Agent-based Bidding in Electronic Markets

A Prototypical Approach

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Abstract: The overall change in computing from manipulation to delegation was already predicted in the mid-90s but hitherto remains a bold vision. Although software agents have the potential of fully automating processes, real world agent-based applications are very limited in number. Even in the case of electronic markets software agents are rarely employed, albeit they can act as autonomous representatives of human negotiators.

The prototypical approach presented in this paper seizes the idea of an agent-based electronic marketplace and describes multilateral negotiations as a core of an electronic trading system. Owing to their open format (i.e. open bidding), agent-based multilateral negotiations are expected to reduce transaction costs and to improve the negotiation outcome. The multilateral negotiations are presented in two different environments: in AMTRAS, an agent-based marketplace for bonds, as well as in VTR, a web-based trading system for stocks. Two key features of these negotiations are the revelation of all bids, and the anonymous nature of trading. The information released in the negotiation constitutes the basis for further research such that the agents are capable of deploying own strategies inferred from the other's bidding behavior. The paper concludes with some recommendations as to how automation of the bidding process can be achieved using software agents' intelligence.

Keywords: Electronic Markets, Automated Negotiations, Software Agents, (Cascading) Dynamic Market Models, Stock and Bond Trading Systems

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1. INTRODUCTION

„The future of computing will be 100% driven by delegating to rather than manipulating computers“ (Negroponte 1995).

Electronic markets have the undisputed ability to speed up processes, provide access for global buyers and sellers, reduce search costs, increase efficiency, and overall reduce transaction costs (Malone, Yates et al. 1987). The notion of ‘Electronic Markets’ rather marks an umbrella term for several variations of electronic markets (henceforth e-markets) than a concrete definition. Schmid and Lindemann (Schmid and Lindemann 1998) suggest a refinement of e-markets based on a phase distinction. Each phase is characterized by a different task that must be achieved before the next phase is triggered: In the information phase, the search of possible contract partners is in the center of attention. Having identified the partner, the agreement phase comprises the negotiation process that may lead to a contract. Finally, in the settlement phase the deals are fixed. In a broad sense, markets that electronically support at least one of these phases are dubbed ‘electronic market’. However, those markets are not in general apt to exploit the e-markets’ endemic abilities. In fact, it relies on the electronic support along the entire transaction. If one phase is semi-automated or non-automated at all, most of the benefits of an e-market can be wasted. For example bulletin board systems frequently facilitate the search but not the agreement. Despite the partial automation, the transaction can be long and costly due to convoluted human negotiation. Hence, only total automation of e-markets, so-called automated negotiation (Jennings, Faratin et al. 2001), are perceived to unfold the full range of the electronic markets’ abilities.

This paper explores ways automated negotiations can be reasonably realized. Thereby, the important issue of information feedback is considered. The remainder of the paper is thus structured as follows: The second section defines bidding as the fundamental part of negotiations. In order to automate the intricate process of bidding, software agents – depicted in section 2.2 – are a promising concept. Section 3 introduces two sample scenarios for open bidding negotiations in different problem domains of securities trading. In both approaches software agents are proxies for human negotiators. The first example represents a single-sided auction setting, whereas the second a double-sided auction setting. The third section closes with a description of the advantages the implemented agent-based negotiations have. Section 4 concludes and presents areas for future work.

2. BIDDING IN ELECTRONIC MARKETS

2.1 Negotiations and Bidding

Bids comprehend the buyer's valuation of a good, which in turn is a function of private and public information (Milgrom and Weber 1982). The bids are determined on the basis of a bidding strategy that specifies how the participants will utilize any information they might observe (Engelbrecht-Wiggans 1980). The interaction among the participants in a negotiation is governed by the mechanism or negotiation protocol. In particular bidding rules – as a part of the negotiation protocol – define the valid actions participants can opt. This also captures the conditions under which bids can be submitted, modified, or withdrawn. The negotiation protocol also governs the outcome function, i.e. which bidder gets the object at which price.

Summarizing, a negotiation necessarily comprises three components: an object, a strategy, and a protocol. Note that the protocol needs not to be fixed in advance (e. g. blackboard systems).

