Case Report on U-Mart Experimental
System: Competition of Software Agents
and Gaming Simulation with Human Agents

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Abstract. U-Mart is an interdisciplinary research program of agent-based artificial
market. U-Mart proposes an open-type test bed to study trading strategies of agents,
behavior of the market and their relationship. Two experiments open to public (Pre U-
Mart 2000 and U-Mart 2001) using the proposed system are held in August 2000 and
in August 2001 respectively. In both cases, More than 40 software agents (computer
programs for trading) participated in this experiment. This paper reports the outline of
these experiments, the trading strategies of the participated agents and the results of the
experiment. While Pre U-Mart 2000 and U-Mart 2001 treated only software agents,
the U-Mart system is designed considering participation of the human players as well
as the software agents. A gaming simulation by human using the U-Mart system held
in Kyoto University is also introduced briefly.

1 INTRODUCTION

Complex behavior of market economy, typically observed in financial markets, is not fully
explained by conventional economic theories. A new approach to this problem is an artificial
market which enables computational experiments on virtual markets using agent simulation[1].

Studies on artificial markets have achieved a variety of interesting results. However, they
also clarified the difficulties peculiar to this agent simulation approach, such as that:

- researchers from different fields need to cooperate due to the interdisciplinary nature of
  this approach,
- it is not easy to design a model which combines complexity (to imitate real markets) and
  simplicity (to enable computational experiments), and
• researchers need to share common understanding on experimental configurations and results which are more complicated than theoretical models.

U-Mart\textsuperscript{1}[3, 2, 4] is a research program to address these problems of artificial market studies. We have developed an artificial market simulation system, called U-Mart system, to provide a test bed for researchers from economics and information science to carry out experiments with common understanding. We are promoting diversified researches on markets by opening this system to public.

We have conducted two open experiment, Pre U-Mart 2000 and U-Mart 2001, on this system, inviting more than 40 software agents from public. This paper reports the result of the experiments, along with the strategies of the participated agents. The U-Mart system is designed to allow human players to participate in market experiments. This paper briefly introduces the human gaming simulation conducted at Kyoto University as well.

2 Outlines of U-Mart System

In the U-Mart system, ‘futures’ of real stock index are traded in a virtual market. This allows the market simulation environment to reflects the complexity of real markets, and at the same time, enables independent price formation. The U-Mart system is implemented as a client-server system, which exchanges information, such as buying and selling, via the Internet using a dedicated protocol implemented on TCP/IP. A sever, which imitates an ‘exchange’, accepts orders from clients, determines prices, matches buying and selling orders, and manages clients’ accounts. Each client obtains the information, such as market performance, from the sever and places order under its own decision. In the U-Mart system, human agents, as well as software agents, are allowed to participate in market experiments. Details of the U-Mart system are provided in [4].

3 Outline of Open Experiment, Pre U-Mart 2000 and U-Mart 2001

3.1 Open Experiment and Its Objectives

We conducted an open experiment, Pre U-Mart 2000, on August 19th. 2000 as a part of 6th. Emergent System Symposium of The Society of Instrument and Control Engineers (SICE) in

\textsuperscript{1}originally called V-Mart
Japan. We also conducted another open experiment, U-Mart 2001, on August 25th. 2000 as 7th. Emergent System Symposium of SICE on same location.

The objectives of these experiments are: to investigate variations of trading strategies and development methods for software agents, and to verify the actual behavior of market simulation among independently developed agents. The participants have received an agent development package of U-Mart system in advance. This package contains templates of simple software agents and track record of J30 stock indices (used as spot data).

3.2 Experimental System

At the occasion of the both experiments, U-Mart committee set up a server machine, and the participants run agent programs on their note PCs connected to the server via Ethernet. The participants and the audience can watch the progress of the experiment through a video projector.

We tested the operation of the system on the first day of the symposium, and conducted the experiment in the afternoon of second day.

