Evolving Bargaining Strategies with Genetic Programming: An Overview of AIE-DA Ver. 2, Part 1

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Abstract

The purpose of this paper is to introduce the software system *AIE-DA*, which is designed for the implementation of an agent-based modeling of *double auction markets*. We shall start this introduction with the current version, *Version 2*, and then indicate what can be expected from the future of it.

1 Introduction

Transactions costs play a key role in determining how great the extent to which electronic commerce can replace conventional ways doing business. The more substantial can transaction costs be saved, the more likely can electronic commerce be dominant. Electronic commerce can contribute to the reduction of transaction costs in many ways, such as reducing physical search space for commodities and price quotes, lengthening business hours, enhancing information quality, and smoothing deal-making processes. Recently, technology based on *software agents*, in particular *intelligent software agents*, has been intensively applied to each of these dimensions. One particular dimension concerning this paper is *bargaining*.

Bargaining is a necessary step to achieve a deal when the price of a commodity or service is not predetermined by only one side of the transaction. In real world, bargaining forms a basis for many deal-making processes. But, a bargaining process can be very time-consuming, and hence the resultant transaction costs can be very prohibitive as well. Therefore, not all business can proceed with a bargaining process unless there is a very efficient way to do. As a result, the *bargaining agent* becomes an important element in electronic commerce.

Depending on the auction style, bargaining strategies can be modeled differently. The specific style which this paper shall address is the bargaining strategies suitable for the *double auction*. One reason to do so is that *double auction* is still one of the most popular auction styles and has been extensively used in financial markets. Nonetheless, the current state of research focuses exclusively on auctions based on the *one-to-one* or *one-to-many* style of auctions, such as the *English auction* or *Dutch auction*. Hence, the purpose of this paper is to initialize a system of intelligent bargaining agents in a double auction market, and study its behavior from both an economic and software-engineering perspectives.

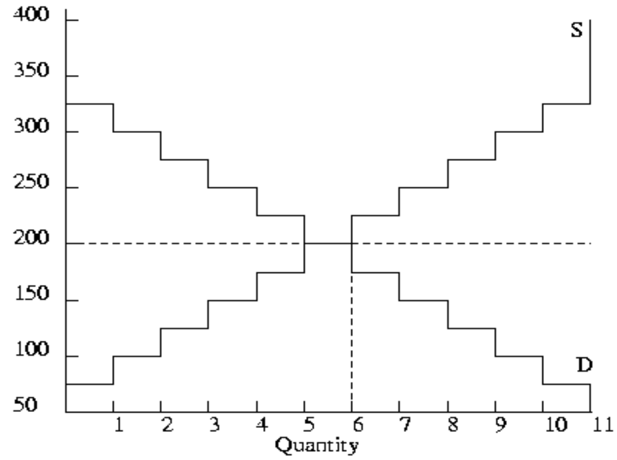

Figure 1. Demand and Supply Curve

The system called *AIE-DA* is written by using the SFI *Double Auction Market* (Santa Fe Institute) as the blueprint.[1] The first part of the paper shall give a review of the main stays of the SFI double auction market. Then, the second part of the paper shall provide an overview of the package.

2 The Santa Fe DA Market

2.1 The Experimental DA Market

The structure of the SFI DA market is very similar to the Arizona *continuous time* experimental DA market ([3]; [4]). In the experimental market, the subjects are divided into a group of *sellers* and a group of *buyers*. Sellers are given a number of units of an arbitrary commodity (*token*), and each unit has a *limit price* (below which it cannot be sold), which is *private* (i.e., known only to the seller of that unit). Buyers are given the rights and means to buy a number of units, and for each unit they are given a *private limit price* above which they must not pay. The array of sellers' limit prices determines the market supply curve, and the array of buyer's limit prices determines the market demand curve. An example with 11 units to trade is depicted in Figure 1.

In the experiments, traders "*quote*" (*bid* and *offer*) prices by typing them into their *computer terminals*: the quotes are then distributed to the other traders, and at any time a buyer can accept a seller's offer or a seller can accept a buyer's bid. This continuous trading process is broken into *discrete periods* or "*days*": at the start of each day, new allocations of selling or buying rights are distributed to the traders.

2.2 Information

At the start of a DA game, the monitor broadcasts *public information* to the traders. Next, the monitor sends each trader a packet of *private information.*

Public information includes:

[1] Useful references on the SFI double auction market can be found in [1] and [2].

