and no third party plays an intermediary role.

However, the most common example of direct trading is "shopping". Producers expose their products in some way and customers can compare by entering several shops. After the customer makes a choice the transaction is performed directly with the shopkeeper. Another good example of direct trading is the use of classified ads. Of course the cases where the parties enter into a direct negotiation without interference of an arbitrator is also an example of direct trading.

The most common example of indirect trading are the auctions. In that case the producers deliver their products at the auction house and the consumers can buy the products using some predefined auction mechanism. In this case the broker brings buyer and seller together and helps the market to set a fair price. Another way of indirect trading is through distributors, which actually buy the products themselves first and later on resell it to the customers.

Although this is not the place to present a detailed analysis of the roles of the broker in indirect trading (see e.g. (Choi 1997)), it is good to at least sketch some of its functions. Although it might seem that brokers and institutions are the same (namely intermediaries in the trading process) we want to stress that they have different functions. An institution is facilitating the trading process and is usually not seen as an extra link in the supply chain. A broker is an extra link in the chain between supplier and customer.

Brokers can have many functions. First of all they might have information about products and/or companies that are not easily available to the potential customers. In that case they can play a role in matching the interests of customers and suppliers.

Usually brokers do not actually provide a mechanism for price discovery. However, they can be involved in price discovery in at least two ways. First of all they can provide information about current (and/or fair prices) to customers and suppliers, therewith in effect influencing that price if the market is quickly changing (e.g. stock brokers) or very opaque (e.g. house brokers). Secondly, they can operate as distributor, thus first buying the products from the suppliers and later on selling them to the customers. By operating this way, the broker actually determines a price together with the suppliers and customers. This can be beneficial for both sides because of the economy of scale that a distributor can realize. Therefore it can claim a lower prize than normal customers from the supplier. The difference in price is usually large enough such that the customers also profit from the intermediary and still can get a lower price.

A third function of the broker is that of organizing the logistics more efficient. This can e.g. be done through keeping stock in a central place.

Another function of a broker is as trusted party in the contracting phase. The broker can organize the contract and validate it against industry standards. Also the broker might have specific knowledge about procedures that should be followed in the process.

In general it can be said that the function of the broker is to provide knowledge for those phases of the transaction where it is not economical for the parties to obtain that knowledge themselves and to provide economies of scale in those cases where that is profitable for both suppliers and customers. See (Moss 1998) for an economical analysis of the profitability of establishing a broker in a market.

There seem to be at least two cases in which direct trading is the most profitable way of trading. First is the case where there is a "good market". I.e. a market with many buyers and sellers, which can easily get into contact and which have enough information to compare parties and products. A good example are the commodity markets. In these markets the existence of brokers is usually not profitable. The second case where direct trading is the most profitable is where direct contact between buyer and seller is important. This can be important because the contract is complicated and very personal, but also because the product is "personalized" or feedback on the products is very important.

3.3 The role of institutions

The role of the (electronic) institution in direct transactions is naturally smaller than in indirect trading. Because in direct trading the contacts are directly between supplier and customer, the institution has little control over the content of the contract and the transaction. However, the institution can provide facilities to the parties to support their contact. E.g. it can provide payment methods, standard contracts, common ontology, etc. One of the main roles of an institution in direct trading will be to reduce the costs and time of the coordination during the establishment of the hierarchy. However, another important role will be to establish the necessary trust between the parties in order to conclude the transaction. This can be achieved by providing securities to the parties with respect to the information they get (e.g. through certificates on data), providing standard internationally recognized contracts, providing settlement constructions, etc.

In the indirect trading the role of the institution will be an intermediary between the two parties. In fact it will support many of the functions that were described for brokers as well. From this role it follows that the institution has more power to control the whole transaction. It can determine the protocol through which the interaction takes place. These tighter control possibilities make it easier to automate parts of these brokered transactions. For instance, an auction protocol can be implemented . It is easy to write software that can operate with the auction protocol and automatically sell or buy products. This situation is different for the direct transactions. It is more difficult to automate a free negotiation than an auction mechanism. Of course many aspects can be supported in direct transactions as well. E.g. the information exchange and even price discovery can be supported by shopping agents and shopping malls.