3.3 Configuration of Experiment

The price determination and contract algorithms are described in [4]. Table 1 shows the parameters for the market. In Pre U-Mart 2000, we use Dow Jones Industrial Average (scaled to J30 equivalent) to prevent participants from estimating the spot market data from distributed J30 data. In U-Mart 2001, we can use J30 data because there are no participated agent who uses pattern matching methods.

<table>
<thead>
<tr>
<th>Item</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underlying Indices</td>
<td>Dow Jones Industrial Average, scaled to J30 equivalent (Pre U-Mart 2000), J30 (U-Mart 2001)</td>
</tr>
<tr>
<td>Period</td>
<td>60 virtual days</td>
</tr>
<tr>
<td>Order Methods</td>
<td>market order/limit order</td>
</tr>
<tr>
<td>Pricing Method</td>
<td>ITAYOSE*</td>
</tr>
<tr>
<td>Pricing Interval</td>
<td>15 seconds (real time)</td>
</tr>
<tr>
<td>Number of Pricing</td>
<td>4 times/virtual day</td>
</tr>
<tr>
<td>Trade Unit</td>
<td>1000-fold of contracted indices</td>
</tr>
<tr>
<td>Bid and Asked</td>
<td>indices in increments of one point</td>
</tr>
<tr>
<td>Price Range</td>
<td>no restriction</td>
</tr>
<tr>
<td>Margin Money</td>
<td>300,000 YEN/Trade Unit</td>
</tr>
<tr>
<td>Settlement System</td>
<td>mark-to-market at closing price of the day</td>
</tr>
<tr>
<td>Membership Fee</td>
<td>none</td>
</tr>
<tr>
<td>Cash on Hand</td>
<td>1 billion YEN/agent</td>
</tr>
<tr>
<td>Loan Limit</td>
<td>30 million YEN</td>
</tr>
</tbody>
</table>

* A pricing method that accumulates orders for a certain period, and decides a price so as to achieve the maximum contracted volume for the accumulated orders.

The exchange (server) settles the accounts of agents at the end of one virtual day. When cash balance of an agent is less than zero after the settlement, the exchange automatically
loan the agent up to its loan limit. The loan costs interest of 10% per annum and the exchange collect it at the settlement of the next virtual day. An agent goes into bankruptcy if the cash balance is still less than zero after obtaining the maximum loan, then the agent is not allowed to make any more deal.

4 Pre U-Mart 2000

4.1 Participated Agents and Their Strategies

Eleven teams participated in the experiment, seven from engineering and four from economics. Each team was assigned a quota of five agents.

The basic strategies of participated agents are mainly based on time-series analysis (technical analysis) or the price difference between spot and futures markets. Some agents have been manually programmed and the others use learning/adaptation methods such as GAs and neural networks. There are other interesting agents such as: the one refers to buying and selling behaviors of other agents, the one implements explicit risk management, and the one learns in real time basis. The followings describe the strategies of each team (for more details, see [6]).

1. University of Tokushima (Engineering): #1 - #5

Authors Takao, I.Ono, N.Ono
Strategy Neural networks (input: time-series of price differences, output: buying/selling) optimized with Genetic Algorithms

2. Kyoto University (Economics): #6 - #10

Authors Koyama, Zaima, Matsui, Deguchi
Strategy short-term and very short-term moving averages, improved version of psychological line[5].

