Multiagent-Based Simulation of Societal Networking in a Consumer Marketplace

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ABSTRACT

The Internet provides a means for customers to compare prices for products from several different sellers. However, the customers act individually and they are missing out on the potential benefits that can accrue from acting cooperatively and in concert. The benefits include lower prices, better terms, improved services, and increased efficiency. Businesses have begun forming supply-chain alliances to achieve these benefits, but it has not yet been feasible among consumers. However, using mobile devices can allow for the sharing of information among consumers. Multiagent networking helps in implementing a simulation for mobile agents in a marketplace of consumers. Using basic knowledge in economics and societal networking to develop the groundwork for the implementation of this architecture will provide results to show the benefits that can be gained by consumers. In this experiment, a grocery market has been set up to demonstrate how communication between honest agents representing consumers can result in a lower overall cost for the community.

Categories and Subject Descriptors

J.4 [**Computer Applications**]:Social and Behavioral Sciences–*economics, sociology.*

General Terms

Economics, Experimentation, Human Factors.

Keywords

Consumer Markets; Multiagent Systems, Agent-Based Simulation

1. INTRODUCTION AND BACKGROUND

Using multiagent systems in software simulations can help in accurately depicting a human society. The simulated societies can be used by researchers to study various societal phenomena, such as buying and selling or paying taxes, or to model changes in society that may take extensive amounts of time or are too complex to be characterized mathematically. They can also be used as ways to discover how to benefit society.

Electronic communication via the Internet, mobile phones, etc. has greatly changed the way information can be gathered. Money can be transferred and items bought from anonymous users and businesses over the Internet, and consumers have the ability to compare prices on different items before purchasing. Relative location to a consumer is of little importance in Internet commerce, which allows social networks to form over great distances and in greater numbers than in a traditional, physical market. As a result, the Internet market has become more competitive in pricing and businesses are forced to offer customers fairer prices.

The opposite is true for the traditional consumer market. Relative distance is an important factor to mobile consumers in deciding on a store from which to purchase goods. Prices at these stores are also not shared globally, so a comparison of prices is rather limited. Customers then have almost no alternative to purchasing from the nearest store, regardless of prices at other stores in the community. This lack of information is often exploited by corporations who intentionally raise the price of one item to a certain point when customers stop purchasing, resulting in maximum profit for the store and a higher cost to the consumer.

A possible solution for a mobile consumer is to take advantage of the speed in which communication can be made via cellular phones. Although each agent has little information themselves, a network of agents can contain a vast amount of information. Communicating this information to other agents in the network can allow the consumers to know the prices at several stores and be able to make a decision on which store is best for them based on individual cost. In MAS, communication between agents still proves to be a complicated task to simulate. In the marketplace, self-interest is of primary concern to agents, and the interest of those in their network is secondary. Greed and honesty take hold in the process of making the decision to share vital information throughout the network. Greedy agents will surely benefit for themselves, but will not try and benefit the community, whereas honest agents will benefit the community, but maybe not as much for themselves as they could.

The desired result of communication between agents in a market for mobile consumers is to get fairer prices at stores. Although this might minimize store profits, the profits will come from all consumers more equitably and will encourage each store to charge prices based on a competitive cost rather than on how much can be charged to an unsuspecting customer. Any degree of consumer networking at such a market should result in lower cost for consumers and, in a completely honest society, should result

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ACM-SE '08, March 28–29, 2008, Auburn, AL, USA.
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in the lowest cost. At this point however, profits may be hurt by the global sharing of information and stores might have to spend more to attract customers, but the result could also be a more stable and predictable market.

1.1 Related Work

Several studies have already been done for mobile agents in various applications. Laukkanen, Helin, and Laamanen developed an architecture for mobile agents to provide better service to mobile devices based on different wireless networks, quality of service, and device limitations. This architecture could relate directly to mobile consumers allowing them to get accurate data in time when traveling [1].

In An Agent-Based Approach for Helping Users of Hand-Held Devices Browse Software Catalogs, the aim was to help users browse software catalogs easier and more efficiently on mobile devices [2]. Using this architecture could make browsing grocery stores more practical to the consumer. The ease of use and efficiency of the mobile architecture would also make the system more desirable.

2. EXPERIMENT

In this experiment, the particular mobile market that will be implemented is several different chains of grocery stores evenly dispersed in a simplistically modeled ten square mile town. A modeled market environment was set up using NetLogo[1], a Java-based multiagent modeling environment. The combination of a simulated economy and a consumer network enables customer and store agents to participate in the market.

