

## **Analysis of Agent Behavior in the Artificial Stock Market**

Takashi Yotsuyanagi, Takahito Yamamoto, Hidenori Kawamura, Azuma Ohuchi

Research Group of Complex Systems Engineering,  
Graduate School of Engineering, Hokkaido University, Sapporo, Japan  
Kita 13, Nishi 8, Kita-ku, Sapporo, 060-8628 Japan  
Tel: +81-11-716-2111(Ext.6498), Fax: +81-11-706-7834  
E-mail: {yotsu, yamata, kawamura, ohuchi}@complex.eng.hokudai.ac.jp

**Abstract:** In this paper, we use U-Mart that is an agent-based artificial market model. U-Mart is more open than the other artificial market, because In U-Mart, not only computer program agents, but also human agents are able to participate in the market. Therefore, the market in U-Mart gets closer to the real markets and the agents that participate in the market make the complex decision. Moreover we expand to the number of brand to plural. This expansion causes to appear the several strategies to make a profit. As one of this example, we treat the portfolio and confirm the possibility of getting the constancy to make portfolio.

### **1. Introduction**

Recently, it is expected that the greatest change, that we have ever had, take place in the markets by Internet and automatic trade with Software Agent. Market simulation that uses various agents on the computer draw attention between the economists and financial engineers in recent years. These simulations are the powerful method that checks the behavior of the dynamic and unbalanced market.

Even if we talk about the market in one word the application range is wide, even the research purpose and method of the market simulation are various. In Santa Fe Institute and Electrotechnical Laboratory, they have modeled the artificial markets after real world markets, changing the behavior of the agent complicatedly with the method of AI and GA. Kephart and his partners pay attention to the competition between the agents that trade information in the network and analyze the markets from the game theoretical view. Takayasu makes the artificial stock market that is composed of the dealer agents following determinism. And he approximates the results with a probable macro model and analyzes the phenomenon such as the distribution of fluctuation. The research of the artificial market is studied as one of the market simulation like that.

Artificial market is also expected even for the place where inspects the various phenomena that break out in the real world. Steiglitz studies the occurrence of bubble and the convergence of the price vibration to the balance price by two kinds of trader. Mizuta and Izumi also analyze the mechanism of the occurrence of bubble.

In this paper, we discuss agent-based artificial market U-Mart. Because many agents of both computer programs and human traders participate in the market through the Internet, the market is more complex and is expected to reproduce the real markets closely. In addition, we append the function that is able to deal for plural brands to the market in U-Mart. And we make an experiment to

confirm the necessity of this appendance in practice.

### **2. Artificial Stock Market**

An artificial market is a literally man-made imaginary market, which is developed for analyzing social systems. Various kinds of agents participate in the market and deal with stocks and futures. As a result, relatively complex phenomena, such as a sudden rise, or a heavy fall in stock prices, are appeared. Therefore, it is useful in the field of finance and economics to analyze these artificial markets. When we consider it from a viewpoint of computer science and artificial intelligence research, artificial market can be regarded as a good benchmark problem for modeling of social systems or designing of intelligent agents. Although the definition of the problem is "to make a bigger profit in the market", any standard strategies how to make a profit, are not existed.

The technology that is required to the research of artificial market reaches in the many research fields of computer science and artificial intelligence research, for example, modeling and reasoning of internal environments (market), modeling and reasoning of external environments (community), calculation of the probability such as risk calculation, dynamical update of model and recursive learning, prediction of the change in the chronological order of the model by deduction and also numerical value calculation, etc. In a market, it is simple purpose to make a bigger profit, but difficult work even for human being to achieve. It is furthermore difficult to automate with a computer much more.

The name called the artificial stock market was used by W.B.Arthur, whose research of the computer simulation is one of the stock market models. In their research, they compared the price in the rational condition with the price of simulation that is formed by agents' transaction. Lux reproduces and analyzes the characteristic of chronological order of the real stock price chart in his artificial stock market that have two kinds of trader, fundamentalists and chartists. These studies are certainly agent-based simulation. But the agents in their studies are similar, because they make these agents themselves. So the agents' behavior only reproduce limited action. It's only natural that so many traders have so many minds in the real world. That is why we use U-Mart, an artificial market project. In U-Mart, the agents of both of computer programs and human trader can participate in market through the Internet; therefore the market is more open than existing markets. In addition, the agents has various strategy and action, the market is more complex and similar to the real market.

