A Quote-Driven Automated Market

Rachel A Bourne and Rehan Zaidi
Department of Electronic Engineering,
Queen Mary, University of London, UK
r.a.bourne,rehan.zaidi@elec.qmw.ac.uk

Abstract

This paper reports on preliminary research into a new type of automated market, namely a quote-driven market. The research aims to develop the necessary market protocols and infrastructure, and to investigate the impact of pre-set parameters on the effectiveness of the market in terms of liquidity, price volatility, throughput and profitability for the market participants. Quote-driven trading is well-suited to products such as financial instruments, bandwidth, electricity—any product that requires real-time trading. In particular, we discuss how this form of regulated but decentralised marketplace may offer advantages over more traditional automated market mechanisms such as auction protocols.

1 Introduction

The potential use of autonomous software agents to act on behalf of individuals and businesses in real-world commercial applications has stimulated a rapid increase in research into negotiation and interaction protocols in multi-agent systems (Beer et al., 1999; Jennings and Wooldridge, 1998). One way to facilitate the interactions between agents, and to enable their designers to equip them with appropriate strategies, is to provide open, regulated platforms within which agents can come together to do business. Moreover, it is to be expected that a simple and transparent regulatory framework will encourage potential participants to join the market, thus enhancing its overall effectiveness (Rosenschein and Zlotkin, 1994).

Recent experiences within the rapidly expanding world of e-commerce and electronic marketplaces (see section 2) have pointed to two issues that may affect the future performance of electronic trading environments: 1) the lack of a truly distributed marketplace; and 2) fragmentation due to asynchronous supply and demand needs of buyers and sellers in terms of both time and quantity. Our work addresses precisely these issues by investigating the potential of a decentralised market framework—the quote-driven market—in which multiple traders act as buffers between buyers and sellers enhancing market liquidity and stabilising short-term fluctuations in supply and demand. In the quote-driven market, marketmakers are intermediaries who are obliged to quote live prices to clients, thus providing a willing counterpart with which to trade, no matter what the current state of the market—a framework that appears well-suited to real-time trading. Although common in financial markets, this approach has not received much attention in the context of multi-agent systems, an arena that may provide new insights into trade-offs between different types of automated markets.

The paper is arranged as follows. Section 2 surveys the current state-of-the-art in automated trading from an e-commerce perspective. Section 3 describes the quote-driven market including the actors and protocols. Section 4 looks at the market parameters and discusses the effects each may have on the market's operation. Section 5 introduces our experimental scenario and how it will be used and section 6 discusses our preliminary findings. Section 7 details related work within the literature. Section 8 concludes with a discussion of the merits of the approach and future research directions.

2 Current and Future E-Markets

Commercially available automated trading agents may still be some way off, but the rise of the Internet, and particularly the increased emphasis on e-commerce, has led to the creation of several types of electronic marketplaces (or e-markets) (Mougayar, 1999).

Business and price negotiation mechanisms conducted on the first generation e-markets have mostly followed the fixed or posted pricing model. Although digital exchanges and auctions sites do introduce an element of "dynamic trading" on the Internet, these are inhibited by the problems of transactional fragmentation for the merchant, liquidity barriers for the auction sites and vertical market saturation for the marketmaker (Jordan, 1999).

A common aspect of e-markets, irrespective of the business model they follow, is that they are inherently closed, standalone marketplaces. This may be because they are operated by single organizations; because they include handpicked or "invited" business partners and/or loyal electronic consumers; or because they assume a high degree of synchronisation between the activities of the market participants. As such there have been few efforts to implement distributed dynamic trading on the Internet, although recent research shows that this could be beneficial to all involved (Priest et al., 2000). At present, the attraction of e-markets can be attributed to factors such as provision of a large base of potential customers and suppliers; reductions of the time scales and overheads of business transactions, thereby improving overall economic efficiency; and reduction of the margins between price and cost.