4. Sofware agents and electronic commerce

In this section we discuss the roles that agents might have in electronic commerce and more specific how they can be combined with the use of electronic institutions. Before going into this discussion we will reiterate the key properties of agents and indicate which type of tasks agents are particularly suitable for.

4.1 Agents

A commonly used definition of intelligent agents states that they are software systems that should be autonomous, pro-active, reactive and sociable (Wooldridge 1999).

The first property (autonomousness) means that the agents should be relatively independent in executing their functions. It means that agents will not be dependent on input of the user for every decision they have to take. In the other hand an agent cannot be controlled in the way objects are controlled. When sending a message to an object this will evoke a method of the object that is executed whenever the message is of the right type and the sender had the right authority (the center of control lays with the requesting object). In the case of agents, the agent will determine itself when it receives the message whether it will respond to the message or not (the center of control lays with the receiving agent).

The last property (sociability) has as consequence that an agent should be able to communicate with its environment and is able to cooperate with it (including other agents). This means that an agent is not completely autonomous, but can be influenced by other agents and the user.

The property of pro-activeness means that agents have their own (in-built) goals that they try to achieve. Therefore they do not rely on explicit commands of a user to start operating.

Finally, the reactiveness of agents means that they can react to changes in the environment. This property balances the pro-activeness somewhat. It prevents that agents only try to achieve a certain goal without looking whether the goal is still achievable, whether the current plan is the best one, etc.

Some other properties that agents can have are mobility and learnability. The first indicates that agents might move themselves from one machine to another (instead of sending messages) and the second indicates that agents can adapt their behavior on the basis of their experiences.

Unfortunately the practical, implemented agents of today do not have all the properties sketched above. However, we will use these properties to see for what type of tasks agents can be most useful.

The first task that comes to mind is that of collecting and filtering information. Agents can move over networks to gather information, compare it and filter the best information based on the past appreciation of the user.

A second type of task that agents are good in is to negotiate in simple ways over resources and other tasks to be performed. A good example is the use of the Contract Net protocol to divide tasks among a set of agents. This feature is very usefull when many heterogeneous systems have to be connected (such as is increasingly the case in organizations where electronic commerce is used). Instead of having to define one fixed overall model in which all systems fit, we can have the agents negotiate the way the systems have to be connected.

A third task that agents can do very well is to distributedly solve a complex problem. This also fits very well with a situation where electronic commerce requires different systems in a company to cooperate in finding the answer to a problem of a customer.

A last task that agents can perform well is to guide and monitor longterm processes that need frequent attention and have a life span of several hours to several months. This feature makes agents very useful to monitor order processes of customers and sending automatic alerts whenever an interesting event (such as completion of production, or late delivery, etc.) occurs.

4.2. Agents and electronic commerce

Agents can play several roles in the (electronic) commerce transactions. At least one should distinguish a role of agents where they support one or both parties in the trading process and a role of the agent as representative of a party in the trading process. There are several examples of agents supporting one of the parties in the transaction. For instance, the already mentioned, shopping agents that compare prices. Another support function is monitoring and signaling an auction in which a user is participating. Instead of the user having to follow the auction, the agent will do this and signal the user whenever an interesting point is reached. The agent can also bid on behalf of the user up till a certain amount and signal the user whenever this amount is reached.

Agents will only be used as user representative if the benefits of using an agent are high and the trust that an agent will realize them are high enough. Practically this means that agents will most likely be used in situations that are characterized by the following aspects:

1. *Interactions are very fast*. For instance for bandwidth trade. There is no time to go back to the user between trading rounds.
2. *Interactions are repeated* with either (a) high communication overheads, or (b) the domain is limited, hence learning by the agent about the user behaviour is effective. Many B2B areas fall within this category.
3. *Each trade is of relative small value*. If each transaction is of relatively small value it is possible to monitor the process and stop the automatic trade after some time without significant losses. It is important to stress the importance of *relatively* here. A small value for a company is completely different from a small value for a private consumer. This implies that most likely we will first see AMEC in business to business settings.
4. *The process is repeated over long times.* The reason for this is two-fold:
    a. There must be a significant gain in order to justify investments in software, hardware, and/or training.
    b. Automatic agent learning of customer preferences is highly desirable as explicit preference elicitation is a very time consuming business.
5. *The product is relatively easy to specify.* A number of traditional difficult computer science problems pose major difficulties to negotiations over complex objects. Such problems are mainly related to semantics of the communication. This is also related to preference elicitation. It is simply too time consuming to tune huge numbers of different parameters.
6. *The procedure is well defined.*If the user knows exactly which steps are followed, the user will more easily trust that an agent will get an optimal deal.