3. Tokyo Institute of Technology - Fukumoto (Engineering): #11 - #15

Author Fukumoto
Strategy Genetic Algorithms (parameters: regression equation, price, volume, bullish/bearish)

4. Tokyo Institute of Technology - Yamamura Lab. (Engineering): #16 - #20

Authors Yamashige, Kira, Ishii
Strategy Neural networks (input: deviation between gradient of moving average and closing price, and deviation between lowest and highest prices in the past, output: expected price)

5. Univ. of Tsukuba and Yamatake Industrial (Engineering): #21 - #25

Author Murakami
Strategy Their agents implement real-time learning of futures price prediction using classifier system

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2 Actual futures markets allows a strategy called “arbitrage”, which gains profit margin from the price difference by combining futures deals and spot deals. Since U-Mart only allows futures deals, the pure “arbitrage” strategy cannot be implemented.
6. Osaka Pref. University (Engineering): #26 - #30

**Author** Mori

**Strategy** The parasitic agents which depend only on ordering information of other agents and follow the majority

7. Osaka Sangyo Univ. (Economics): #31 - #35

**Authors** Taniguchi, Ozaki

**Strategy** Trend follower, contrarian, and reactor to the gradient of price movement.


**Author** Sato

**Strategy** Day trader

9. Kyoto Sangyo Univ. (Economics): #41 - #45

**Author** Nakashima

**Strategy** dollar cost averaging method, ‘ren-gyo-soku’ method (a method of technical analysis)


**Author** Ishinishi

**Strategy** Arbitrage

11. Osaka City University (Economics): #51 - #55

**Author** Shiozawa

**Strategy** Basic technical analysis.

4.2 **Experimental Result**

We have conducted the experiments twice with different spot price series. The numbers of attended agents are 47 for the first round and 43 for the second round. Not every team uses its full quota of five agents.

![Figure 2: Prices and Traded Volumes for 1st. Round (left) and 2nd. Round (right)](image-url)
<table>
<thead>
<tr>
<th>Agent</th>
<th>1st. Round</th>
<th>2nd. Round</th>
<th>1st. Round</th>
<th>2nd. Round</th>
</tr>
</thead>
<tbody>
<tr>
<td>#41</td>
<td>3,960,884</td>
<td>#12</td>
<td>3,005,755</td>
<td>3</td>
</tr>
<tr>
<td>#27</td>
<td>582,474</td>
<td>#13</td>
<td>1,792,902</td>
<td>3</td>
</tr>
<tr>
<td>#26</td>
<td>380,437</td>
<td>#18</td>
<td>1,686,144</td>
<td>4</td>
</tr>
<tr>
<td>#7</td>
<td>317,955</td>
<td>#19</td>
<td>820,168</td>
<td>4</td>
</tr>
<tr>
<td>#5</td>
<td>310,538</td>
<td>#43</td>
<td>710,379</td>
<td>9</td>
</tr>
<tr>
<td>#33</td>
<td>307,773</td>
<td>#44</td>
<td>388,575</td>
<td>9</td>
</tr>
<tr>
<td>#21</td>
<td>266,145</td>
<td>#27</td>
<td>285,245</td>
<td>6</td>
</tr>
<tr>
<td>#28</td>
<td>258,410</td>
<td>#7</td>
<td>254,108</td>
<td>2</td>
</tr>
<tr>
<td>#16</td>
<td>225,309</td>
<td>#16</td>
<td>206,260</td>
<td>4</td>
</tr>
<tr>
<td>#30</td>
<td>204,743</td>
<td>#9</td>
<td>197,120</td>
<td>2</td>
</tr>
</tbody>
</table>