When talking about auctions, the importance of competitive bidding is frequently emphasized. Competitive bidding refers to negotiation with competition among the (human- or software-) agents on at least one of the demand or supply side. Usually, efficient allocations are imputed to bidding competition (McAfee and McMillan 1987). The intuition is straightforward: The bid takers try to maximize their expected profit (or information rent) which marks the difference between the bidder's valuation of the item and the price they have to pay.² The lower the bid, the higher is the information rent. However, a lower price also reduces the probability to obtain the information rent, since another bidder can win the auction. If the number of bidders is increased, the winning price converges to the highest valuation (McAfee and McMillan 1987).

By varying the trading rules, the designer of an electronic market can influence the market outcome. Since there are myriads of ways how to define trading rules, a comprehensive depiction of the design space is impossible. In the following, the issue of open versus sealed bids is highlighted since the format of the bids is deemed crucial for an effective automation of the negotiation (see section 2.2).

In the case of sealed bids, the negotiators have to submit their bids without any information feedback. In the case of open bidding, the participants can take the information feedback and the expected reactions of the remaining bidders into consideration when they place their bid. Information feedback can affect the negotiation outcome in two ways. Firstly, it can stimulate competition: This competition leads to an adequate price discovery because bidders who are uncertain about the value of the

object/ good learn from each other and adjust their valuations.³ Secondly, information feedback may be used by bidders to collude and form an auction ring. In markets with high participation (liquid markets) collusion in ascending auctions is unlikely to occur since everyone can top the highest bid. In less liquid markets sealed bids are considered advantageous because the missing information feedback complicates collusions (Wolfstetter 1995).

2.2 Automated Negotiations

Today's human-based negotiations suffer from some disadvantages: they are slow and their outcomes are often sub-optimal due to issues such as culture, ego and pride (Fisher, Ury et al. 1991). It is frequently argued that negotiations can be streamlined by the means of software agents. The advantages of an *automation* in general are manifold. The most striking effects are the reduction of negotiation time, the potential for the negotiator to participate in multiple (simultaneous) auctions and the reduction of transaction cost. Furthermore, the use of software agents bears potential for the negotiation itself. Before the potentials are depicted, the notion of a software-agent is briefly introduced.

An agent is „one who acts for or in the place of another and by the other's authority“ (Merriam-Webster 2002). It can be regarded as a service provider acting autonomously, executing desired tasks, reacting on environmental changes and reporting the tasks result. In contrast to conventional software that is managed by human manipulation, software agents operate autonomously, i.e. without direct user interactions (Maes 1994).

In their seminal paper Jennings and Wooldridge compile a list of common agent-properties, the “key hallmarks of agenthood”, being autonomy, social ability, responsiveness, and proactiveness (Jennings and Wooldridge 1996). Franklin and Graesser add temporally continuity, ability to learn, flexibility, and mobility to this enumeration (Franklin and Graesser 1997).⁴

Notwithstanding what perception is adopted, the software agent paradigm appears to be promising in the case of automated negotiations: Software agents have the capability to encapsulate information and their given strategy. Furthermore, they can anonymously interact with their environment; this means that software agents can autonomously participate in a negotiation and perform all the necessary tasks as a substitute for the (human) negotiator. Summarizing, software agents can keep control over the negotiation process: With their encapsulated information the software agent can perform the bidding, receive and analyse counter-bids, retrieve strategies and preferences, and, finally, adapt their strategies.

Nonetheless, automated negotiations create several problems. Probably the most unpleasant one concerns the security of confidential information.

As automated negotiation systems have to match offers, they automatically receive information concerning the traders' actual willingness to pay for a good and their general strategic behavior during negotiations. Taking the sensitivity of this information into account security has to be guaranteed in order to build up trust. Otherwise the pivotal question whether or not the traders accept the automated system is negated.

Summarizing, if market design aims at high participation, the previously mentioned insights imply that – particularly for objects with affiliated valuations – an open bidding procedure is recommendable. In contrast to human negotiators, software agents can participate in numerous negotiations at a time. The gained information can be instantaneously used to reconsider the strategy and adapt their bids. Of course, the impact of market design on participation requires that the system adequately resolved the issue of security and trust has been built up.

In the next section two prototypical agent-based systems are introduced in order to clarify the design of an agent-based market. Thereby, the design process – as well as the negotiation protocol – with respect to technical and economic feasibility is presented in more detail.