However, even when the process steps are clear the process itself might still be vague. First of all the product might be difficult to specify. In that case the consumer or supplier might want to start with a vague (or incomplete) description and fill it in during the negotiation. This uncertainty about the actual product makes it very difficult to delegate the trading to an agent, which needs a clear goal to operate reliably. A second major problem is that the user does not always know on forehand what he will accept as a good deal. It is clear that a consumer wants the price to be as low as possible if he negotiates about price only. However, when negotiations are performed over multiple attributes, the relative importance of the attributes is usually not fixed at the start. E.g. when negotiating about price and guarantee a customer can indicate that it finds price very important and guarantee hardly (say they get an importance mark of 90 vs. 10%). However, he might find during negotiation that whenever the price drops below a certain level no guarantee can be given at all. Although it might be that the utility, calculated on the basis of the scales and relative importance he gave earlier, is maximal at that price he still wants some guarantee on the product and decides to go for a sub-optimal price. The main point here is that people usually do not foresee the consequences of their choices for the utilities of the attributes on the final outcome.

Besides the above points that prohibit an easy delegation of the trading process to agents, it might also be that the trading process itself is either not very clear or very complex and context dependent. E.g. if the negotiation is very complex with several parties at the same time or about many interrelated issues, it is not very likely that a customer will delegate this task to an agent.

The representative role is most likely to occur when market mechanisms are used for trading. For the market mechanism there are at least a number of cases where the trust needed is relatively low, the procedures are quite simple and clear and thus the advantage of delegating this task to an agent can be high.

In the other hand setting up a hierarchical relationship is a complicated process that requires the building up of trust between the parties. This will not easily be delegated to a piece of software. However, also in a hierarchy agents can have an important role. First of all the agents can be used to assist in setting up the hierarchy. In the past this was a complicated process, where many agreements had to be made. However, with the advent of "virtual enterprises" where different independent organizations form a company for a specific project or purpose, it becomes more easy to couple several organizations into a hierarchical relation. In cases where the interactions between different organizations are well defined this might be automated using agents (something that is not feasible at this moment yet, due to the fact that exactly those interactions between organizations are usually not formally defined).

Agents can also be used to support the logistics in a hierarchical relation (see Nissen 1999). Of course one could think of using a traditional ERP package like SAP or Baan, or a Work Flow Management package to streamline the logistics. However, these software packages start from the idea that all the logistics is controlled through one organization. It means that the control of the logistics process is centralized as well. In the case of a hierarchical relation between companies this is not (always) the case. Each company is at least to some extend autonomous. Therefore resource allocations as made in the traditional Work Flow Management and ERP packages cannot be made in this case. The use of autonomous agents to represent departments and organizations might solve this problem. Instead of just allocating a task to a resource, the allocation is done through a request that can be negotiated by the agents.

As said before the role of agents is most clear in case a market mechanism is used to perform the transactions. In this case agents can be used to compare products of several producers and help to find the best bargain, but they can also be used to perform the actual transaction. Only in the last case do we speak of actual agent mediated electronic commerce. If a direct trading procedure is followed, agents of producers and consumers should negotiate the deal and inform their users. In case the negotiation is very simple (or not existing as in the case of fixed price markets) this can be done without the use of an institution. E.g. an agent can buy a CD at CD-now, because the transaction is completely specified and simple. However, in most cases a certain context is needed in which the transaction can be performed. This context can be formed by an institution. In the next section we will discuss what role institutions can play when agents are used for electronic commerce.

4.3 Agents and institutions

The institution determines the way that the parties can conduct the transaction and provides an infrastructure to do it. Therefore the institution provides the standard for the agent interactions, which simplifies the agents that only have to cater for one ontology and protocol instead for a different one for each agent they interact with. Good examples are Kasbah and AuctionBot, market places where agents can buy and sell goods. They give a predefined structure for specifying the product and also facilitate the negotiation process (about the price of the product).