*1: price unit: 1,000 YEN, *2: team is represented by their entry number

### Table 2: Top 10 Performance of Agents for 1st. and 2nd. Round

### Table 3: Performance of Teams at Pre U-Mart 2000

<table>
<thead>
<tr>
<th>Team</th>
<th>1st. Round</th>
<th>2nd. Round</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kyoto Sangyo Univ.</td>
<td>2,717,039</td>
<td>–1,059,526</td>
</tr>
<tr>
<td>Osaka Pref. Univ.</td>
<td>1,512,561</td>
<td>–4,309,662</td>
</tr>
<tr>
<td>Univ. of Tokushima</td>
<td>661,096</td>
<td>–1,393,736</td>
</tr>
<tr>
<td>Kyoto Univ.</td>
<td>635,519</td>
<td>–1,175,857</td>
</tr>
<tr>
<td>Sato (NDA)</td>
<td>622,257</td>
<td>111,153</td>
</tr>
<tr>
<td>Osaka Sangyo Univ.</td>
<td>501,101</td>
<td>–1,504,747</td>
</tr>
<tr>
<td>Yamamura Lab. (TIT)</td>
<td>358,853</td>
<td>2,751,064</td>
</tr>
<tr>
<td>Univ. of Tsukuba and Yamatake</td>
<td>332,358</td>
<td>192,780</td>
</tr>
<tr>
<td>Osaka City Univ.</td>
<td>156,941</td>
<td>–53,780</td>
</tr>
<tr>
<td>Fukumoto (TIT)</td>
<td>–232,420</td>
<td>4,079,164</td>
</tr>
<tr>
<td>Ishinishi (NDA)</td>
<td>–4,711,406</td>
<td>–99,237</td>
</tr>
</tbody>
</table>

descending order of 1st. round profit (unit: 1,000 YEN)

### 4.2.1 First Round

The spot price series for the first round repeats up and down several times and ends at the beginning price. Figure 2 (left) shows the transitions of price and trade volume. Table 2 and 3 show the performance of each agent and each team at the end of the game.

The heavy rises and falls are repeated at the beginning because of excessive limit order and market order combinations. Five agents go into bankruptcy during 11th. and 14th. virtual days. No agent goes into bankruptcy before 11th. because rises and falls do not occur at the closing price, which directly affect to the end of the day settlement (c.f. 2nd. round). After the five agents go into bankruptcy, the market calms down and the deals are made around the spot price. The trade volume increases at the rapid price movements because of the huge volume of market orders.

### 4.2.2 Second Round

The spot price series for the second round shows long-term downtrend. Figure 2 (right) shows the transitions of price and trade volume. Table 2 and 3 show the performance of each agent and each team at the end of the game.
The second round shows only a few times of rapid price movements. This is because the price movement at the first day is too big (the futures price is 19,332 YEN, while the spot price is 3,178 YEN) and the market closes at this price. Three agents go into bankruptcy and the other agents are damaged seriously as well. Consequently, the trade volume decreases after the second day. Two more agents go into bankruptcy on 12th. day because of the huge price movement at the closing. Total of five agents go into bankruptcy on second round. The trade volume increases at the rapid price movements because of the huge volume of market orders.

4.3 Variety of Agents

Eleven teams participated in these experiments and the variety of the agents exceeded our expectations.

When agents show similar behavior, deals tend to fail because their decisions are similar. In such a case, to achieve deals, agents which place random orders need to be introduced on the market. In our experiments, the prices have been formed between the varied agents without random agents.

Although several teams use the same analysis methods (moving average and psychological line), the final asset of these teams differs remarkably. This means that these teams interpreted the indices differently in implementation of the methods as software agents. Technical analysis indicates “the time to buy (or sell)”, but it does not recommend “the amount to buy (or sell) in which price”. We expect that this point is clarified with larger number of experiments.

It is interesting that the agents #41-45 (selling only/buying only) and #26-30 (do not use price data) have made good results especially on the first round. It does not mean that these strategies are always effective. However, they are obviously against the common practice that winners need to predict the future based on price data and to manage their position appropriately. Their successful performance contribute to the variety of agents.

In the future, more agents will implement the position management (implemented only on #11-#15) or the online learning for real-time modification of strategy (implemented only on #21-#25).

4.4 Reason of Heavy Rises and Falls

The heavy rises and falls occur at the beginning of both rounds. At these experiments, we have not restricted the price range and the agents are allowed to place orders at unrealistic price. Although these unrealistic orders normally do not affect price determination, they may be contracted when huge volume of market orders are placed. In the price determination algorithm of U-Mart system, selling market orders are considered as “limit orders lower than the lowest limit order” and buying market orders are considered as “limit orders higher than the highest limit order”. This makes the price formation vulnerable to huge volume of market orders (See Figure 3).