In the future, the coming together of the global economy and the Internet will provide us with a dynamic information economy (Kephart et al., 2000), which will see millions of economically motivated software agents exchanging information goods and services with humans and other agents. However, for such a scenario to materialise, the e-markets of today will have to evolve to be open and truly global. This requires the spelling out of explicit rules of engagement between electronic businesses. One implementation of such open rules can already be seen in the RosettaNet initiative (`www.rosettanet.org`), which aims to bring together the numerous entities involved in the IT industry.

Another trend that may go a long way towards shaping the evolving world of e-commerce, is the identification of new products and services that may be traded over the Internet, taking advantage of its inherent features. As well as financial instruments such as shares, which are already traded on automated exchanges (e.g., `www.tradepoint.co.uk`), there is a move towards the "commodification" of electricity (Amin and Ballard, 2000; Reticular Systems Inc., 1999), bandwidth (e.g., `www.rateXchange.com`), CPU cycles and, ultimately, information itself. Not only do these "commodities" need to be packaged conveniently as marketable products (or goods) for the purposes of trading (Henderson, 1999; du Pre Gauntt, 1998), but the markets themselves require a proper framework that satisfies the needs of all the entities involved including the buyers, sellers, marketmakers, brokers and the regulatory authority.

Our work on the quote-driven market intends to address these themes through the use of marketmakers operating within a decentralised real-time framework.

3 Quote-Driven Market Structure

The essence of the quote-driven market is that the marketmakers, or traders, act purely as intermediaries between the buyers and sellers, or clients. Marketmakers act as principals in transactions taking on positions in the product; a trader with a long position has product to sell, while one with a short position has sold more than he owned. The traders thus provide a service to clients: each client is free to buy or sell product whether or not there exists a willing counterpart in the marketplace; the trader provides the price and acts as the counterpart in the transaction. Clearly, traders expect to benefit financially from providing this service and, conversely, clients must be willing to pay some amount for the service provided. What is not clear, however, is what a fair price for such a service should be, and to what extent this may depend on the market parameters.

In a quote-driven market, a client wishing to buy or sell quantities of product requests live prices, or quotes, from traders, one of whom subsequently acts as the counterpart in the client's transaction, should his price be acceptable. Note that the traders do not (necessarily) have any end use for the product being traded, they purely act as go-betweens in the market[1]. This contrasts both with order-driven markets, in which counterparts are matched against each other, the traders taking a commission on the transaction, and with auction protocols, in which buyers and sellers come together synchronously to trade, requiring a third party (the auctioneer) to determine the winner of the auction and the price at which goods are to be exchanged. Thus, in a quote-driven market, fluctuations in the clients' supplies and demands are smoothed over by the traders; the market as a whole stands to benefit from this buffering effect, which ought to lead to greater liquidity and less price volatility.

The quote-driven market operates through a system of clearly defined market parameters and roles, decentralised real-time trading and centralised but longer-term enforcement of regulations by the institutional body, to which all clients and traders belong. Clients are free to trade with any trader and interact with them by requesting quotations. Each trader must make a live, two-way price at which he is obliged to trade with the client in any quantity within the pre-set market trading limits (the market size). The quote is composed of a bid price, at which the trader is willing to buy, and an offer price, at which he is willing to sell. The maximum difference between the bid and offer is fixed and known as the trading spread. Thus whenever a trader quotes a price, he does not know which way the client is inclined to deal and therefore has an inbuilt incentive to quote a price that reflects his true valuation of the current market value of the product. Additionally, traders may request quotes from, and trade with, other traders in amounts up to the market size. This allows traders to square their positions by selling a long position or covering a short position, and to take advantage of any differential pricing.

In the past, markets such as these have been operated with clients and traders communicating, for example, over the telephone; in the automated setting, communication occurs via simple two-way one-to-one protocols (i.e., request-quote-trade-acknowledge). The automation of the protocols does not require any sophisticated technology other than secure authentication protocols. On the other hand, the strategic behaviour of traders—the prices made and decisions about interacting with other traders—are design decisions that are likely to be extremely complex. However, whatever the strategic deci-

[1]However, typically the traders will be "owned" by some larger interested party.