As said before, in the case of indirect trading there exists a natural institution in the form of the broker that mediates in the transaction. In case of an auction, this is the auction house. The auction house determines the procedure through which products can be delivered at the auction as well as an auction mechanism that determines the way products can be bought.

In all cases holds that the more elements of a transaction protocol are determined by the institution the more efficient the transaction can be performed. That is, the interaction between the agents is more determined and thus the communication complexity reduced. However, it also holds that the more elements of the transaction protocol are determined by the institution the less flexibility there is to "negotiate" a deal. E.g. in an auction every item is traded separately and basically on price only. It is not possible to buy a whole package of products at once for a lower price.

Institutions that employ very rigid and well-defined protocols for the interactions are the best context for the use of agents in electronic commerce at this moment. First of all the users can trust the agents more easily if the procedures are well defined and rigid. Also the agents that enter the institution can be very simple in terms of communication. The ontology with which products, that are traded, are described is fixed by the institution. This means that matching supply and demand is greatly simplified. Also the model of the outside world can be limited to those elements that are relevant for the protocol and they do not have to adjust to unexpected events in the outside world (all events are determined by the rigid protocols). All the intelligence can be put in the modules that determine the best strategy under the fixed protocol for the transaction process. Therefore the trust of the user in the delegation of the task to the agent is bigger.

One of the disadvantages of institutions that employ rigid protocols for the trading procedure is that many current procedures cannot be captured in that rigid way (yet). In fact one of the few procedures that can easily be formally modeled and implemented is the auction model. For each of the auction types one can very precisely and formally define the procedure to which the participants must adhere. This is one of the main reasons why auctions became a popular form of electronic commerce.

One way of extending the use of institutions and agents is to formalize richer trading procedures such that they can also be handled in the same way as auctions. For instance, multi attribute auctions are an example, as well as multiple linked auctions. Although some first attempts are made in these directions (see e.g. Gutman 1998; Matos 1998, Preist et.al. 2001, Shehory 2001), little formal theory is available to make adequate models for the protocols needed in these situations and especially for the strategies that should be used for the agents in these situations.

5. Future roles of institutions and agents in electronic commerce

Although the section above already indicates a number of useful roles of institutions and agents in electronic commerce, we feel that the potential of agents and institutions is much bigger.

It is possible to look at institutions that do not fix the entire transaction procedure, but only give some boundaries or support. For instance, it is well known that the negotiation process itself is very complicated. However, the institution might support (or enforce) certain types of negotiations that are still feasible for agents. The main question is, how to extend the negotiation possibilities. Which type of products are traded that need these types of negotiations? If these products are mainly traded through the hierarchy mechanism it might not be very useful to develop such a market mechanism.

Another way of extending the use of institutions is to just let them give support to the trading process without having them dictate the protocol used. E.g. in the negotiation phase the institution might keep track of all commitments that are made so far and that cannot be reneiged. It can also set the boundaries in between which negotiation can take place, such that the negotiation is fair for both sides. This can be achieved by indicating the norms that both parties have to adhere to while interacting through the institution. These types of extensions are also useful in the cases where the parties are trading directly, but need a trusted third party to secure the trading process.

Two things have to be done for these types of extensions of institutions to work. First, the institutions should be described formally. Whenever institutions adhere to strict protocols like the auction mechanism, the description of the institution can be given in terms of several finite state machines that are linked. One finite state machine describes the auction itself, the others describe the payment procedure, entering the institution, etc. Finally one finite state machine describes how one gets from one "scene" to another. E.g. from registration to auction and subsequently to settlement or exit.

However, when the protocols within the institution are not that rigid, it is also not possible to define the working of the complete institution as a set of protocols anymore. What is needed is a normative description of the boundaries of the behavior of the participants within the institution and possibly the penalties incurred when those norms are violated. One way of achieving this is through the use of deontic logic as used in e.g. (Dignum 1999; Meyer & Wieringa 1993)

The second element to be adjusted are the agents that operate within these institutions. Because the protocols are not all fixed anymore, it is important that the agents know what protocol they are following when interacting with other agents. So, the agents must also have a representation of different types of protocols to be used and their abilities to follow those protocols. E.g. there might be agents that can only negotiate about prices using a common haggling protocol of alternating bids that converge to a compromise. Other agents, however, might negotiate about the price using arguments for each bid. Or agents might negotiate over many aspects of the product at the same time. There should at least be a "uniform" way to specify the abilities of the agents to handle all types of different protocols.