2.1 Economics

A realistic economy is a very difficult element to simulate in a multiagent system. There are many outside variables that affect the economy in a grocery market. Variables such as the overall market of goods, macroeconomic demand and supply shifts, and supplier costs of the stores help in determining the shelf price that consumers pay. For simplicity, better control, and clearer results, these large-scale economic factors have been left out of the environment and replaced with constants or random set values. The variables of focus are the supply and demand of the microeconomic market. Furthermore, stores provide only one diminishable item, and for this experiment that item is milk. Milk was chosen because it is one of the few items in a grocery market that is inelastic with no substitutes, thus making it more susceptible to price gauging.

To start out, store prices are set based on a range observed recently at local grocery stores. Stores will randomly set the price at milk between \$3.50 and \$4.50. This incorporates the constant of the macroeconomic market and varied supplier costs, and closely represents actual local competition in a market without consumer networking. These prices fluctuate depending on microeconomic supply and demand. Prices are recalculated based on customer demand at the time of restocking. In order to isolate suppliers from local grocery stores, in this simulation the stock is infinite and shelves are "restocked" and priced on the same schedule – once a week. This will allow the focus of the experiment to be directed to the store and not include outside factors.

Supply and demand will cause the prices to fluctuate or remain fairly constant. In the grocery market, prices hardly ever reach either extreme (extremely high or low profits for the store). To simulate this aspect without a supplier cost, a floor price of \$2.50 is made for the milk. With a floor on the supply side, a ceiling must be set on the demand side. This ceiling is described in the agents section. Supply and demand determines the price based on the percentage of total consumers purchasing milk during a week.

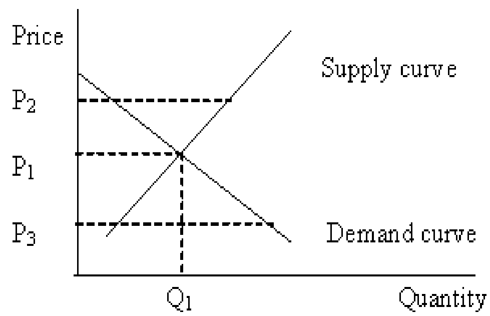

Figure 1. Supply and Demand Relationship [3]

The best illustration of how the economics in this experiment's environment works is in Figure 1. In this simulation, prices only move up and down the supply curve. Shifts of the graph to the left or right due to item scarcity or other factors are not modeled.

Another factor that cannot be overlooked in a mobile market, especially with today's rising gas prices, is fuel economy. Often without communication, consumers will shop at the store nearest to them due to this variable. This must also be considered when designing a method for the lowest cost to the consumer. According to the Bureau of Transportation Statistics[2] in 2002, the average fuel efficiency of passenger cars and light trucks was around 20 miles per gallon. Fuel cost adds to the cost of groceries, and it might not be cost-effective for a consumer to travel across town to save ten cents on a particular item. Because of the rising prices of gas and this additional cost to consumers, stores that are spaced farther apart from each other may be able to reap a slightly higher margin of profit, even with consumer networking.

2.2 Networking

As mentioned above, the purpose of this experiment is to discover if agent communication can result in a lower consumer cost. In order for the agents to establish a connection, a mobile agent network must be set up. There are a couple social networks that could be implemented to accomplish this. The first social network that will be described is a "small world" network, also known as the Six Degrees of Separation. This model is based on the idea that everyone is no more than six degrees, or hops, away

[1] http://ccl.northwestern.edu/netlogo/

[2] http://www.bts.gov

from anyone else in the world [5]. This model is more accurate in a physical communication environment, where agents know each other by meeting face to face. In Figure 2, the blue "people" represent consumer agents. These agents are connected in a small world network, each having an average of four connections and being no more than six hops away from every agent.

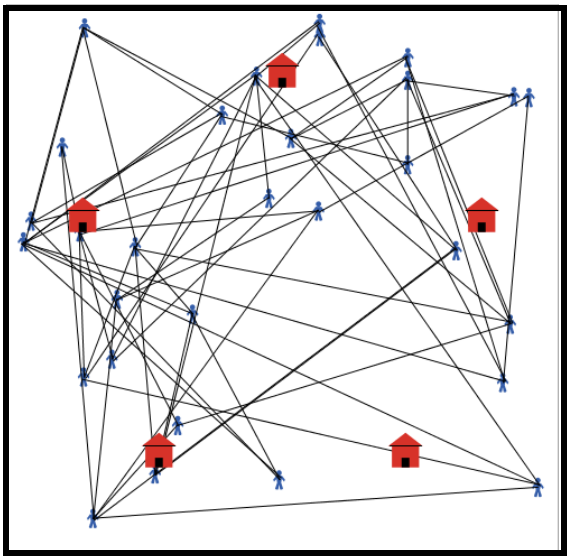

Figure 2. Small World Network using Wilenski's model [5]

