An Evolutionary Framework for Studying Behaviors of Economic Agents

Wolfgang Ketter
Dept of Computer Science and Engineering
University of Minnesota
ketter@cs.umn.edu

Alexander Babanov
Dept of Computer Science and Engineering
Dept of Economics
University of Minnesota
babanov@cs.umn.edu

Maria Gini
Dept of Computer Science and Engineering
University of Minnesota
gini@cs.umn.edu

ABSTRACT

We propose an evolutionary framework for studying agents that interact in electronic marketplaces and describe how to use the framework to study the dynamics of interaction and evolution of agent strategies. We present experimental results from a simulated market, where service providers compete for customers using multiple strategies. The results show how service providers of different strategies adapt to occupy distinct niches in the market.

Categories and Subject Descriptors

K.4.4 [**Computers and Society**]: E-commerce; I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence

General Terms

Economics, Experimentation

Keywords

Evolution, Adaptation and Learning

1. INTRODUCTION

We propose a large-scale evolutionary simulation environment for studying economic agents that interact in electronic marketplaces. Our goal is to learn a set of parameters and a corresponding niche in the market where a strategy has a competitive advantage over other strategies.

Evolutionary frameworks have been used extensively in Economics [**?**, **?**]. Economists have long recognized the need to construct computational systems for rigorous studies and testing through controlled experimentation. Evolutionary systems are relatively straightforward to construct. Using an evolutionary approach allows one to simulate the evolution of a society of agents and to analyze how different strategies change over long periods of time due to interactions with other strategies.

AAMAS'03, July 14–18, 2003, Melbourne, Australia.

The major drawback of current evolutionary systems is that they require a homogeneous representation of the agent strategies, which is dictated by the reproduction rules. This, in turn, discourages the sharing of evolutionary frameworks among different research groups.

2. PROPOSED APPROACH

The method we propose extends the evolutionary approach and allows strategies to be represented in a heterogeneous way, yet allows them to be reproduced and compete in the same environment. We divide the agents in different types according to the strategy they use. Each type keeps its genetic information in a separate gene pool. The structure of a gene pool depends on the agent type. At the start of the simulation each strategy is equally beneficial.

Once the simulation starts, agents who fail to satisfy a predefined performance criterion are removed from the market at regular time intervals and, eventually, replaced by more fit entities. The system observes the distribution of the surviving agents and learns the probabilities with which representatives of each agent type should enter the market. After deciding the type of the new agents, the appropriate reproduction rules are used and the new agents are added to the market. Completely new strategies can be added in a similar way to the market while the simulation is running.

2.1 Test Model

We have conducted a variety of experiments with a simple supply-demand model, where various types of suppliers of a service and customers live and interact in a circular city [**?**]. The model is a discrete-event simulation governed by a few parameters, such as frequency of customer requests, customer utility function, and initial distribution of supplier types. Since the focus of this research is on studying strategies of suppliers, the society of customers is fixed and does not change during the simulation. The society of suppliers is the one that evolves over time to meet the demands of the customers.

Customers come to the market for a single transaction at random intervals governed by a stationary Poisson process with a fixed frequency. The density of customers is inversely proportional to the distance from the center of the city. Upon entry, a customer chooses the supplier that provides the service at the minimum net price. We define the net price c as a function of the supplier's price p, distance to the customer d, and delay due to servicing previously

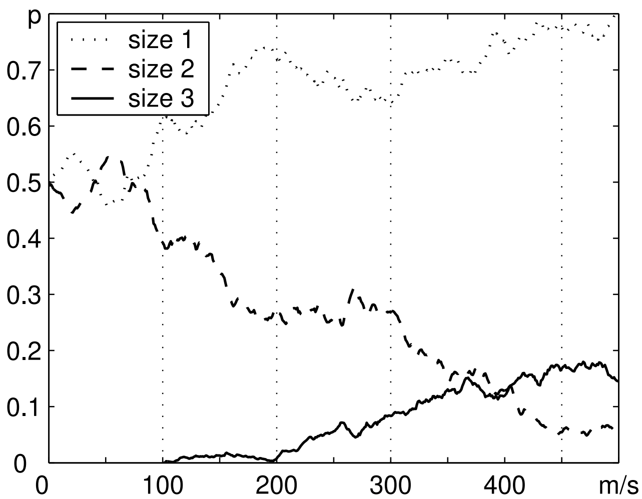

Figure 1: Probabilities of supplier entry as a function of milestones. Size 3 suppliers are introduced at milestone 100.

scheduled customers Δt:

$$c = p + d \times c^{\text{mile}} + \Delta t \times c^{\text{time}}$$

where c^{mile} and c^{time} are the cost per mile of travel and cost per hour delay respectively.