3. AGENT-BASED BIDDING

The potentials of the transaction process automation with software agents have been discussed in several publications (for an overview see Guttman, Moukas et al. 1998). As previously mentioned existing approaches and applications can be distinguished by the extent they electronically support the transaction phases (see section 1). Frequently, the classification ranges from simple search agents (e.g. Bargain Finder), over communication agents up to more sophisticated transaction agents such as AVALANCHE. In most of these cases, transaction agents only comprise static pricing, i.e. the agents follow the principle of take-it-or-leave. Only few agent systems really supply a dynamic pricing facility (Guttman and Maes 1998). Take-it-or-leave is one way to go, but in many cases the seller can attain a better price employing a dynamic pricing mechanism (e.g. an ascending auction).

In this context, the sample prototypes embody an agent-based dynamic pricing environment. The first example AMTRAS additionally allows for multi-attribute bids, whereas VTR supports price-based bargaining only. The intuition for the (micro-) structural differences stems from the domain. In order to present an overview of the specific domains, the market design approach proposed by Budimir et al. (Budimir, Holtmann et al. 2002) is briefly sketched. Accordingly market design is divided into five steps: (i) product definition or selection, (ii) investor identification, (iii) demand evaluation, (iv) market design and implementation, and (v) testing.

3.1 Agent mediated Trading System (AMTRAS)

AMTRAS⁵ (for a detailed description see Weinhardt and Gomber 1998; Gomber 2000; Budimir, Holtmann et al. 2002) is a web-based bond trading system designed for the needs of the German market.

3.1.1 The System

(i) Product Definition/ Selection:

The fact that almost all bonds are negotiated one-to-one via telephone gave rise to the development of an agent-based trading system. Since traditional trading systems failed to satisfy the participants' heterogeneous needs less than 10 % of the trades are conducted via exchanges, the portion traded on electronic systems is even smaller (Weinhardt and Gomber 1998).

(ii) Investor Identification:

An attempt to establish a successful trading system must particularly fulfill the needs of the most important investor group. In the case of the German bond market, institutional investors dominate the trading. Overall, retail investors are of negligible relevance in this segment.

(iii) Demand Evaluation:

The special needs of the identified interest group were collected by numerous detailed analyses of the existing literature and by a number of expert interviews. The surveys yielded that most investors have similar requirements concerning *liquidity*, *anonymous trading*, *avoidance of front-running* but have different requirements concerning the *degree of transparency and immediacy* (Gomber 2000).

(iv) Market Design/ Implementation:

Reflecting the fact that different trading mechanisms satisfies a different vector of needs designing *one* mechanism that meets the requirements for a number of investors remains a question of high complexity and huge compromises (Macey and O'Hara 1997). This intuition leads to the concept of Dynamic Market Models (henceforth DMM) where investors can *transaction-wisely choose* their most convenient trading mechanism (Neumann, Holtmann et al. 2002). The fundamental idea behind DMM is that free market forces can do a better job in choosing the appropriate mechanism than a system designer (Amihud and Mendelson 1985).

Faced with heterogeneous investor groups, the multi agent system AMTRAS embodies a DMM. Among others, AMTRAS realizes a multilateral negotiation facility, which is depicted in section (v). The negotiation mechanism frequently supplies the bidders with

information. Since for bonds the common value model with affiliated information applies, information reduces uncertainty and increases overall price quality.

(v) Testing:

The evaluation of the system primarily focuses on a functionality testing (debugging). The prototype is designed as a proof-of-concept, the issues of performance and scalability are of secondary concern. Nonetheless, several trading treatments are pursued by members of the Deutsche Boerse testing whether or not the needs of the traders are fulfilled through the multiple trading vehicles.

3.1.2 Single-sided Negotiation in AMTRAS

The multi-attribute matching process is divided into three phases which are sequentially conducted, being product matching, partner matching, and price bargaining (Weinhardt, Gomber et al. 2000). A successful (multi-attribute) product- and partner matching can entail a price-based bargaining process.

Among other price discovery mechanisms, AMTRAS facilitates agent-based 1:n negotiations, i.e. one negotiator-agent (either seller or buyer) initiates the negotiation and the i -agents ($i=1, \dots, n$) on the other market side (buyers or sellers, respectively) can participate. This implies that only the i -agents are directly competing with each other. However, as several negotiations for one good can simultaneously take place, there is also (indirect) competition between the single initiators.