In the second social network, physical communication is not necessary, nor is the connection as random. A preferential network is one that is very commonly seen amongst websites and in the Internet market. It is also becoming more and more prevalent in online forums and web logs where physical interaction is not needed to gain connections. Popularity plays a key role in a preferential network in that the agent with the most connections is more likely to gain more connections. Users want to connect to the metaphorical hubs that can offer them the most information. On the other end, agents with very few to no connections are not likely to end up gaining many more. In Figure 3, a preferential network has been established between the consumer agents. Several popular hubs have been established while many outliers are connected to them with few other connections.

For this simulation, due to the network's occurrence in electronic communication, the preferential attachment network was used for agent communication. It would also be more practical and beneficial for the agents to use, because the agent with the most connections will contain the best and most recent information. Mobile agents not connected to the popular hubs will receive a delay in information, resulting in a possible higher cost than expected. How the agents use the connections established in the preferential network will be discussed in the next section.

2.3 Agents

In this simulation, there are two classifications of agents: stores and customers. Each class has its own variables, properties and schedule.

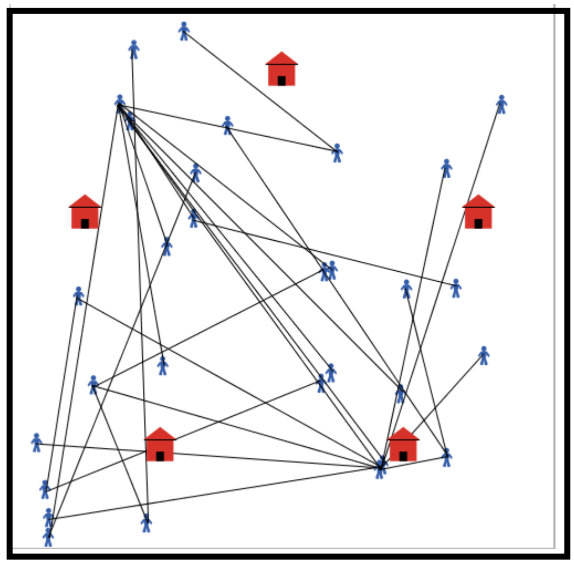

Figure 3. Preferential Network using Wilenski's model [4]

As a rough estimate to the number of stores in a dense city, there are five evenly spaced stores established in the five square mile simulated environment. Each store contains a unique number and a set of variables. These include supplier cost, a store's stock, number of consumers visiting the store, and an inventory list. The supplier cost is set up anywhere from \$1.00 to \$1.50, and remains constant throughout the simulation. As mentioned in Section 2.1, this cost also acts as a supply side price floor in order to prevent loss in profit. The store's stock is incremented rather than decremented at each purchase. This number signifies how much of the product was sold, and used in the recalculation of prices based on the density of consumers in the environment. The number of consumers visiting the store at a time is just a monitoring variable so a store's popularity can be shown at any given time. The inventory list is simple but flexible and is a list of lists that contain the item in the first position in the list and the price of the item in the second position. For this experiment, there is only one list containing the price of milk and a shelf price that is randomly allotted to each store between \$3.50 and \$4.50 that changes with each restock.

Customers contain the variables needed to shop for groceries and communicate with one another. These variables include their home location (randomly scattered), three different action states, the location of their nearest store and best store, a tolerance level, and 4 list and physical memory variables.

The three different action states of each agent are Boolean variables that are triggered when the agent is at the store, at home, or just purchased an item. If the agent is at home, the "at store" and "just purchased" variables are false and the customer goes to the store. If all three are false, the agent is on the way to the store, and continues to travel. Once the customer arrives at the store, "at store" is set to true, and the customer purchases his items. The "just purchased" variable is then set to true, and the desired messages are sent to the agent's network, and "at store" is set to false. The customer then returns home. This cycle keeps each agent independent from one another so they are all not congregating at the stores simultaneously.