Table 1. Recent artificial stock market studies

Researcher	Analysis of Theme	Brand size
H. Takayasu	Probability process	1
W. B. Arthur	Comparison of hypothesis of rational expectation	1
L. Lux	Characteristic of time series	1
S. -H. Chen	Verification of economical theory	1

### 3. U-Mart

#### 3.1 U-Mart project

U-Mart is a research project to construct an artificial market in which many agents of both computer programs and human traders participate in the market via network. The aim of this project is to provide a forum where research on market structure analysis is carried out and a common testbed for researchers who are interested in economics, financial engineering, artificial intelligence, and computer science. U-Mart can put the price itself. Dealing with overhead futures to the stocks that exist really, U-Mart can maintain connection to real world. The characteristics of the project are coexistence of human beings and computers and relation to real world, dealing with futures.

Various clients ("U-Mart clients") have dealings with connecting to the server ("U-Mart server") equivalent to the commodity exchange through the Internet. The communication between the server and the clients is done in SVMP (Simple Virtual Market Protocol). The U-Mart server works as a real market, collecting orders by agents, deciding the price, and the paying/receiving the price to/from agents, except for the fact that real cash is not moved. The results of trades are just registered in the server, and that trade histories and final results will be open to all participants, that is, the aim of the project is to provide a research forum for both computer science and economics researchers to compete on improving programming and economic skills in the market.

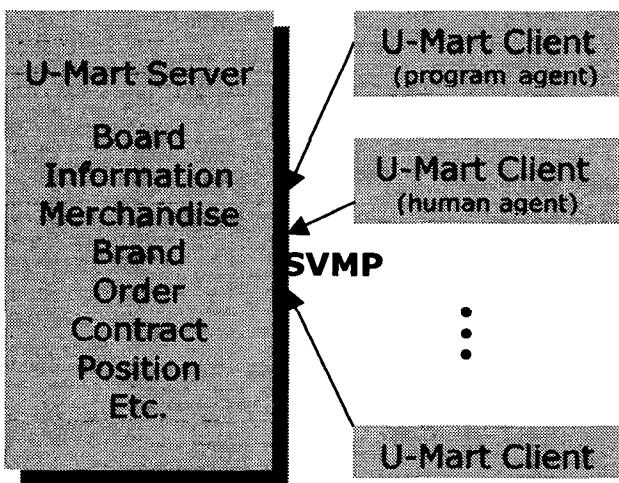


Fig.1 Construction of U-Mart System

#### 3.2 U-Mart server

##### 3.2.1 U-Mart specification

U-Mart Server consists of the network component that is the process of the communication with clients and the database component that is the search and renewal of data.

The server program is constructed on a Linux machine and both the network part and the database part are written by JAVA. This server materializes the communication part in the network component with TCP, and database part with "PostgreSQL".

##### 3.2.2 Server specification

The services that the server offers are attestation service that is carried out when the trader log in, transaction service that make the queries of the order and the position, and information service that offered board information (the present price), and price information (history of price data, settlement information of the day, etc.).

The transaction adopts the interval system. Although an order receives it at any time in this system execution carries out the settlement every regular interval. This is due to the consideration to the participant of net delay.

##### 3.2.3 Merchandise specification

Merchandise is the overhead future of the stock prices or the stock prices index that exist really.

The details are as follows.

- Brand ID: Merchandise ID + limit month+ reserve space
- Limit month: 12<sup>th</sup> limit month
- Last settlement day: Day after last trade
- Last settlement way: Margin of last spot price

##### 3.2.4 Transaction specification

There are two of 'normal' and 'cancel' in the attribute of the order.

Each detail is as follows.

Normal request

- Request ID: Given by the server
- Trade type: Sell or buy
- Order type: Market or limit
- Number of trade

Cancel request

- Request ID: Given by the server
- Canceled Request ID
- Number of trade

As for the management of the position (the trading volume that is memorized in the server), the server holds the contract volume of the day for every agent, and also holds already existed volume and their balance for every member, every brands and every trade. The settlement of accounts exchanges the difference that occurred by NEARAI. And the positions that exist at last trading day automatically settle by opposite trading with the close price of spots in the final settlement day. The traders

need to pay the margin for every units of the trade.

### 3.2.5 Connection and relation between server and clients

Between the server and clients, they communicate with TCP/IP sockets each other. The port number in the initial setting is 5010.