The negotiation process is characterized as follows: after the trader specified his order a representing agent is on the agent platform instantiated. If the trader marks the offer as negotiable, price-based negotiations can occur. As soon as two or more agents, at minimum one on each side, start to search for corresponding negotiable products, the negotiation is triggered. The negotiation process is divided into rounds. The rounds are clocked meaning that after a given period the next round is announced. At the beginning of every round the agents have to reveal their actual bid. Once two corresponding bids can be executed against each other, the trade occurs. The clearing price is determined by the last bid. The negotiation proceeds until either the whole amount is settled, or negotiation time is run out, or the process is canceled by the initiator.

The human negotiator is given the possibility either to delegate the offer to an agent or to manipulate the agent. Delegating refers to the option *submitting*; whereas manipulating refers to the options *modifying*, *withdrawing*, *accepting* and *declining* bids.

Both the bidders and the initiator can always *submit* an agent representing their price-time strategy for a fixed amount of bonds.⁶ Figure 1 sketches the case where the initiator is a seller. Three buyers are competing

for the volume of 25,000 of a specified bond. The seller's previous bid was € 103.00, his current bid is approximately € 102.70 with an actual reservation price of approx. € 102.10. As this screen shows the seller's perspective, one can observe his bidding strategy and the bid history of all participating agents. As previously mentioned in every round new bids (i.e. information) of all agents are revealed.

In AMTRAS the human negotiator has always the opportunity to seize control over his agent's bidding behavior. By *modifying* the human negotiator posts the adjusted price-time strategy to his agent. Accordingly, future bids follow no longer the obsolete strategy. In the example the seller may want to emend his agent's strategy as he observes a rapid increase of buyers bids in round five. The future bids are raised to have a new reservation price of probably € 102.50 or even to € 102.70.

Each human negotiator can *withdraw* from the negotiation at any time.

Figure 1. Sellers' perspective of an AMTRAS negotiation.

There are two configuration options for the competencies of the agents being indicative and obligatory. Indicative means that the agent tries to succeed in the negotiation and reports the negotiation outcome to his (human) principal. The (human) negotiator decides whether or not the trade is acceptable. In the case of obligatory bids, approval is not necessary. The agent independently fixes the deal and only reports the outcome unless the principal has not withdrawn yet.

3.2 Virtual Trading Room (VTR)

VTR⁷ (for a detailed description see Budimir and Holtmann 2001; Neumann, Holtmann et al. 2002) is a web-based stock trading system designed for the needs of retail investors' OTC trading.

3.2.1 The System:

- (i) Product Definition/ Selection:
Stocks are for the largest part of the German retail investors still the most popular products. In Germany (after-hours) stock trading for retail investors is implemented by traditional dealer markets only (e.g. Cats-OS, Xeos).
- (ii) Investor Identification:
Since the mid-90s – when the first online brokers entered the market – private investors have been increasing in importance as potential customers. Hence, private investors awakened the interest of market/exchange operators. However, this newly developing customer segment is not easy to serve taking the heterogeneity of their preferences into account. The heterogeneity captures (among other factors) the differences of deposit volumes, trading frequency and most notably experience in securities trading.
- (iii) Demand Evaluation:
The demand profile of an individual is closely linked to his trading frequency, motivation and strategies, ranging from long-term investment to so-called “heavy traders”. The latter generally conduct more than one hundred trades a day for arbitrage reasons. Therefore they request an institutional investor-like treatment and additionally specialized trading vehicles (Weinhardt, Gomber et al. 2000; Budimir and Holtmann 2001). As scientific literature remains silent about private investors' demands, surveys of market research institutions have been analyzed and diverse interviews have been performed with leading brokers.
- (iv) Market Design/ Implementation:
As demand profiles are heterogeneous and liquidity matters in OTC trading even more than in established exchange markets, VTR embodies the concept of cascading DMM (cDMM). cDMM extends the concept of DMM in a way that investors can trade against but also inside the (quoted) spread. The concept of a quote-driven market is combined (among others) with order-driven mechanisms for price determination Hit&Take and Hit&Chat.
- (v) Testing:
The evaluation of the system has been conducted following a two-tier testing procedure: Tier 1 regards the functionality (debugging),

tier 2 encompasses financial experiments. Laboratory experiments give evidence that the utilization of cDMM meet the previously stated expectations (Budimir and Holtmann 2001).