Tolerance levels are designed as a ceiling price to go along with the stores' floor price. The demand side must also have a threshold that is an indication for customers they are paying too much. Tolerance levels are different from person to person, so within each agent, a random level is set in the range of $4.20 to $5.70. If the tolerance level is reached at any store, the customer will resort to their nearest store next visit or the next nearest store if the tolerance level is reached at the nearest one. The nearest store variable is calculated because of this, and also gives the customer agent a store to visit at the start of each simulation. Best stores are calculated by comparing a customer's history with other prices that have been sent to them and adding the distance cost. Unless the tolerance level is reached, the agent will continue to go to whichever store is best.

Customer agents also contain memory, both cognitive and hardware. In their physical memory, they contain a history list, which records the price and store of their last visit, and a grocery list that contains the item(s) the consumer would like to purchase. In hardware memory, there is a send list and a receive list, or an outbox and an inbox. In the simulation, these represent data that would be entered into or stored on a PDA, mobile phone, or other handheld device. These hardware variables are the basis to information sharing in the environment. Customer agents use these lists by entering in their receipt, or what is in their history right after purchasing. They pass this information out using the preferential network to all their linked neighbors, as shown in Figure 4. In this experiment, the assumption is made that all agents are honest and submit accurate information across their entire network. Unfortunately, this is not the case in the real world.

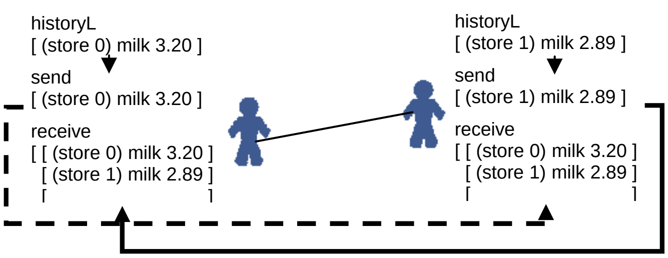

Figure 4. Information sharing between agents

In a desirable marketing environment, all consumers would be willing to help one another out to obtain better prices for the community. Selfish consumers do exist, however, and are only interested in benefiting for themselves. This brings up the issue of the greedy agent and the lying agent.

Greedy agents (Figure 5) hurt the consumer community by using the network to take all the information, but sending nothing. These agents may find a store with an extremely low price and realize that the least amount of customers shopping at this store, the lower his price will stay. Greedy agents introduce a delay into the network by causing others in the network to find the low price store by chance or by another agent. Lying agents (Figure 6) harm the consumer network more severely by taking in all information, but sending out false prices. This impacts the network more because a higher price is being sent out for comparison rather than no price at all, keeping customers away from this store. Introducing selfish agents into the marketing environment presents two difficulties. The first is including a reputation for each agent. This would be needed to protect other agents from agents who are consistently selfish, and trust those who are always honest. The second difficulty is deciding when it is appropriate for an agent to be selfish, and assign different behaviors to different agents.

By sharing information, customer agents are able to decide on the store with the lowest cost with their available information. Each customer visits the store once a week, and at each visit information is sent out to the customers in their network. Stores respond to this every two weeks when the shelves are "restocked" and the prices are recalculated based on the percentage above and below equal distribution (discussed in Section 2.1).

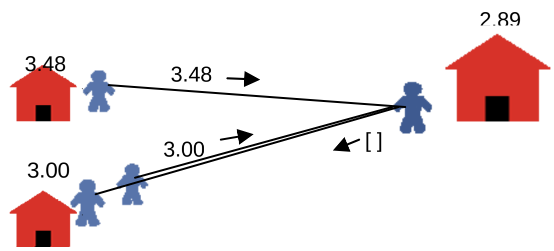

Figure 5. Diagram of a Greedy Agent

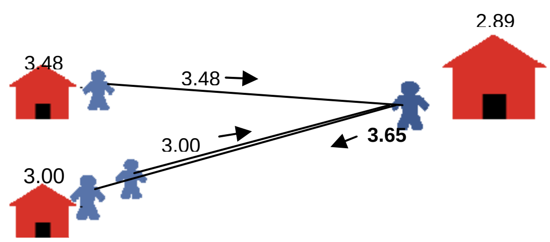

Figure 6. Diagram of a Lying Agent

3. RESULTS

For the mobile marketing experiment, a five square mile simulated market was constructed using the before mentioned economics, networking and agents. The settings included 50 randomly placed customer agents and 5 evenly dispersed stores. Customers are all honest agents and visit the store exactly once a week. Their distance cost is calculated by $2.78 per gallon of gasoline at 20 miles per gallon. Each store restocks and recalculates its price every 2 customer cycles (2 weeks), and only evaluates one item. The simulation is run for two years, or 104 customer cycles. Three runs of both networks (off and preferential attachment) were done to ensure accurate results and reproducibility.