We present some examples of the way of request and return defined by SVMP when we buy or sell the merchandise.

- OrderRequest
  - Argument: BrandID, New or Repay, Sell or Buy, Market or Limit, Price, Number of trade
  - Return: Receive or Not, OrderID, Receive time
- TodaysQuotes
  - Argument: BrandID
  - Return: Receive or Not, Date, Time, Contract Price, Contract Number,
- BoardInformation
  - Argument: BrandID
  - Return: Receive or Not, Last Update Date of Board, Marker Sell Number, Market Buy Number, Price (If the trade type is Limit type), Limit Sell Number, Limit Buy Number

## 4.Plural brands trade

The futures that are the brands of a transaction in present U-Mart Server are only one brand. However, the transaction brand exists plural and the trader selects several brands using various analysis methods in the real world transaction. Thus we expand the function of U-Mart Server to deal for the plural brands of the futures.

### 4.1 Necessity of plural brands

The formation of the portfolio is conceivable as one of the function that becomes possible by dealing for the plural brand.

Originally, "portfolio" was the word that means "paper clip", but this word has come to mean the possession securities, because there were many cases that the securities were stored by the paper clip. When the investor considered the securities that he possessed as a unit, it is called "portfolio".

The portfolio indicates about the aggregate of the finance property that individual investors possess. Those contents are conceivable variously, for example, the stocks, bonds, etc. Combining the distribution of such property well, the actual investors increase the property of them and also hedge to avoid risk. Namely, becoming to be able to deal for plural brands, various purposes to make the transaction is appeared and investment become complicate. Moreover, the market gets closer to the real markets.

### 4.2 Realization to plural brands

Although U-Mart Server is designed for dealing with plural brands fundamentally, there was an imperfect part in its program. Therefore, we changed the server

program so that we are able to manage plural brands. We changed such parts that we raise below specifically.

In U-Mart server, agents deal for only J30 future that isn't existence actually, and also the only J30 spot price data. ("J30" is average of 30 stock prices listed in Tokyo stock exchange.) Therefore we expand to deal plural brands adding more futures, and spot price data. The data, in this experiment, take out several periods of certain ranges from the record in the past of J30 and made the fluctuation data of each plural brand's stock price. We changed the database structure in U-Mart server, as we can manage the plural brands to preserve to the database of the server, and each agent has the number of brands in the database.

## 5. Experiment

We make the two experiments that reproduce the risk avoidance by the portfolio dealing for the plural brands.

### 5.1 Market

We make the two markets. One is the market whose brands fluctuate opposite, named market A (Fig2). The other is the market whose brands fluctuate similarly, named market B (Fig3). As for the merchandise, we prepare two brands of the futures, brand A and B, for simplicity. And the agents that make the transaction are two types. First type of program agents trade only one brand whether brand A or brand B. Second type of program agents trade two brands both brand A and B. The period when agents make the transaction is 120 days. In this experiment, we used each 120 days spot data in the past of J30.

### 5.2 Agents

We made four program agents that trade brand A, and also four program agents that trade brand B. These program agents request the price around the spot price of the day. This spread follows normal distribution. And these program agents calculate the numbers of the brands at random. We call these agents "single-trade-agent". And, two agents participate in the market, who deal for both brand A and B by utilizing the technical index that calculates the timing of BUY or SELL statistically from the data of the movement of price in the past. We call these agents "plural-trade-agent". Specifically the agents used the "moving average" in this experiment.

Moving average is one of the most utilized techniques in the technical index. This index removes the short-term vibration, so this is useful of sensing the trend the market. The moving average is calculated by averaging the price of fixed dates. For example, to find the five dates moving average, we calculate the average of past five dates including the day. This calculated value is five dates moving average. The longer we fix this period, the smoother the moving average curve is, and the smaller the fluctuation of short-term is. We use the three different date moving average in order to know the timing of the trade. When short-term average curve crosses middle-term average curve from lower to upper, this cross point is called golden-cross. This cross point

indicates that we should buy the merchandise at that time. On the contrary, when short-term average curve crosses middle-term average curve from upper to lower, this cross point indicates sell-signal. This cross point is called dead-cross. In this experiment, these agents buy/sell the both brand A and B simultaneously, applying the moving average to brand A.