3.2.2 Double-sided Auction in VTR

Implementing the concept of cDMM, VTR combines an agent-based (multilateral) negotiation procedure with double auctions. For any tradable product, a double auction is automatically generated. The number of traders on each market side is per-se not constrained. On specification of the order, the negotiator has the option to

- a) take part in the double auction by determining the desired product, price, and amount.
- b) delegate an order to a software agent. Similar to the first option, the negotiator has to determine the desired product, price, amount, and additionally a price-time strategy.

In the former case, the offer is going to be posted in the open order book (henceforth type-1-orders), whereas in latter case the agent takes care of the offer (type-2-orders). Type-2-orders can engage into a multilateral negotiation process, and moreover the offers are automatically placed into the order book. This implies that type-2-orders can be matched either with type-2-orders or as well with type-1-orders.

The multilateral negotiation process is characterized as follows: The specification of a type-2-order requires a price-time strategy in an AMTRAS like graph. A trade occurs if a buy and a sell order can be executed against each other to a price of the last bid.

The left part of Figure 2 illustrates the price time strategy, whereas the right part shows the order book of the corresponding double auction. In this case the trader is a buyer. He decides to renew his bid nine times 30 seconds each, hence the graph is divided into nine parts. Each bid can be revised before this rounds starts. The trader can arbitrarily set both, the number of changes, i.e. the rounds, and the intervals between them.

The two horizontal lines determine the current “Bid-Ask” spread where the upper line at € 112 represents the lowest sell (A1 in the order book) order and the lower line the highest buy order (B1). The bold line depicts the trader’s strategy. For simplicity it is assumed that all other traders leave their bids unchanged. Then the trader will start bidding at € 108, topped by the bids B3, B2 and B1 (those bids are, however, too low to be executed against A1). Five rounds later, the agent adjusts the bids such that a deal with sell-order A1 can be clinched. In case that the trader’s volume is higher than that of A1, the trader remains in the negotiation. In this example, the agent decreases his bid before jumping up to € 113.

The real outcome cannot be predicted as easily because the simplicity assumption that the other participants keep their bids constant does not hold.

Figure 2. Buyers' perspective of a VTR agent based double auction.

3.3 Reconsidering multi-lateral Negotiations

The implemented multilateral negotiation process is likely to allocate the objects to bidders who value them most. Furthermore, the open format of bids allows bidders to learn about the others' valuations. In the affiliated setting, revealing the private information to all bidders during the process lessens the uncertainty about the (common) value of the object. Thus, bidders feel more comfortable with own valuation and may raise/lower the revenue depending on the direction either forward or reverse. On the other hand, open format auctions often support collusion and entry deterrence (Klemperer 2002).

a) Collusion

In the case of ascending auctions, it is easy to form an auction ring. The cartel agreement is self-enforcing because the ring members cannot gain by breaching the agreement. If a ring member does not abstain from bidding, the *designated winner* can realize the breach and raise his bid as well. The threat of auction rings is even increased when competition is weak.

b) Entry Deterrence

In ascending auctions usually the bidder with the highest valuation will eventually outbid the competitors⁸. Even if the valuation is only slightly

higher than the second highest is, the bidder with the highest valuation will top the others. Accordingly, other traders have only little incentive to enter the negotiation, particularly if participation requires costs.

The concept of agent-based multilateral negotiation retains the advantages of open format auctions without incurring their detrimental effects.

In the VTR negotiation collusion is less hazardous because the implemented *double-sided auction* creates a situation in which breaching is more profitable than complying with the collusive agreement. All members of the ring are exposed to the threat that someone breaks the agreement and is hence tempted to breach as well (Clauser and Plott 1993).

In the AMTRAS negotiation the issue is more subtle: Recall, that the terminal time is not necessarily a-priori known. Overlapping bids are instantaneously executed against each other. This implies that breaching a collusive agreement can clinch the deal. In this case, there is no time for the auction ring left to top this bid. Accordingly, collusive agreements are unlikely to occur since there is also an incentive to break the agreement.