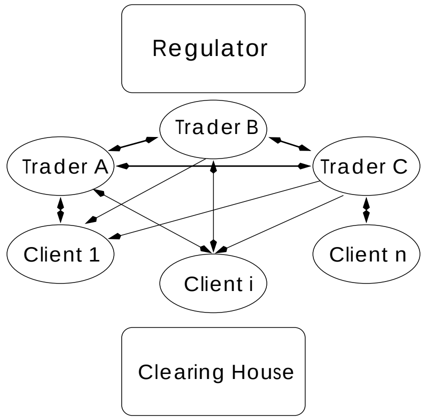

Figure 1: Actors in a Quote-Driven Market.

sions of traders, the performance of the market is necessarily affected by the market infrastructure and, in particular, the pre-set market parameters (market size, trading spread, time limits for responses, etc.).

The market is enforced by a central authority, here termed the regulator. Unlike an auctioneer, the regulator plays no part in the day-to-day operation of the market but acts purely as a watchdog. The de-coupling of operation and regulation within the market means that all members have a stake in enforcing the correct functioning of the system as a whole. Members who experience violations of market protocols report them to the regulator who takes due consideration and enforces the appropriate penalty. The penalties associated with violations are also pre-set parameters and this process might also be automated.

Figure 1 shows a diagramatic representation of the whole market. It includes one further participant, the clearing house, which acts as the settlement and delivery mechanism for the product being traded. Whenever a trade is agreed, confirmation is sent by both parties to the clearing house for matching. (The communication channels between the traders and clients and the regulator and clearing house are not shown.)

4 Market Parameters

This section looks at the market parameters that the quote-driven market requires and how they may affect the operation of the market.

4.1 Trading spread

The trading spread is the difference between a trader's bid and offer price. Since traders are obliged to provide both a buying and selling price, it is in their interest to make as accurate a price as they can, that is, to ensure that their true valuation lies within the trading spread.

All things being equal, in a stable, liquid market, a trader may expect to buy on his bid and sell on his offer, thus making a profit; in such cases, the trading spread compensates the trader rather like a commission. However, since the trader is taking on a position in the product, he runs the risk that the market will move against him (or in his favour). So the trading spread also acts as a buffer against movements in the market. There needs to be a balance between a wider spread—to provide an incentive to the trader—and a tighter spread—to minimise the price clients pay for a liquid market.

We anticipate that, as the spread decreases, traders become more speculative, trying to guess future market direction, which may lead to greater price fluctuation. Conversely, as the spread widens, the cost to clients becomes more significant, leading to less liquidity.

4.2 Market trading limits

The market stipulates the maximum and minimum quantities of product for which a trader's price is valid. Clients may deal in any amount within these limits though traders may agree to accept trades in larger (or smaller) sizes.

At the lower end, the minimum limit may represent the smallest amount of product on which the trader could recover his dealing costs; for example, the trading spread multiplied by the minimum size. At the upper end, the maximum limit represents the largest amount of product a trader is willing to take on before he changes his price; for example, in a rapidly changing market, a trader would not wish to trade in unlimited amounts of product. In general, we would anticipate that the larger the maximum size, the more liquid the market, since clients will find it more reassuring to buy and sell large amounts of product if they know that it is easy to liquidate their holding in the marketplace.

4.3 Number of traders

The number of traders is critical in determining their own potential for profit. Although clients may be willing to pay some price so that a liquid market is maintained (as discussed above), there is a limit. At some point, more traders will imply less profit-making potential. On the other hand, a single trader may monopolise the market leading to a poor service for clients. It seems likely that a minimum of two competing traders will be needed to maintain the market.

4.4 Response times

There are two time limits. Firstly, traders are expected to respond to quotes within a certain time from the request (time to respond); and secondly, quotes are not active indefinitely so that clients must deal within a certain time of receiving the quote (time to trade).

If the time to respond it too great, the market will hardly be liquid. However, a trader may need some time to compute his quote and, in busy markets, may have to provide many quotes at one time. Traders who fail to respond quickly enough may be reported to the regulator; after numerous such offences, penalties will be imposed on the trader by the regulator (acting for the market institution as a whole).