### 5.3 Results

The fluctuation of the property followed by the passage of time is expressed in the graphs, the horizontal axis is time and the vertical axis is property (Fig.5, 6). These graphs show the fluctuation of three agents' property. One agent deals for brand A, and another agent deals for brand B, those two agents trade at random (single-trade-agent), and the other agent deal for both brand A and B with technical index (plural-trade-agent).

In the market A, the single-trade-agents' properties extremely fluctuate, because the spot prices fluctuate wildly. But the plural-trade-agents' properties are stable and constantly increase. This is because dealing for plural brands causes the effect of avoidance of risk. On the contrary, Fig 6 shows the single-trade-agents' properties are not so fluctuate, in addition single-trade-agents' and plural-trade-agents' are not different fluctuate. That is why the spot price curves are not so wildly. From these results, we confirm that we can model the hedge in certain situation.

## 6. Conclusion

We showed the outline and the advantage of U-Mart. U-Mart is more diversified than the conventional artificial markets that researchers have often studied, because of various agents' participation. We constructed the new mechanism of transaction, to deal for plural brands, that cause the market more close to real transaction, and we confirm the efficacy of new mechanism by the experiment. As a result, we make sure that there is a possibility that agents can make a profit and get constant profit.

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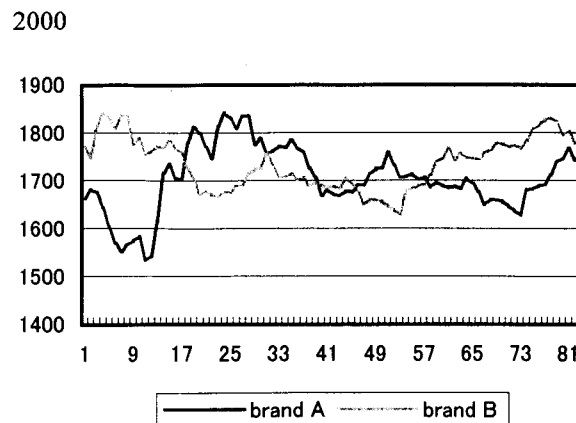


Fig.2 The fluctuation of the two brands' spot price in market A

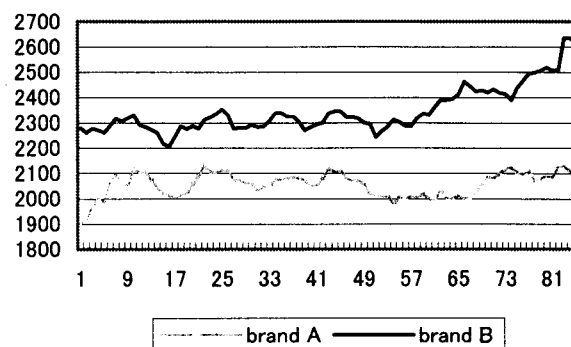


Fig.3 The fluctuation of the two brands' spot price in market B

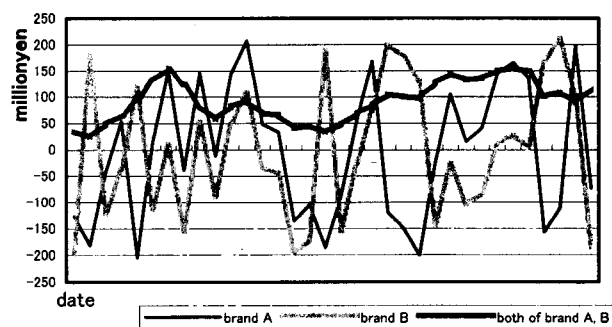


Fig.4 The fluctuation of the property followed by the passage of time in market A

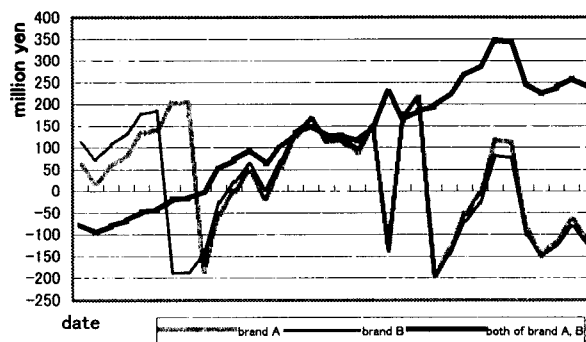


Fig.5 The fluctuation of the property followed by the passage of time in market B