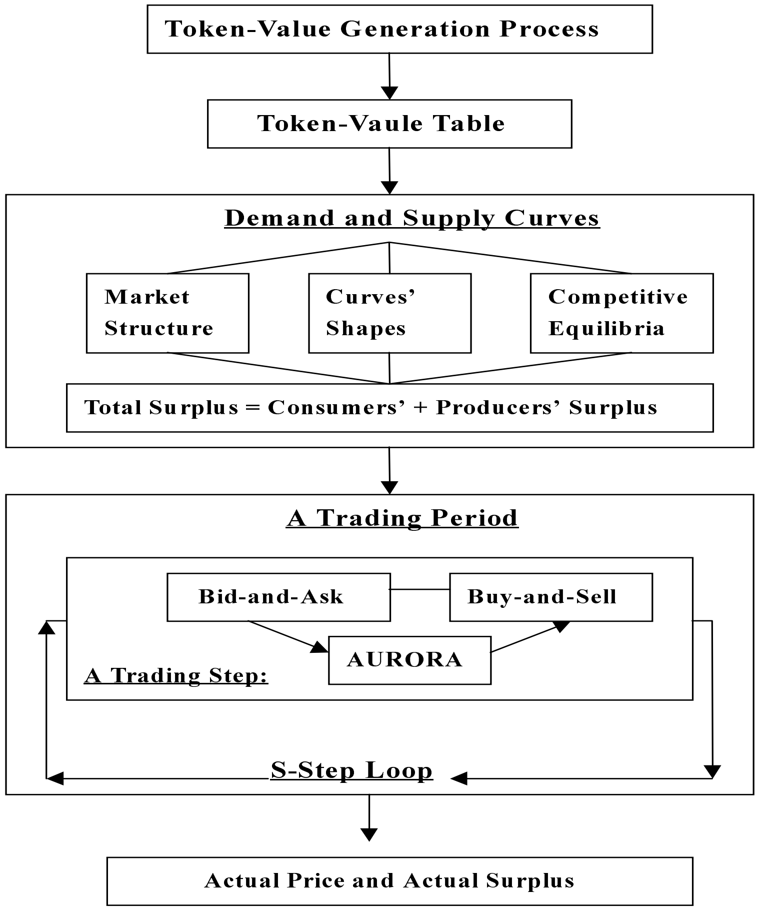

Figure 2. The Flow Chart of the SFI Double Auction Market

- the number of buyers
- the number of sellers
- the number of rounds, periods, and time steps
- the number of tokens each agent will have, and
- the joint distribution F from which the traders' token values are drawn.

At the end of each **bid-and-ask step** (see Section 2.4), the trader is informed of

- each others' bids and asks,
- the current bid (highest outstanding bid),
- the current ask (lowest outstanding ask),
- the holder of the current bid, and
- the holder of the current ask,

At the end of each **buy-and-sell step** (see Section 2.4), the trader is informed of

- whether there is a successful trade, and, if so,
- the trading price.

Private information includes:

Table 1. Token Table: (Gametype 6453)

	Buyers				Sellers			
Token	B1	B2	B3	B4	S1	S2	S3	S4
	First Run							
T1	845(+)	859(+)	863(+)	860 (+)	736(+)	735(+)	740(+)	729(+)
T2	834(+)	828(+)	841(+)	842 (+)	756(+)	762(+)	768(+)	742(+)
T3	818(+)	801(-)	823(+)	804 (-)	806(+)	818(-)	814(-)	806(+)
T4	786(-)	794(-)	806(-)	788 (-)	869(-)	872(-)	870(-)	881(-)
	Second Run							
T1	754(+)	760(+)	761(+)	751 (+)	651(+)	666(+)	646(+)	661(+)
T2	722(+)	708(+)	717(+)	719 (+)	661(+)	675(+)	659(+)	665(+)
T3	691(=)	705(+)	690(-)	702 (+)	680(+)	683(+)	680(+)	693(-)
T4	681(-)	678(-)	689(-)	691 (=)	779(-)	776(-)	788(-)	774(-)

Two runs of the Gametype 6453. Due to the stochastic of the token-value generation process. Even with the same Gametype, the table of token values quite likely can be different.

- traders' realized token values.