In the first run, networking was turned off. Customers did not communicate with one another the price of an item at any store, just as the mobile market is presently. In Figure7, the results are shown in a NetLogo graph. The x-axis represents average price, and the y-axis represents time.

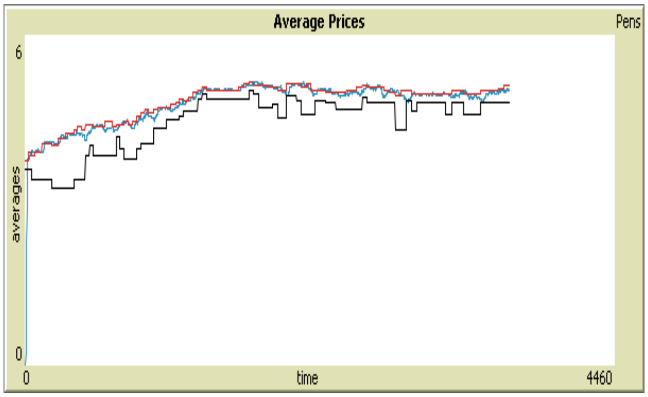

Figure 7. Simulation with No Networking

The blue pen is the graph of customer averages, the red pen of store averages, and the black pen is the store with the lowest price. In this graph, the prices steadily rise, and level off around the average tolerance level of the customers. This shows the stores desire to push the prices up as high as possible without losing their customers, even if they are making an already high profit.

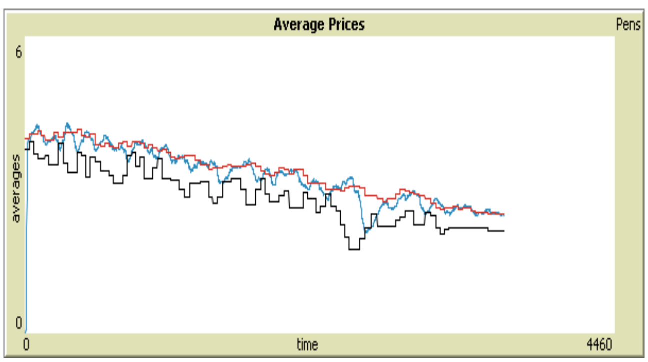

Figure 8. Simulation with Preferential Attachment

In the second run of the simulation, the network was switched to preferential attachment. This will show the effects communication has on the market and test the hypothesis to discover if communication results in a lower cost to the consumer. Figure 8 shows a NetLogo graph of the results with the same parameters as the previous run, except for the networking. This graph differs from the first in that it has a gradual downward slope. The customer average also remains further below the store average at more times than in the first, and gets closer to the store with the lowest price.

4. CONCLUSIONS

With the results presented in the graphs in Section 3, it is clearly shown that customer networking provides a lower cost to the customer. Stores are also not harmed, as they still make a fair amount of profit over their supplier cost. The results for this experiment prove the hypothesis that using consumer networking like that which is available in the Internet market can be beneficial to the mobile consumer.

In order to model this simulation in the real world, software designers and consumers must be willing to make the change. It would be a software designer's goal to make something quick and easy to use for mobile agents on a mobile-based platform, such as a PDA or cellular phone. The network can be implemented several ways. First is as a mobile application, such as one that the simulation was run on, where consumers can communicate only with their peers or others they come in contact with. This is a secure way to view information, and also would result in a bigger percentage of honest agents. A downside to a limited network is that all information at all stores may not be known. A second method could be to create a centralized website that consists of thousands of grocery stores categorized by location that many users can update. This would result in a more complete database of items and stores, and an easier comparison for consumers. It could also be a haven for misinformation and lying agents, and could take away from the mobility of the network.

4.1 Future Work and Improvements

Although the simulation presented gives desired results, there is still work needed to make it function accurately. This simulation is simply the groundwork for an idea that could change mobile marketing for consumers. Macroeconomics was left out of the simulation to provide for a more controlled environment, however, the system would be more efficient and could be modeled for longer periods of time. Also, in the future I plan to work on the intelligence of customers and the stores so customers can make decisions on more than one item and to give more options to the stores in trying to gain more of a profit, as would happen in the real world.

In conclusion, this foundation has showed that it is possible for networking in the mobile market to achieve a lower cost to the customer while still maintaining market competitiveness.

5. ACKNOWLEDGMENTS

This work was done at the University of South Carolina as part of the Research Experiences for Undergraduates in Multidisciplinary Computing project and supported in part by National Science Foundation Award # 0353637.

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