The next question is how to develop the institutions and agents together to make it really work. The agent should know both the protocol of the institution, which can be still very precisely specified and definite as well as the possible protocols that can be used within the different phases of the trading procedure.

The ideal situation would be an institution where all types of agents could trade their products. The "simple" agents only accept a very simple transaction protocol. They might miss the very best bargain, but could be very efficient. The "complex" agents can accept both the simple as well as the complicated protocols and can thus trade with simple agents but also try to conduct real negotiations with other complex agents. This means that the protocols for negotiation should be built in a modular version where each module can be seen as an extension of the basic module.

Although we discussed the use of protocols and the composition of protocols as if it is already possible to do this, in reality there are many problems to be solved in this area. First of all, the problem to verify whether the actual protocol used by an agent conforms to the formally specified protocol is undecidable (Wooldridge, 2000). Although this might seem trivial, experience has shown that many small variations emerge of standard protocols and it is not at all clear whether these variations are compatible.

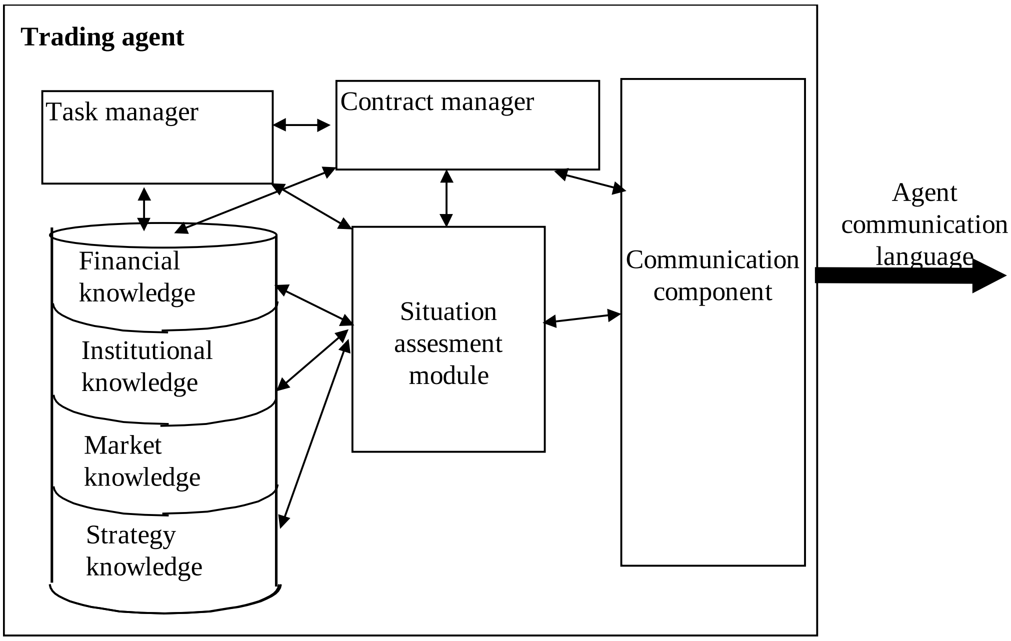
The next problem is to determine whether two protocols used by different agents can be coupled consistently for an interaction. E.g. can different types of Contract net protocols be combined? If this types of combinations are allowed, can we prove that the resulting interaction does not deadlock or continues infinitely?

5.2 Trading agents

All of the above actually assumes that there is one institution where all agents meet. But in an open environment there will be many different institutions. So, for the future it seems important that agents are able to move to different institutions and compare the products and processes at those institutions. E.g. some auctions may use a descending bidding protocol while others use an ascending bidding protocol. How should an agent determine in which auction to participate to get the best bargain? Is it possible to participate in both auctions in parallel and use that as an advantage? Although the institutions give a context in which to perform a transaction, the existence of multiple institutions creates new possibilities and problems for agents again.

