Artificial Markets and Adaptive Agents

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The Problem: The project aims to study the design, development and characterization of artificial financial markets, as well as the cooperative behavior of intelligent adaptive distributed agents. The other goal of the project is to develop a software infrastructure on the Web which will be used as control laboratory for human-based experiments. This research can give insights for designing general-purposed artificial markets (financial and non-financial).

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, coevolve, and cooperate in *societies of learning agents*.

Previous Work: In 1990 Santa Fe Institute organized the Double Auction Market Tournament whose goal was to analyze the game played by computerized trading strategies and compare the performance of different strategies [4]. By the same institute, an artificial stock market, a simple evolutionary model characterized by artificial life, was studied. In that model, intelligent agents optimize their profits using genetic algorithms. The behaviors of individual agents and the overall market were observed and analyzed. On the other hand, in the University of Iowa's political stock market [1], speculators bet on the outcome of some future political events, such as the U.S. presidential elections. The market provides an experimental study for investigation of human trading behaviors. There are also various projects on market based-mechanisms aiming to tackle the problem of resource allocation in distributed system with multiple intelligent agents [5].

Approach: Our proposed research consists of two 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. **Web Market Design and Implementation** — Implementation of 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 with asymmetric information, and (b) performance and characteristics of automated market-making strategies. In the study of information aggregation and dissemination, trading agents determine the price to trade based on their private information about the economy and past price information. In preliminary work we have shown that computer agents using simple heuristics (an empirical Bayesian approach) can accomplish what human traders do in the corresponding experimental markets [2, 3], or fail whenever humans fail. Applying reinforcement learning, we model an electronic market-maker that is able to learn their strategies through trial-and-error in a dynamic interactive environment. 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.

Difficulty: The project aims to understand aspects of distributed intelligence in systems of agents that learn, interact, cooperate and evolve. Conventional supervised learning may be inadequate in modeling behaviors in these markets where concepts in evolutionary dynamics and game theory are involved.

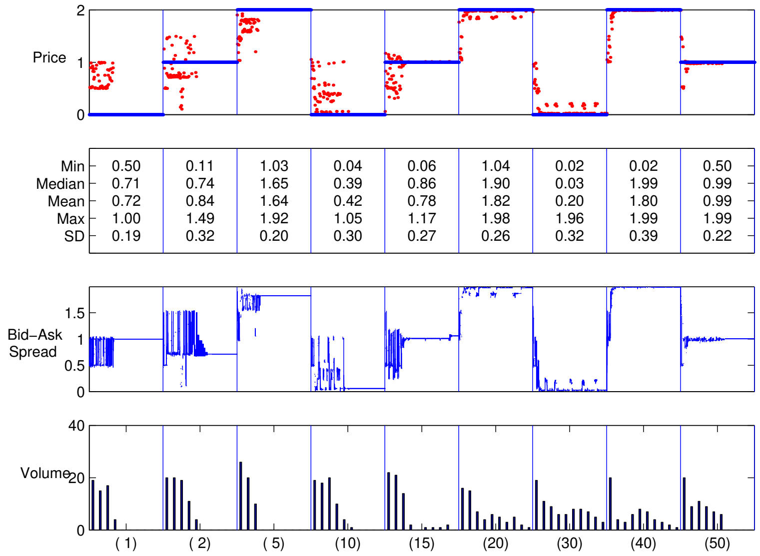

Figure 1: Information aggregation by intelligent agents: the price converges to the equilibrium price. The figure shows the price, price statistics, bid-ask spread and volume in runs 1, 2, ..., 40, 50.

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 place the adaptive agents in an evolutionary environment, by parameterizing the learning algorithms and letting these parameters mutate and evolve subject to selection pressure. Regarding the research in markets, we will focus on issues such as market structure, trading dynamics and knowledge distribution, market pathologies and artificial versus human agents.

Research Support: Research at CBCL is supported by by a grant from the National Science Foundation under contract ASC-9217041.

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