Multiple Market-Maker Behavior in Artificial Financial Markets

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The Problem: This project is intended to study the behavior of intelligent market-makers in a competitive environment. Our artificial financial market can be populated by various types of trading agents with varying levels of intelligence. This provides a framework for testing the behavior of simple and adaptive market-makers who compete with each other for profits, and for comparing price behavior in markets that use multiple competitive market-makers (like NASDAQ) and markets that have a single market-maker for each stock (like the New York Stock Exchange).

Motivation: In the past few years, many algorithms for coping with different aspects of learning have been developed. Recently there has been a growth of interest in the problem of distributed learning and learning in non-stationary environments, both of which are typified by the learning problem faced by societies of agents. Agent-based modeling of artificial markets allows us to study how software agents capable of learning can interact both competitively and co-operatively.

Previous Work: This project draws heavily on research at CBCL on learning in artificial financial markets [4, 9, 3]. Previous research has focused on the learning problem of a single market-maker with affirmative obligations to maintain the quality of the market [3]. In a multiple market-maker setting, the quality of the market should emerge from competitive behavior between the market-makers [8]. Some simulations of the NASDAQ stock market have been carried out, but none of them have focused on market-maker behavior or on adaptive agents [5, 2]. This work draws on the literature on double auction markets [6] and on market microstructure for theoretical grounding (good surveys of the market microstructure literature can be found in O'Hara [8] and Madhavan [7]) and on work in agent-based market simulation at CBCL [4] and elsewhere([2]; *inter alia*).

Approach: We are simulating markets populated by artificial trading agents. Some of these agents conform to standard models in the finance literature (for example, we use uninformed or liquidity traders who trade randomly, and informed traders who know whether the market price overvalues or undervalues the stock), while others use more sophisticated learning or rule-based models for trading. We are performing experiments with both simple heuristic market-makers as well as more complex adaptive market-makers. We are studying both the adaptive behavior of market-makers in a multi-agent setting and the dynamics of the market itself.

In terms of market dynamics, we are comparing, among other indicators, the order flows generated, smoothness of market prices, and average size of the bid-ask spread between markets with multiple market-makers for each stock and those with a single specialist. In our studies of the adaptive behavior of market-makers, we will be studying the differences in behavior that occur when more than one agent is learning in a setting where the optimal strategy is dependent on the behavior of other agents which may also be learning.

Difficulty: In this project, we are trying to deal with two significant problems, one from a theoretical and the other a practical standpoint. Multi-agent learning in nonstationary environments is a difficult problem. Very few algorithms are known for dealing with situations in which one agent's behavior affects the environment for other agents, and yet all the agents are learning and thus changing their own behavior [1]. The other major problem is that most theoretical models of financial markets are very simplistic and do not deal with the complexities of markets in the real world. We hope that the results of our simulations will reveal interesting properties of real markets and learning which go beyond existing simple theoretical models.

Impact: This research should provide insight into the dynamics of financial markets with liquidity provided by the presence of multiple market-makers. The simulation results will help to understand the differences between markets like the NYSE and NASDAQ, at least at a simplified level. Further, the framework of market-making in an artificial financial market is a good testbed for investigating theories of multi-agent learning in competitive settings.

Future Work: We are presently simulating the structure of financial markets with multiple market-makers. The next step after validating our models is to contrast market dynamics in multiple and single market-maker settings assuming that the market-makers are not learning but continue to follow simple rules for setting

bid and ask quotes. Following that, we plan to start investigating the learning problem for market-makers in the multiple market-maker case.

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