Bi-directional Double Auction for Financial Market Simulation

(Extended Abstract)

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ABSTRACT

Typical Double Auction (DA) models assume that trading agents are one-way traders. With this limitation, they cannot directly reflect the fact individual traders in financial markets (the most popular application of double auction) choose their trading directions dynamically. To address this issue, we introduce the Bi-directional Double Auction (BDA) market which is populated by two-way traders. Based on experiments under both static and dynamic settings, we find that the allocative efficiency of a static continuous BDA market comes from rational selection of trading directions and is negatively related to the intelligence of trading strategies. Moreover, we introduce Kernel trading strategy designed based on probability density estimation. It significantly outperforms some popular DA trading strategies including ZIC [4], ZIP [1], GD [3] and RE [2] in our experiments.

Our contributions are as follows. (i) We introduce the Bi-directional DA market which is populated by two-way traders. (ii) We create Dual and Bi trading direction algorithms for the BDA market. (iii) We develop a customisable platform for conducting various computational experiments regarding dynamic DA market. (iv) We reveal interesting properties of the BDA market. (v) We design Kernel trading strategy that significantly outperforms several popular existing ones in heterogeneous games.

Categories and Subject Descriptors
H.4 [Information Systems Applications]: Miscellaneous

Keywords
Double auction, Artificial market, Multi-Agent, Kernel

1. INTRODUCTION

In recent years, computer scientists are increasingly involved in building market systems [5] that often employ double auction (DA) mechanism for its high efficiency of resource allocations. It is well-known that the dominant application of DA is the financial market. In such a market, traders are usually sellers and buyers simultaneously. Hence, we introduce a Bi-directional Double Auction (BDA) market model, in which the trading activity of every individual trader can be bi-directional. The selection of trading direction (buy or sell) is through trading direction algorithms. Then the order price is decided by trading strategies. Meanwhile, we introduce Kernel trading strategy designed based on probability density estimation. It significantly outperforms some popular DA trading strategies including ZIC [4], ZIP [1], GD [3] and RE [2] in our experiments.

2. TRADING DIRECTION ALGORITHM

Dual and Bi are trading direction algorithms developed in the BDA market. Dual mimics the way human traders decide their trading directions in a stock market. Dual is intuitive, simple and fast while generating fairly high allocative efficiency (93.6%). In contrast, Bi is complicated and resource-demanding. However, it is non-parametric and features learning ability. As a result, it generates higher allocative efficiency (96.1%) than Dual.

2.1 Dual

In Dual, trading direction are chosen by comparing private valuations with the asset’s market prices. Let v be the private valuation of a trader and a be the current market price, we introduce α to represent the uncertainty degree of the trader’s private valuation. When v(1 − α) ≤ a ≤ v(1 + α), direction decisions are probabilistic because valuation is not definitely higher or lower than the market price. We use sigmoid function to translate v − a into a value between 0 and
1 to represent the probability of buy denoted by \( P(isBuy) \),
\[
P(isBuy) = \frac{1}{1 + e^{-\beta(\lambda - v_p)}}
\]  
(1)

where \( \beta > 0 \) is introduced as the trader’s risk attitude and \( \lambda \) is a normalization factor. The probability of sell is \( P(isSell) = 1 - P(isBuy) \). \( \lambda \) is derived by,
\[
\frac{1}{1 + e^{-\lambda v_a}} = 0.99
\]  
(2)

Due to the symmetric nature of sigmoid function, \( P(isSell) \) reaches the maximum when \( v - v_p = -v_a \).

### 2.2 Bi

A bid (ask) from a low (high) valuation trader should have a smaller chance of transaction than that from a high (low) valuation trader as long as the offer is “sensible”\(^1\). Based on this idea, we design \( B_i \). In \( B_i \), we calculate how likely a new shout at the price of \( v \) is going to be transacted by building probability density estimators on transacted shout prices. After each transaction, two probability density functions \( K_x(x) \) and \( K_v(x) \) can be estimated based on the last maximum \( m \) transacted bids and asks up to the ones of the last transaction, respectively. Accordingly, we can compute two cumulative probabilities,
\[
P_b(v) = \int_v^\infty K_b(x)dx
\]  
(3)
\[
P_a(v) = \int_0^v K_v(x)dx
\]  
(4)

Trading direction is buy if \( P_b(v) > P_a(v) \) and vice versa.

### 3. KERNEL TRADING STRATEGY

Kernel trading strategy is also constructed based on \( K_b(x) \) and \( K_v(x) \). Assuming in the last \( m \) transactions, the lowest transacted bid price is \( b \) and the highest transacted ask price is \( v \). We define searching spaces for the optimal bid and ask as \([\min(0, b(1 - 0.05) - 0.05v), v]\) and \([v, \pi(1 + 0.05) + 0.05v]\) to make the search comprehensive and efficient simultaneously. Moreover, we use \( K'(p) \) to denote the transaction probability of price \( p \) on the estimated probability density curve. Thus, the optimal bid \( b^* \) or ask \( a^* \) can be found by,
\[
b^* = \arg\max_{p \in [\min(0, b(1 - 0.05) - 0.05v), v]} K'(p) \cdot (v - p)
\]  
(5)
\[
a^* = \arg\max_{p \in [v, \pi(1 + 0.05) + 0.05v]} K'(p) \cdot (p - v)
\]  
(6)

Because \( K(x) \) is a probability density function, \( K'(p) \) actually represents a tiny area around \( p \),
\[
K'(p) = \int_{p-\delta}^{p+\delta} K(x)dx
\]  
(7)

where the default value of \( \delta \) is 0.01.

### 4. EXPERIMENTS

In the framework of the BDA market, we devised many interesting experiments (see Table 1). The static games investigate the efficiency of a static continuous BDA market and profitability of trading strategies. The dynamic

\(^1\)An offer is sensible if the bid price is not greater than \( v \) or the ask price is not less than \( v \)

<table>
<thead>
<tr>
<th>Table 1: Experiment configuration details</th>
</tr>
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<table>
<thead>
<tr>
<th>Experiment</th>
<th>Efficiency</th>
<th>Profitability</th>
<th>Dynamic Efficiency</th>
<th>Profitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>GD group</td>
<td>93.6%</td>
<td>79.6%</td>
<td>99.9%</td>
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games are designed to simulate real financial market. In static games, we find: 1) The market allocative efficiency largely comes from traders’ rational choices of trading directions. As long as the trading direction algorithm is incentive compatible, the market efficiency improves from 69.9% (efficiency of stochastic trading directions) to 93.6%. 2) With rational trading directions, the more intelligent the trading strategies, the less efficient the market. 3) The market is more efficient and stable if traders private valuations are less uncertain. In dynamic games, market provides rational time-series and Kernel group’s average wealth exceeds that of GD group (2nd best wealth maker) by 1.36%.

### 5. CONCLUSION

This paper presents the design and implementation of bi-directional double auction market which is developed to simulate a two-way trading financial market. Through experiments, we find that trading direction algorithm is critical to the allocative efficiency of the BDA market and our new Kernel trading strategy demonstrates superior performance to others in terms of both making profit in static BDA market and maintaining wealth in dynamic BDA market.

### 6. ACKNOWLEDGMENTS

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### 7. REFERENCES