Furthermore, the use of software agents alleviates the entry deterrence issue. Since an agent's participation costs in an auction converge to zero, an obstacle that prevents from participating is lessened. However, participating in multiple negotiations raises the costs of coordination. The entry deterrence issue is therefore not fully removed.

4. CONCLUDING REMARKS

As demonstrated in the previous sections software agents can support market participants in three ways. Firstly, by taking on time-consuming, repetitive tasks like searching for possible counterparts, the market participants can be tremendously relieved. Secondly, by employing software agents the human negotiator can act anonymously. Particularly in the case of information-motivated trading (e.g. insiders), anonymity is desirable whereas in the case of non-informed trading it is not. This is because the non-informed traders cannot identify the insiders. Thirdly, software agents can support or even seize total control over the bidding process itself. In a first step undertaking the bidding also discharges the (human) negotiator from participating in a negotiation. However, the potentials of intelligent software agent are higher than that: Recall that information feedback following an open bidding procedure can contribute to better price qualities. Therefore it is necessary to perceive the newly revealed information immediately and utilize them in subsequent bidding stages. The analysis of bids and the deduction of own actions are not yet supported by the software

agents of both prototypes. Hitherto, they are not really ‘intelligent’ – the human participant is in charge of strategy amendments.

‘Intelligence’ of agents can be classified following the nice approach given by Caglayan and Harrison (Caglayan and Harrison 1997). They define three ascending dimensions of intelligence.

1. Understand Preferences:

The first dimension refers to the ability of understanding preferences and act accordingly. It thus requires a formal representation of the preferences.

Both systems presented in section 3 satisfy this dimension since the human negotiator can delegate static, i.e. information-invariant, time-price strategies to software agents.

2. Develop Strategy:

The second dimension refers to the ability of inferring strategic rules. The agents depicted in section 3 generate their bids independent of any signals from the remaining agents. Accordingly, they do not satisfy this dimension of intelligence.

As a best practice example, the CONSENSUS agents (Benyoucef, Alj et al. 2001) attain this dimension by using complex feedback rules for defining the agents’ behavior.

3. Adapt Strategy:

The third dimension refers to the skill to learn, where learning describes the adaptive changing behavior of the strategies due to new experiences. In these cases, the agents can independently adapt their strategies based on the experiences of previous negotiations in order to improve their performance.

Until now there are just very few approaches dealing with this problem.

Combining machine learning and agent based bidding behavior together appears to be an amazing challenge for future research. Once agents achieved level 2, or even level 3, more sophisticated applications are viable: For example the agents could act as arbitrageurs by swapping in-between different markets (or market models, respectively). Overall, this feature would enrich the concept of Dynamic Market Models in way that the detrimental effects of fragmentation are alleviated even if the market mechanisms are not cascading.

5. ENDNOTES

1. Note that reverse and forward auctions are mathematically equivalent. For simplicity reasons only forward auction setting are used throughout the paper.
2. This is especially true for affiliated bidders’ valuations, i.e. the valuation are positively correlated to some extent Milgrom, P. R. and R. Weber (1982).

4. For further definitions and explanations on software agents see e.g. Jennings, N. R., P. Faratin, et al. (2001).
5. AMTRAS has been a co-operation project of Deutsche Boerse, living systems, Compaq (formerly DEC) and the Chair for Information Systems, Giessen, now Chair for Information Management and Systems, University Karlsruhe.
6. The negotiators can in fact additionally submit a list of market participants they (don't) want to trade with and some kind of a fuzzy description of the product they want to trade – AMTRAS performs a partner and product matching before the agents meet each other in the price determination/ negotiation process. We do focus on the latter in this paper (for further information to the different matching types see Weinhardt, C. and P. Gomber (1998).
7. The concept of the VTR has been developed in co-operation with BROKAT Technologies. VTR has been build as a prototypical system at the Chair for Information Systems, Giessen, now Chair for Information Management and Systems, University Karlsruhe, and is now rebuild for practical use by trading-fair.
8. Hence in this respect, sealed formats are more advantageous since "weaker" bidders can win a negotiation under realistic circumstances. The prices yielded by a sealed-bid auction are one the other hand less likely to attain an efficient allocation.

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