If the time to trade is too great, traders will be exposed to the quotes they have given, making it hard for them to assess their liabilities. If the time is too short, clients may not have the opportunity to check sufficient other prices in the market before deciding with whom to trade.

In the automated setting, in particular with markets being conducted over the Internet, some secure means of establishing when requests, quotes and trades are sent by one party, and arrive at another, will be required. This is an important consideration, particularly given the possibility of incurring penalties for violations.

4.5 Cost of running positions

This is a crucial factor in a trader's ability to make a profit. Bearing in mind that traders assign no instrinsic value to the product they are trading, any cost of running a position eats into their profit (or increases their loss).

In order to maintain a liquid market, it must be technically possible for traders to run long and short positions. How this is achieved will depend on the domain, but there is likely to be a borrowing cost associated with being short and possibly costs associated with running long positions as well (e.g., owning bandwidth that remains unused over long periods is likely to be costly).

5 Experimental Scenario

In order to establish and evaluate the properties of this quote-driven approach, we have developed a simple scenario in which we simulate the supply and demand in the market (i.e., the clients) and use real traders, with independent strategies[2], to make prices. Note that since this research is interested in the design of the electronic marketplace, not specifically in the strategic response to it, it is appropriate to use a variety of different traders.

Traders are required to conform to the market requirements, that is, to quote prices and trade as per requests from clients. The clients are generated randomly with trading limits around a mean that reflects the current value of the product. Thus we can control the supply and demand, and the exogenous market value, and the amount of surplus profit available for marketmakers. The clients attempt to obtain quotes from all traders and deal with the one who quotes the most favourable price, subject to their limit. Additionally, some clients merely check the traders' prices and report these to the regulator (e.g., to obtain the current market price)[3].

[2]These are programmed by MSc students taking our "Intelligent Agents and Multi-Agent Systems" module, to whom we are indebted.

[3]However, if these price-checking clients obtain quotes such that one trader's bid is higher than another trader's offer—colloquially known as a *backwardation*—the client will buy from one trader and sell to the other, recording the profit it makes in-between. Such clients can be thought of as acting as speculators in the market. In the real-world, this sort of client behaviour is frowned upon!

In these initial stages of experimentation, the only information available to traders is through interaction with clients and other traders. To discover the prices being made by others, a trader must expose himself to quoting a price in return. Similarly to auction settings, traders experience the "buyer's curse" (Sandholm, 1999), in that whenever they trade with a client, they know that the price they quoted was the highest or lowest. However, traders cannot make a profit without trading; moreover, trading with clients is generally more profitable that trading with other traders because when acting as a client, a trader must pay the full asking price himself. A trader who is long may deliberately attempt to make the lowest price in the market, in order to be the one who makes the sale. Rather than being a curse, trading with clients is the simplest way for a trader to make a profit, provided his prices allow him to do so.

Simulated market conditions will include stable as well as bullish and bearish markets. Because the supply and demand in the market are controlled, and the clients limits are known, it is possible to record data such as how much surplus profit is available to traders; this can be compared with the overall profit they realise. Other interesting features include the way in which the traders' prices fluctuate with changes in supply and demand (including rates of change); price variations among traders; how much client business can be completed successfully; and the effects of varying trader numbers, response times, trading spread, etc. on these results.

This simplistic scenario has been used to focus on the macro-level design issues of the market; for example, development of the market protocols; establishing appropriate response times; and to throw up any unforeseen implementations issues. As such, it should be viewed as an exercise in rapid prototyping, rather than a testbed for empirical studies. Following on from this, we intend to develop a simulation platform in a real-time domain on which the quote-driven approach may be validated and empirically compared with other forms of automated markets.

6 Discussion of Results

At present, our results are too preliminary for formal analysis; however, we remark on several issues that have arisen through the implementation of the scenario as a real-time multi-agent system.

The messaging system used by traders is based on the Pathwalker programming library written in Java and developed by Fujitsu Laboratories Ltd (`www.fujitsu.co.jp/hypertext/flab/free/paw/`). This system handles all messaging passing and queuing, which has enabled the market protocols to be implemented through a simple hierarchy of classes (Register, Request, Quote, Trade, etc.). The actual response times are of the order of milliseconds, indicating that the framework may be suitable for real-time trading.