Of course, it does not seem very feasible for user agents to know how to choose the best institution and trading procedure. This requires specialized "trading" knowledge, which cannot be required from the agents at the user sites that actually just want to buy or sell a product and only have specialized product knowledge. One way to remedy this problem is through the development of specialized "trading agents" that have knowledge how best to trade in certain institutions. If an agent wants to buy a product it will give a description and a price limit to a trading agent. This trading agent will find the best institution to suit your needs and negotiate the best deal within that institution. Although there is a general tendency in electronic commerce to abolish intermediaries, it seems that this is a viable area for a new type of intermediary!

A possible architecture of such a trading agent is given in the following figure. It is based on (Tsvetovatyy, 1997; Verharen, 1997; Dignum et.al., 1997; Norman et.al., 1997).



The knowledge base consists of several parts: the financial knowledge (about ways of payment), institutional knowledge (about the protocols and norms of institutions), market knowledge (about the type of market that is suitable for which type of product) and strategy knowledge (about strategies for interacting most profitable within an institution).

The communication manager takes care of all communication with other agents within and outside institutions. It also receives all messages from other agents and sends it to the most appropriate module. It incorporates some knowledge on communication protocols that it should follow (outside institutional protocols). Messages can be anything from bidding on a product, to a payment order to the bank.

The contract manager has control over the negotiation phase in the sense that it keeps track which negotiation strategy is followed, how successful it is and finally which commitments (contracts) have been made. Once a contract has been made, the contract manager keeps track of the fulfillment of the contract. I.e. it will initiate payment at the right moment, check delivery, etc.

The situation assessment module is the decision module of the agent. In this module all knowledge of the agent is consulted and a decision is made about where to sell or buy a product, when to start, when to quit negotiations, etc. This module also contains the goals of the agent as set by the clients. E.g. sell this product as quick as possible, but not below a certain price.

The task manager is a module that plans all actions of the agent. It schedules the actions based on all commitments and resource availability.

6. Conclusions

Although many people see electronic commerce as a technology driven development, we have shown in this paper that it is an (important) part of some more fundamental developments in doing business. It is important to have some understanding of these developments to understand the main importance of electronic commerce for business. It should never be forgotten that technology has a supporting role for business. Therefore any technological development (such as the use of software agents and electronic institutions) should be judged from the perspective of how it can advance business in the end.

Agents can be used in many ways in the electronic commerce process. In order to use them as mediators it is almost always necessary to create a context in which the trading of the agents takes place. Only when the procedures of the trading are well defined it is feasible to delegate the actual trading to an agent. This context can be provided in the form of an institution. So, institutions can function in two ways. They can be instruments for intermediaries and used to support the function of the intermediary party in the trading process (indirect trading). Institutions can also be used to create a trusted and well-defined environment for direct trading parties.

At the moment agents are mainly used in the indirect trading processes, because in those processes there are well defined protocols and institutions that are dictated by the intermediaries of the trading process (the most famous one being the auction houses). In order to use agents in more complex trading processes, the institutions should be extended to allow more types and more flexible protocols. Only when these can be formally defined and the boundaries of the behavior of agents within the institutions is clearly defined can agents successfully be employed in these more complex trading processes.

The institutions should be flexible enough to provide different types of scenarios. Depending on the type of product and market situation a certain type of trading can be chosen. This means that agents should be able to select the proper (most efficient or profitable) trading procedure for the case in hand. If the chosen procedure allows some freedom within the interaction (e.g. negotiating in different ways) the agent should agree with the other party on a common acceptable way of interacting. One cannot expect all agents to have the same capabilities, therefore agents should be designed in such a way that they can deal with both simple and complex agents in the context of the same institution.

A new challenge will be to design trading agents that function as intermediaries for the trading procedure. They have specialized knowledge on strategies and trading protocols, such that the agents of the trading parties only have to have product and market knowledge and can leave the burden of finding the suitable trading procedure to the trading agent.

Some other more general challenges that have to be faced in order to deploy software agents in electronic commerce have to do with the development of agent technology as a whole. Although agents are being build for industry already, there is no general accepted methodology for designing and implementing multi-agent systems yet. Until some industry standard is set many companies will not venture to use agents for their software systems due to the risks in maintaining such systems.

The last challenge we want to mention is the lack of a comprehensive agent theory. Although there are formal theories for several parts of agents there is no (generally accepted) theory that can describe all aspects of agents in a multi-agent system. (Even the widely quoted BDI theory is far from complete and leaves many choices for the implementation).

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