2.3 Token-Value Generation Processes

Token values are represented by T_{jk} where j indexes the trader, and k indexes the token assigned to the trader. Tokens are randomly generated according to

$$T_{jk} = \begin{cases} A + B + C_k + D_{jk}, & \text{if} \quad j \quad is \quad a \quad buyer, \\ A + C_k + D_{jk}, & \text{if} \quad j \quad is \quad a \quad seller, \end{cases} \tag{1}$$

where

$$A \sim U[0, R_1], \tag{2}$$

$$B \sim U[0, R_2], \tag{3}$$

$$C_k \sim U[0, R_3], \tag{4}$$

and

$$D_{j,k} \sim U[0, R_4] \tag{5}$$

Each of the four digits of the gametype variable corresponds to $\{R_1, R_2, ..., R_4\}$ according to the base-3 coding,

$$R_i = 3^{k(i)} - 1 \tag{6}$$

where $k(i)$ is the ith digit of gametype. Notice that when

$$R_1 = R_2 = R_3 = 0, \tag{7}$$

we have a model of standard independent private values where tokens are independently uniformly distributed on the interval $[0,R_4]$.

For example, two runs of a token-value gametype "6453" with 4 buyers and 4 sellers, and with four token assigned to each trader, is shown in Table 1. Here, "6453" implies

$$A \sim U[0, 728], B \sim U[0, 80], C_k \sim U[0, 242], D_{j,k} \sim U[0, 27].$$

The competitiveness of each position token is indicated by signs "+", "-" or "=" appearing inside the bracket. "+" indicates an intra-marginal (competitive) position, whereas "-" indicates an extra-marginal (non-competitive) position. The position exactly in between, which is not different from the competitive equilibrium (**CE**) price, P^*, is denoted by "=". In this specific example, there is an unique P^*, 691, for the second token-value table, whereas only a CE interval of P^*, (806, 814), for the first one.

In addition to P^*, once a table of token values is generated, the shapes of demand and supply curves are also determined, and hence the *total surplus* (**TS**), where

$$TS = \sum_{j \in buyer,k} (T_{j,k} - P^*)^+ + \sum_{j \in Seller,k} (T_{j.k} - P^*)^-, \tag{8}$$

"+" above refers to the positive part of the function, and "-" the negative part of the function.

2.4 Trading Procedure

An individual DA game is divided into one or more *rounds*, and each rounds is further divided into one or more *periods*. Time is discretized into alternating bid/ask (**BA**) and buy/sell (**BS**) steps. A trading period is simply a set of S alternating **BA** and **BS** *steps*. Transactions are cleared according to the **AURORA** rule.

1. **The BA Step:**
   The **DA** market opens with a **BA** step in which all *software agents* (**SAs**) are allowed to simultaneously post bids and asks based upon the *bargaining program* (to be detailed later), Bid_j ($j \in \{Buyer\}$)and Ask_j ($j \in \{Seller\}$).

   $$Bid_j = Bid_j(x_1^j, x_2^j, ...), \quad j \in \{Buyer\} \tag{9}$$

   and

   $$Ask_j = Bid_j(x_1^j, x_2^j, ...), \quad j \in \{Seller\} \tag{10}$$

   where $x_1^j, x_2^j \in \Omega \cup \Omega_j$. Ω is the *public information* of the DA game, and Ω_j is the *private information* of the DA game, to which we shall come back later. The bids and asks in one trading period is exemplified in Figure 3.

2. **The BS Step:**
   During the BS step, either player can accept the other player's bid or ask. If an acceptance occurs, a transaction is executed. If both parties accept each other's offers, the auctioneer *randomly* choose a price *between* current bid and ask to determine the transaction price.

3. **The AUORORA Rule:**
   The **AURORA** rules were inspired by the similar rule by the AURORA computerized trading system developed by the *Chicago Board of Trade*. **AURORA** rules stipulate that only the holder of current bid (**CB**) or current ask (**CA**) are allowed to trade. By the AURORA rule, the actual transaction price (P) is *randomly* determined as follows.

   $$P \sim f[CA, CB], \tag{11}$$

   where f is a probability density function. For example, f can be an *uniform* or a *triangle* distribution. Figure 4 is the time series of actual price, current bid and