Suppliers enter the market with a certain size, which determines how many customers each can serve concurrently, and a pricing strategy. The price level is assigned on entry and it is maintained during the lifetime of the agent. Every supplier is audited at regular time intervals and removed from the market if its profit becomes negative. The more suppliers having a certain strategy are in the market, the higher is the probability that new suppliers of the same strategy will enter the market.

To maintain diversity in the strategies, a small fraction of the suppliers entering the market uses either a completely new or a retired strategy. This allows any of the strategies that have disappeared from the market to be tried again at a time that might be more favorable.

2.2 Simulation Results

The results of one of our experiments are shown in Figures **??** and **??**. Figure **??** displays the market entry probabilities for each of three strategies over time. Each *milestone* (m/s) in the figure corresponds to roughly 2.5 million transactions. At the beginning of the experiment there is an equal number of suppliers of size 1 and size 2.

We can observe several trends in this experiment. Before milestone 200, suppliers of size 2 lose to suppliers of size 1. Suppliers of size 3, which are introduced at milestone 100, do not have much influence until around milestone 200. The picture changes quite rapidly between milestones 200 and 300. Suppliers of size 3 gain a considerable presence in the market and gain market share at the expense of suppliers of size 1. Suppliers of size 2 maintain approximatively the same market share. After milestone 300 the situation changes again, but this time suppliers of size 2 lose, while suppliers of size 1 and 3 gain presence in the market.

Figure **??** shows a snapshot of the city at milestone 500.

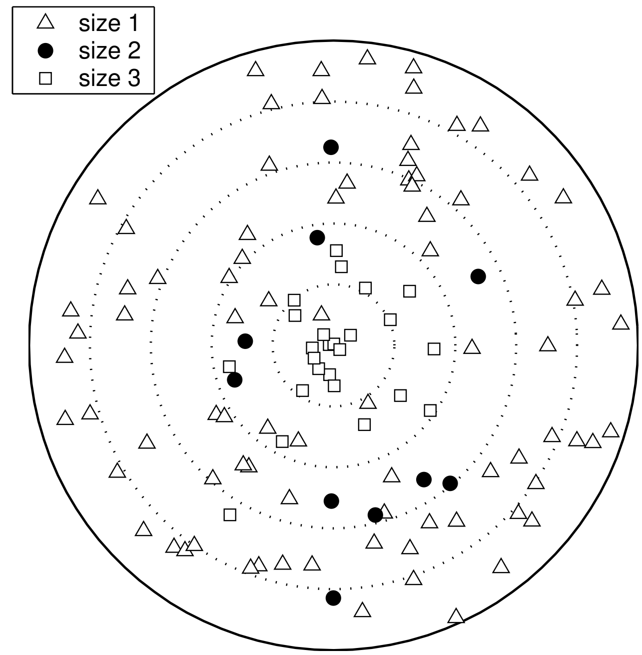

Figure 2: Distribution of different supplier types in the city at milestone 500.

We see that suppliers of size 1 and 3 form "zones of control." Size 3 suppliers control the center of the city while size 1 suppliers occupy the periphery. Size 2 suppliers have a hard time finding their place in the market, after suppliers of size 3 have stabilized.

3. CONCLUSIONS

The evolutionary framework we have presented allows us to observe how strategies emerge over time. Suppliers having the same strategy occupy certain market niches in a dynamic equilibrium with others. As a result, the evolutionary framework discovers several coexisting desirable strategies, not only a single optimum one. An important conclusion from all the experiments is that all types of agents evolve as one society, despite the fact that they use different strategies, information pools, and reproduction rules.

4. ACKNOWLEDGMENTS

Partial support gratefully acknowledged from NSF under awards NSF/IIS-0084202 and NSF/EIA-9986042.