Evolutionary Stability of Behavioural Types in the Continuous Double Auction*

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Abstract

In this paper, we investigate the effectiveness of different types of bidding behaviour for trading agents in the Continuous Double Auction (CDA). Specifically, we consider behavioural types that are *neutral* (expected profit maximising), *passive* (targeting a higher profit than neutral) and *aggressive* (trading off profit for a better chance of transacting). For these types, we employ an evolutionary game-theoretic analysis to determine the population dynamics of agents that use them in different types of environments, including dynamic ones with market shocks. From this analysis, we find that given a symmetric demand and supply, agents are most likely to adopt neutral behaviour in static environments, while there tends to be more passive than neutral agents in dynamic ones. Furthermore, when we have asymmetric demand and supply, agents invariably adopt passive behaviour in both static and dynamic environments, though the gain in so doing is considerably smaller than in the symmetric case.

Summary

The last decade has seen a significant change in the nature of electronic commerce with the emergence of trading agents, software that is capable of autonomous and flexible action to achieve its objectives and that is endowed with sophisticated strategies for maximising profit in different types of market mechanisms. Now, one of the most important such mechanisms is the Continuous Double Auction (CDA), a symmetric auction with multiple buyers and sellers. CDAs are so important because they are the principal financial institution for trading securities and financial instruments (e.g. the NYSE and the NASDAQ both run variants of the CDA institution). However, developing agents that can participate in the CDA is difficult because it is not amenable to a game-theoretic analysis and there is no known optimal strategy. Therefore, a number of heuristic strategies have been proposed, each of which has a particular behaviour in the market. Given this, in this paper, we are not concerned with developing yet another strategy, but rather we are interested in how a particular characteristic of such strategies impacts upon their behaviour and their effectiveness. The characteristic in question is the *aggressiveness* of the bidding behaviour, here defined as how eager an agent is to transact. We focus on aggressiveness in particular because we believe it is a key determinant of success in the market. In particular, we consider three behavioural types:

1. The *neutral* agent always submits the quote (a bid or an ask) that maximises its expected profit. This is the most common type of behaviour and is one that is often hardwired into various strategies.

2. The *passive* buyer (seller) submits a lower (higher) quote than its neutral counterpart in order to try and obtain a more profitable transaction. Thus if it does transact, it makes more money because it pays less (if it is a buyer) or receives more (if it is a seller).

3. The *aggressive* buyer (seller) submits a higher (lower) quote than its neutral counterpart in order to try and improve its chances of transacting as it offers more (if it is a buyer) or asks for less (if it is a seller) with the aim of making sure that it can trade.

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At this time, comparatively few researchers have considered the issue of varying aggressiveness in a market context. Abreu *et al.* describe the evolutionary stability of behaviours in a reputational model of bargaining, and how players can be more profitable when adopting passive or aggressive behaviour. Thus, while they show that this attitude can have a significant effect on the outcomes experienced, they do not consider the CDA. Walsh *et al.* do consider the CDA and they use an evolutionary game-theoretic (EGT) analysis to examine the interaction of a number of common strategies. Thus, their analysis provides an insight on the population proportion that will adopt each strategy. But, while they restrict their analysis to a particular set of well-known strategies, we are more interested in whether a particular strategy can perform better if it is passive, neutral or aggressive. Phelps *et al.* also use an EGT analysis, but they compare two double auction mechanisms, the call and continuous, given that similar strategies are available for both mechanisms. Thus, they are interested in the performance of double auction mechanisms given particular strategies (including one that is evolved using a GA).

Against this background, we believe this study of behavioural types is important because it provides an insight into how this fundamental aspect of bidding behaviour affects the system's performance. Thus, these results apply to any CDA strategy that is capable of adjusting its behaviour along this dimension (e.g. GD, ZIP or RB). Such insights are important because if an agent can be more profitable by deviating to another behaviour, then it will do so. However, with every agent in the market doing this, the population distribution of types can change significantly. Now, an effective trading agent can use knowledge of such dynamics to decide on what behavioural type to adopt given the particular population distribution of types. Furthermore, because behavioural aggressiveness is usually an endogeneous aspect of a strategy, such an analysis can assist the strategy designer when assessing the effectiveness of various strategies. To perform our analysis, we adopt a similar EGT approach to that of Walsh *et al* and we choose EGT because it allows us to study the dynamics of the CDA when agents are allowed to evolve in terms of the behaviour they adopt. To do this, however, we need to describe the model in a form that abstracts the complex bidding that the CDA mechanism entails, into a simple normal-form game. By so doing, the CDA then becomes amenable to such an analysis. In particular, we develop a set of strategies that vary only in terms of their different behavioural types.

As electronic marketplaces become ever more common, we believe software agents will increasingly come to dominate the trading landscape. Their ability to quickly make informed decisions, based on the available data, make them ideal candidates for automated trading. To this end, analysing the impact of varying one of the fundamental characteristics of their bidding behaviour in a range of market situations is an important step. In particular, in this paper, we show that in a symmetric market, an agent is more likely to adopt an evolutionary stable neutral behaviour. However, when there are market shocks that increase the equilibrium price but maintain the symmetry of the market (meaning agents have to update their beliefs of the market) neutral is no longer the behaviour agents are most likely to adopt. In this case, more agents change to being passive. We also observe that changing behaviour is not particularly profitable for an agent in an asymmetric market.

For future work, we intend to look at other types of symmetric and asymmetric demand and supply, and other types of market shock in order to obtain further insights into how a trader's behaviour changes in yet other types of market. For completeness, we also aim to address the limitation of our model where an agent has the same behavioural type when it is both a buyer and a seller. In particular, we believe that separately analysing these two roles can be more insightful, particular in asymmetric markets, where we do not expect the same behaviour from them.

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