There are two types of agents which place excessive orders. One type gives “very low buying limit and very high selling limit” (i.e. #38) and another type gives “very low selling limit and very high buying limit” (i.e. #35). We had assumed that they do not affect the market because the former type has difficulty in making deal and the latter type goes into bankruptcy.
immediately. However, they have hazardous nature to rattle the market in relation with market orders. We may need to restrict the price range or to reconsider the price determination method.

5 U-Mart 2001

5.1 Participated Agents and Their Strategies

After the Pre U-Mart 2000, we received a massive feedback that setting U-Mart server is time consuming job and sample agent is rather complicated. In U-Mart 2001, we then prepare stand alone experimental system. In this sytem, participants can make their agent by implementing just one function.

As a result, participated agents are classified into following three types:

- Using stand alone system:
  - Kyoto Sangyo University (Economics), #1
    Author Koyama
    Strategy Moving average + arbitrage
  - University of Tokyo (Engineering), #2, – #6
    Author Kobayashi
    Strategy Prediction by ARMA model.
  - Osaka Prefecture University (Engineering), #7, #8
    Author Nakajima, Ariyama, Ishibuchi
    Strategy Fuzzy rule base.
  - Chiba Institute of Technology (Engineering), #9
    Author Arai
    Strategy Arbitrage
  - Kyoto University (Economics), #10
    Author Narihara
Strategy  Arbitrage considering position.
– Kyoto University (Economics), #11
Author  Zaima

Strategy  Using RSI (relative strength index).
– Kyoto University (Economics), #12, – #20
Author  Inoue

Strategy  Arbitrage
– National Defense Academy (Engineering), #21
Author  Vincent
Strategy  Using the difference between today’s and yesterday’s price.
– Tokyo Institute of Technology (Engineering), #26, – #30
Author  Ishii
Strategy  Regression analysis + Arbitrage optimized by multi-objective genetic algorithm.

• Modifying conventional sample agents:

– National Defense Academy (Engineering), #22, – #25
Author  Kawachi
Strategy  (1) Martingale strategy, (2) Stop-loss strategy.
– Osaka City University (Economics), #31, – #33
Author  Kumei
Strategy  (1) Arbitrage, (2) Using the difference between today’s and yesterday’s prices, (3) Following the trend.
– Osaka City University (Economics), #34
Author  Gotou
Strategy  Modeling on day trader.

• Writing agents from scratch:

– Osaka City University (Economics), #35 – #39
Author  UedaHashimoto, Hashimoto
Strategy  Divination by tarot cards.

5.2 Experimental Result

We have conducted the four experiments with different spot price series: upswing, down-swing, changeover, and oscillation. In each case, we carry out two types of trials: participated agents only and participated agents with random agents. Adding random agents means that the market impact of participated agents becomes weaken. Figure 4 shows the transitions of price and trade volume.

In the upwing and downswing case, the futures price are strongly tied in the spot price, whereas there are violent fluctuations in changeover and oscillation case. This shows the difficulties in predicating on no trend situation.
Table 4 shows the top performers in each game. In all market conditions, the list of top performers with random agents are almost same as the list without random agents. We can’t say that there is an agent who are good at every situation. However, the arbitrage agents made good records across the various market conditions.

We have to mention that random traders are also not so bad. Placing orders randomly means that short and long position are nearly equal and ordering at random price in the vicinity of spot price is approximately equal to the arbitrating.

Figure 4: Prices and Traded Volumes of U-Mart 2001: (a) Upswing, (b) Downswing, (c) Changeover, (d) Oscillation

Table 4: Top performers in each market conditions. Numbers in parentheses shows the result including random agents.