Once the traders have registered with the regulator, there is at present no facility for them to deregister and back out of their responsibility to make a market for clients. Therefore, if a trading process goes off-line, it is in the interest of its owner to reinstate it as quickly as possible, since during its down time it is likely to be subject to fines for failing to respond.

One important feature for the market regulator is how to establish the veracity of reports for infringements. For example, suppose a trader simply fails to report a trade to the clearing house, how would a client prove that the trade took place? In financial institutions, these sort of disputes are resolved by arbitrators examining telephone conversations, all of which are recorded[4]. In theory, a similar system could be implemented to record messages sent and received by market members, but ultimately disputes such as these would be subject to arbitration by the regulator.

Note that our work is not specifically focused on security and integrity issues—the registration process assumes that traders and clients are vetted and assigned unique identities that can be used for secure bilateral communication channels to be established. It is likely that security and trust models being developed elsewhere (Robles et al., 2001) may be adapted for use within this framework.

Overall, the market operates as expected and provides encouraging support for the view that the decentralised nature of the market interactions is likely to be highly scalable and well-suited to real-time trading.

7 Related Work

Huhns and Stephens (1999) identify two main strands to research into multi-agent system design, namely environment-centred and agent-centred. The former deals with mechanism design, that is, how to create agent societies in which the individuals have an incentive to behave appropriately (Rosenschein and Zlotkin, 1994; Sandholm, 1999), while the latter studies the strategic behaviour of individual agents, i.e., how best to behave in response to a given environment.

Our research takes an environment-centred view of this problem. Criteria for evaluating negotiation protocols and interaction mechanisms are identified by Sandholm (1999) as: social welfare; pareto-efficiency; individual rationality; stability (participants are motivated to act according to a known strategy, e.g., telling the truth); computational efficiency; and distribution and communication efficiency. The key idea is that creating the right environmental conditions should facilitate negotiation, encourage self-interested agents to participate in cooperation, and hence lead to more efficient use of resources while not disadvantaging the individual.

The most widely studied automated market mechanisms are auction protocols (see e.g., Sandholm (1999)). Perhaps one of the reasons that auctions have been so popular among agent researchers is that, under certain circumstances, they have provable properties such as optimal strategic behaviour; pareto-efficient allocation of goods to the bidder who values them most highly; and revenue equivalence to the seller. On the down-side, auction protocols are not collusion proof; rely to some extent on the integrity of the auctioneer; may require centralised control; and may require synchronisation of many actors. More sophisticated protocols, such as double auctions, which use general equilibrium theory, have further disadvantages associated with the computational complexity of the auctioneer's role (Friedman and Rust, 1993)

The effects of market mechanisms have long been studied in the economic and financial literature (see e.g., Garbade and Silber (1979)). Quote-driven markets have existed for some time in the financial sector, particularly the bond markets, alongside order-driven or "jobber" markets such as those of the London Stock Exchange; recently, they have been recommended for relatively illiquid stocks by the Securities and Exchange Board of India specifically to increase their liquidity (Securities and of India, 1999). Others have recommended order-driven markets to be run alongside quote-driven or call auctions in stock exchanges (Handa et al., 1998).

8 Conclusions and Future Work

This paper has presented a novel approach to automated markets that has the potential to allow more liquid and accessible electronic marketplaces through the automation of the intermediary. We have argued that providing incentives to third party traders can lead to a better overall service for clients wishing to trade goods in real-time. As such, this type of market could provide an alternative to auction protocols that are arguably overly prescriptive in the ways agents interact with each other.

The protocols used so far are sufficient for maintaining the market. More flexible protocols are being developed that will enable more protracted negotiation over specific trades (e.g., price, size, delivery time, etc.) to take place; these negotations are usually conducted once the most favourable trader has been located.

The experimental scenario we have developed will be adapted so as to provide a testbed for comparative studies that will be used to establish the trade-offs that occur between the quote-driven market and alternative automated markets.

[4]There are anecdotal reports of these recordings being doctored on occasions.

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