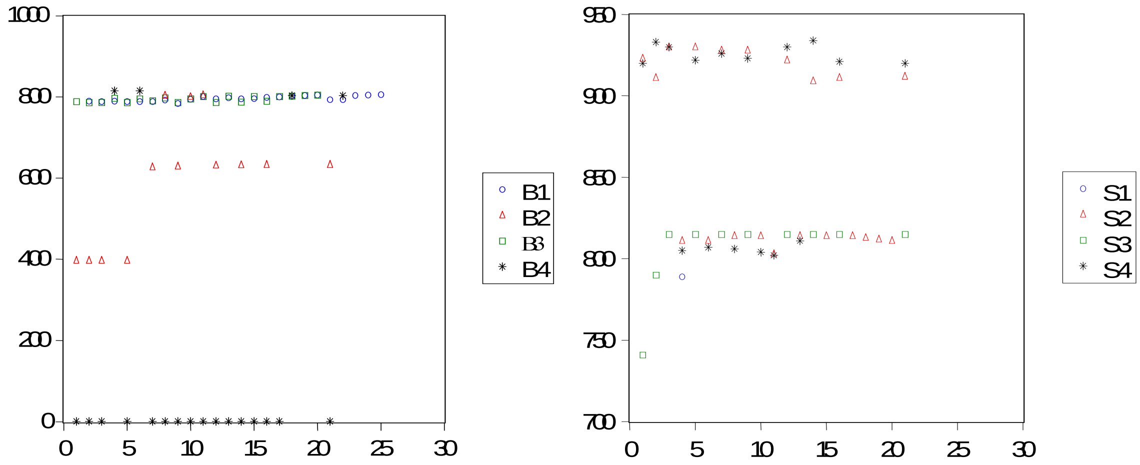

Figure 3. Bids and Asks in a Trading Periods

Results from a single run of the electronic DA market with 4 buyers and 4 sellers and 25 steps in a single trading period based on the first run of the gametype 6453. See Table 1.

current ask in one trading period (25 steps) of a DA market with 4 buyers and 4 sellers.

2.5 Basic Statistics

Once actual price is observed, a series of statistics frequently used in experimental economics is listed. First of all, from the *individual viewpoint*, each trader's profit can be computed as follows:

$$\pi_j = \sum_{k \in bought} (T_{jk} - P_k), j \in Buyer, \tag{12}$$

and

$$\pi_j = \sum_{k \in sold} (P_k - T_{jk}), j \in Seller, \tag{13}$$

where π_j is trader j's profits. From the viewpoint of allocative efficiency, the actual social surplus (**AS**) is simply the sum of profits earned by all traders, namely,

$$AS = \sum_j \pi_j \tag{14}$$

Then the *allocative efficiency* (**AE**) of the market, defined as the total profit earned by all the traders divided by the maximum possible total profit that could have been earned by all the traders (expressed as a percentage), is

$$AE = \frac{AS}{TS} \tag{15}$$

This finishes our review of the SFI DA market. To warp up, a flowchart is given in Figure 2.

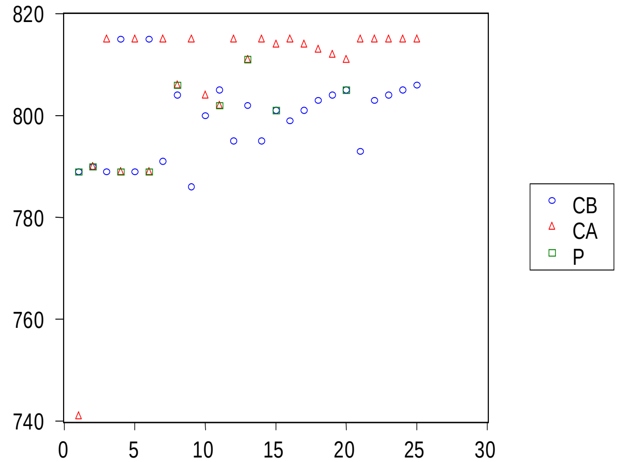

Figure 4. Time Series of the Actual Price, Current Bid and Current Ask

Results from a single run of the electronic DA market with 4 buyers and 4 sellers and 25 steps in a single trading period.

References

[1] Rust, J., R. Palmer, and J. Miller (1993): "Behaviour of Trading Automata in a Computerized Double Auction Market," in D. Friedman and J. Rust (eds.), *The Double Auction Market: Institutions, Theories, and Evidence*, Addison Wesley. Chap. 6, pp.155-198.

[2] Rust, J., J. Miller, and R. Palmer (1994), "Characterizing Effective Trading Strategies: Insights from a Computerized Double Auction Market," *Journal of Economic Dynamics and Control*, Vol. 18, pp.61-96.

[3] Smith, V. (1962), "An Experimental Study of Competitive Market Behaviour," *Journal of Political Economy*, 70, pp. 111-137.

[4] Smith, V. (1992), *Papers in Experimental Economics*, Cambridge University Press.