Algorithmic Trading with Human Agents and Computer Agents in an Artificial Stock Market

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Introduction

- Artificial Stock Markets have emerged as simulation environments, where

  - to test, understand and model the already complex human behaviors and

  - to analyze the impact in the system of algorithmic trading where humans and software agents may compete on the same market.
Back-testing is the process of testing a trading strategy using historical data.

The aim of a double auction system is to maximize the number of shares exchanged between buyers and sellers. The price of a stock is given by supply and demand.

\[
Price_{new} = \begin{cases} 
  Price_{old} + \text{Tick} & \text{IF } V_B - V_S > 10 \\
  Price_{old} - \text{Tick} & \text{IF } V_S - V_B > 10 \\
  Price_{old} & \text{otherwise}
\end{cases}
\]
Model Framework of the Artificial Stock Market

1. WHILE (market is open) DO
2. IF double auction mode THEN
3. IF time to apply tick passed THEN
4. Change all Stocks Price with a tick
5. Process Orders for a cycle
6. IF a time frame has passed THEN
7. Change time period to all stocks
Types of Agents

Artificial Stock Market

- Market Maker
- Random
- Human User
- Volatility
- MACD
- Maximum Price Forecast

Rule 1

Rule 2
Random Agents and Market Maker Agent

• Random Agents are used to have liquidity on the market

• The Market Maker Agent trades the fundamental value of the company.
Rule 1 Agent Type

- IF stock X is in portfolio AND Y is not in portfolio AND X is greater than UpThreshold AND Y is below DownThreshold in NoOfDays THEN sell stock X and buy Y
Rule 2 Agent Type

- IF stock X is in portfolio AND Y is not in portfolio AND X is greater than up UpThreshold OR X is below DownThreshold THEN sell stock X and buy Y that has the highest fall in NoOfDays
MACD Agent Type

- IF X is not in portfolio AND the histogram changed from negative to positive THEN buy X
- IF X is in portfolio AND the histogram changed from positive to negative THEN sell X
Maximum Price Forecast Agent

• IF (stock X is NOT in portfolio) AND (Forecasted Max is greater than Max Threshold) THEN Buy shares of stock X
• IF (stock X is in portfolio) AND (stock X rose Profit Threshold) THEN Sell all shares of stock X

\[ \text{ForecastedMax} = \sum_{k=0}^{K-1} \beta_k \times \text{close}(t-k) \]
Volatility Agent

• IF (Stock X is not in portfolio) AND (Stock X Volatility is in interval \([a,b]\)) THEN Buy shares of stock X

• IF (Stock X is in portfolio) AND (stock X rose Profit-Threshold) THEN Sell the shares of stock X
Human User
Volatility Clustering

- Volatility clustering represents periods of low volatility followed by periods of high volatility.

Intraday Volatility of C1

Volatility clustering represents periods of low volatility followed by periods of high volatility.
Non-Gaussian properties of the return distribution

Log-Log-Plot of the empirical complementary cumulative distribution function (ecdf) of absolute returns for Ford and the Gaussian distribution of the same returns.

- the slope of ecdf is different than the slope of the Gaussian distribution
Non-Gaussian properties of the return distribution

Log-Log-Plot of the empirical complementary cumulative distribution function (ecdf) of absolute intraday returns for C1 and the Gaussian distribution of the same returns.

- the slope of ecdf is different than the slope of the Gaussian distribution
Back Testing

<table>
<thead>
<tr>
<th></th>
<th>250 days</th>
<th>500 days</th>
<th>750 days</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Top:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R1: 15.2%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R2: 11.4%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M: 11.01%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Loser:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R2: -4.4%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R2: -8.37%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R2: -8.6%</td>
<td></td>
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</tbody>
</table>

Market Maker, rule 1 (R1) and rule 2 (R2) agents and MACD (M) agents
## Double Auction – Virtual Stock Market

<table>
<thead>
<tr>
<th>Top Computer Agents</th>
<th>Profit/Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market Maker</td>
<td>6125.64%</td>
</tr>
<tr>
<td>Rule 1</td>
<td>47.77%</td>
</tr>
<tr>
<td>Rule 2</td>
<td>7%</td>
</tr>
<tr>
<td>Volatility</td>
<td>0.5%</td>
</tr>
<tr>
<td>Maximum Price Forecast</td>
<td>-0.1%</td>
</tr>
<tr>
<td>MACD</td>
<td>-44.63%</td>
</tr>
<tr>
<td>Random</td>
<td>-1004.441%</td>
</tr>
<tr>
<td>Agents with the highest loss</td>
<td>Loss</td>
</tr>
<tr>
<td>Random</td>
<td>-2357.615%</td>
</tr>
<tr>
<td>Rule 2</td>
<td>-716.67%</td>
</tr>
</tbody>
</table>
Double Auction – Virtual Stock Market (VSM)

- The VSM was open for 60 days
- There were 36 people registered and 19 traded
- In total they placed 1278 orders which represent 1,212,945 shares
- The most active traders traded 308, 178 and 173 orders.
- The most active trader made millions from just 20,000 initial wealth, having a profit of 84,432%. The other top traders had profits of 3,675% and 1,493%
Conclusions

• Rule 1 is better than rule 2 in a bullish market and rule 2 is better than rule 1 in a bearish market

• MACD methods are suited to detect a trend and they create a trend for a small trend

• Usually human users trade more when they have profits – when it is a bullish market

• Some people do not like to sell, they buy shares of stocks and they don’t sell them