Study of Artificial Financial Markets with Adaptive Trading Agents

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The Problem: The project aims to study various ways of designing intelligent trading and market-making agents. We will then study cooperative behavior of agents under previously developed artificial financial market environment. This research can give insights for designing general-purposed artificial markets.

Motivation: In the past years, we and others have developed some basic families of algorithmic components for coping with multiple aspects of learning. It is natural to probe directly into the evolution of intelligence and learning mechanisms and into the problem of distributed intelligence such as collective learning, coordination and competition. In this project, we focus on an agent-based modeling of artificial markets: how software agents endowed with learning abilities might interact, co-evolve, and cooperate in *societies of learning agents*.

Previous Work: The project draws on at least three distinct literatures: the market microstructure, the experimental markets, and the simulated markets. Studies in market microstructure provides important background and context for the experiments and simulations[6]. Another alternative to the theoretical approach is an experimental one in which individuals are placed in a controlled market setting, given certain endowments of securities and cash, and allowed to trade with each other.[2, 5] Lastly, computer simulations of markets populated by software agents extend the experimental approach by allowing the experimenter to test various theories of learning behavior and market microstructure in a controlled environment[4, 3].

Approach: Our proposed research consists of three complementary parts:

1. **Artificial Market Dynamics** — Construction of *artificial financial markets* with adaptive trading and market-making agents whose behavior and performance are studied.

2. **Theoretical and Computational Studies of Market Equilibrium** — Study of theoretical reasoning of the market equilibrium.

3. **Web Market Design** — Improvement of the web market design to create a robust infrastructure on the Web which will be used as control laboratory for human-based and for human+software-agents-based experiments and as a teaching tool in classrooms.

In **Artificial Market Dynamics**, we have constructed various simulations to study (a) the efficiency of information aggregation and dissemination in a market, and (b) performance and characteristics of automated market-making strategies. In the study of information aggregation and dissemination, we have tried trading agents with identical, and heterogenous preferences[1]. The result shows that our trading agents can accurately infer and aggregate diverse pieces of information in many circumstances, and they have difficulties in cases where human traders are also unable to determine the rational expectations of equilibrium.

For **Theoretical and Computational Studies of Market Equilibrium**, we will use artificial markets with software agents to simulate such market equilibrium. There are many trading strategies that we can design and will study how the market equilibrium emerges and how this is related to individual's preferences.

For the **Web Market**, its main goal is to provide a test bed for conducting large scale market experiments involving both human and artificial trader and market makers. The Web Market is an Internet-based electronic market which is designed to be fully automated in the trading process.

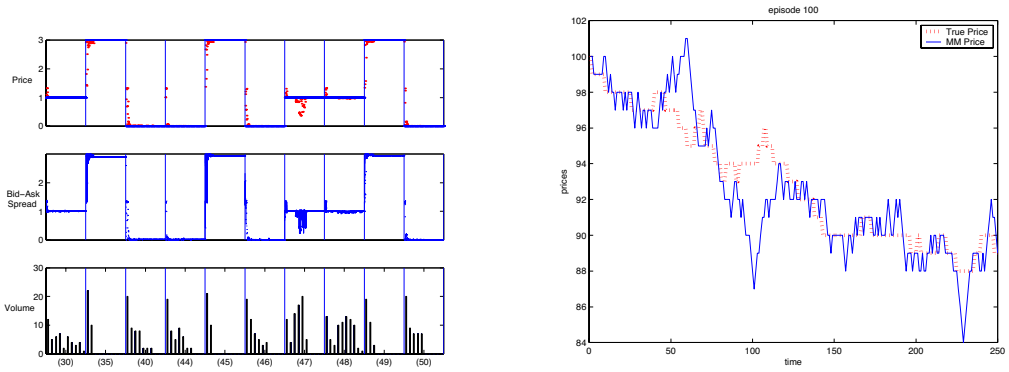

Figure 1: (a) Typical Realization of Artifical Markets Experiemnts (Information Dissemination with Identical Preferences. (b) Typical Realization of Market-Making using Reinforcement Learning (Episode 100)

Impact: This research can give insights for designing general-purposed markets and how they work from different points of view. The questions we ask in this project lie at the intersection of several disciplines, from computer science (distributed systems of agents), to learning (learning is a key aspects of the artificial agents and possibly of the market structure), to economy (financial markets are the primary focus), to cognitive sciences (interaction between agents' biases and properties with the overall behavior of the market).

Future Work: In the next phase of the project, we will carry out two distinct studies.

1. **Artificial Market Dynamics** — In small number of cases, the previous study showed different behaviors from human-based experimental markets. Thus, we will conduct a further investigation in more sophisticated learning algorithms for our agents, non-price learning and communication by human subjects, and the dynamics created by heterogeneous preferecnes. Additionaly, we will try our adaptive market-making strategies in more realistic and complex market environments, and study the possible refinement of the learning techniques to deal with such complex environment.

2. **Theoretical and Computational Studies of Market Equilibrium** — We will try to find a theoretical and computational explanation of relationships between the market equilibrium and traders' heterogenous preferences.

Research Support: Research at CBCL is sponsored by grants from: Office of Naval Research (DARPA) under contract No. N00014-00-1-0907, National Science Foundation (ITR) under contract No. IIS-0085836, National Science Foundation (KDI) under contract No. DMS-9872936, and National Science Foundation under contract No. IIS-9800032.

Additional support was provided by: Central Research Institute of Electric Power Industry, Center for e-Business (MIT), Eastman Kodak Company, DaimlerChrysler AG, Compaq, Honda R&D Co., Ltd., Komatsu Ltd., Merrill-Lynch, NEC Fund, Nippon Telegraph & Telephone, Siemens Corporate Research, Inc., Toyota Motor Corporation and The Whitaker Foundation.

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