<table>
<thead>
<tr>
<th>Market Conditions</th>
<th>Ranking</th>
<th>Upswing</th>
<th>Downswing</th>
<th>Changeover</th>
<th>Oscillation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>#16 (&lt;#17)</td>
<td>#17 (&lt;#11)</td>
<td>#36 (&lt;#41)</td>
<td>#34 (&lt;#17)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>#3 (&lt;#4)</td>
<td>#18 (&lt;#42)</td>
<td>#38 (&lt;#40)</td>
<td>#18 (&lt;#34)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>#34 (&lt;#36)</td>
<td>#4 (&lt;#15)</td>
<td>#23 (&lt;#42)</td>
<td>#17 (&lt;#3)</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>#27 (&lt;#34)</td>
<td>#38 (&lt;#40)</td>
<td>#22 (&lt;#36)</td>
<td>#8 (&lt;#18)</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>#13 (&lt;#25)</td>
<td>#29 (&lt;#28)</td>
<td>#5 (&lt;#22)</td>
<td>#7 (&lt;#4)</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>#26 (&lt;#18)</td>
<td>#10 (&lt;#16)</td>
<td>#26 (&lt;#38)</td>
<td>#19 (&lt;#8)</td>
</tr>
</tbody>
</table>
6 Experiments with Human Agents

Heavy rises and falls have resulted at the beginning of the experiments with software agents. What happens if more sophisticated human agents deal in this virtual market? The U-Mart system can answer this question since it is designed to allow human agents to participate in market experiments.

As an example of the behavior of virtual markets constructed by human agents, this section introduces the experiments conducted at Kyoto University as a part of a lecture on gaming simulation\(^3\).

The experiments with human agents have been conducted three times under the similar conditions as Pre U-Mart 2000 and U-Mart 2001, using different spot data for each time. In these experiments, small number of software agents are introduced on the market. They place limit orders at the prices determined by random numbers which comply with normal distribution around the spot price.

Initially, the students made deals without strategy. It was natural because they were not familiar with the client software and they did not know much about futures markets or futures trade mechanisms. However, they started to understand these mechanisms by accumulating experience and became more strategic.

The result of third experiment (conducted on November 16th.) is shown in Figure 5. It shows the transition of the spot price, the virtual market price (U-Mart Price), and the asset position of each agent. In this experiment, a software agent has made the best profit among one software agent and seven human agent (including one faculty), and three students go into bankruptcy.

![Figure 5: Experimental Result with Human Agents](image)

According to the students’ reports after the experiments, the bankrupt students predict down-trend of spot price in long-term. They focuses on buying initially and continues selling after that, then go into bankruptcy along with the up-trend of spot price. On the other hand, the profited students respond to short-term price movements. They make small profits with a

\(^3\)“Economics System Gaming” (Dr. Deguchi) given at School of Economics, Kyoto University. This is a two class period on end (180 min.) biweekly lecture geared to undergraduate and graduate students.
general strategy, that is to sell when price increases and to buy when price decreases. They maintain the stable position.

The experimental results show remarkable differences on behavior of human agents and the present software agents. Human agents not only make technical analysis of short-term price movement, but they predict long-term market trend and conceive a strategy based on impression.

Although the software agent has made the best profit in this experiment, it highly depends on contingency in connection with the used spot data and the strategies of human agents. From now on, more experimental cases need to be accumulated to analyze U-Mart as a market and to examine differences between human and software agents. We will also look into the availability of this system as an educational tool.

7 Conclusion and Acknowledgements

In this paper, we have reported on the experiments of open-type artificial market, U-Mart, conducted with software agents and/or human agents. The results of experiments have shown the possibility to construct a variety of software agents and clarified the strategic differences between human and software agents. We will carry this study program forward by integrating the knowledge obtained from both type of agent simulations. It is also interesting that the results indicated the usefulness of the U-Mart system as an educational tool for both economics and information science.

At the last, we are grateful to the participants of Pre U-Mart 2000 and U-Mart2001, and everyone concerned with 6th. and 7th Emergent System Symposium. Also, we would like to thank the students participated in the experiments in Kyoto University.

References


