Algotrade - Market Making

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Abstract. This paper investigates the effectiveness of market-making algorithms in enhancing liquidity and reducing bid-ask spreads within Vietnamese financial markets. We present a novel experiment utilizing a custom-designed market-making algorithm, tailored to the specific characteristics of Vietnamese markets. The algorithm will operate within a simulated environment replicating real-world Vietnamese market data. The paper outlines the design of the experiment, including the market-making strategy employed and the metrics used to evaluate its performance. The primary objective is to assess the impact of the algorithm on key market health indicators like order book depth, bid-ask spread, and overall market efficiency. The findings of this experiment will provide valuable insights into the potential benefits and considerations for implementing market-making technologies in the Vietnamese financial landscape

Keywords: Algorithmic Trading · Market Making · Bid-Ask spread.

1 Introduction

In academic literature, numerous market-making models have been introduced since the 1980s. Among the early influential works, two key papers stand out: Ho and Stoll's and Grossman and Miller's. Ho and Stoll developed a significant framework addressing the primary challenge faced by market makers: inventory management [3]. Grossman and Miller, focusing on liquidity, proposed a straightforward three-period model that included both market makers and final customers, providing insights into equilibrium and contributing to the literature on price formation[2]. While Grossman and Miller's work is crucial for advancing beyond a simple Walrasian view of markets, it offers limited assistance in developing market-making algorithms. Conversely, Ho and Stoll's paper, despite taking over 25 years to influence subsequent research, laid the groundwork for a modern mathematical approach to algorithmic market making.

A key work in the modern literature on market making is the paper by Avellaneda and Stoikov, which revitalized the dynamic approach initially introduced by Ho and Stoll. They demonstrated how market makers could utilize stochastic optimal control techniques to manage their quoting and inventory strategies [1].

In this paper, we demonstrate the pros and cons of Avellaneda and Stoikov's method by adding Poisson distribution to estimate the maturity time.

2 Methods

2.1 Algorithm

As a market maker, we aim to implement an algorithm that continuously places bid and ask quotes in the limit order book. However, we recognize that there are brief periods when holding one-sided quotes is necessary for profitability. This situation arises when buy and sell orders are not filled within the same time interval.

Our strategy operates as follows: Throughout the trading day, we post a bid and ask spread if we have no active orders in the limit order book. If only one of these orders gets filled, we wait for t seconds for the other order to be executed. If it remains unfilled, we cancel the outstanding order and place new bid and ask quotes. Finally, whenever both orders are in the limit order book, we update our quotes every second. A summary of the trading algorithm is shown in:

Algorithm 1 Overview models

```
while current time < end time do
    datetime, price = get tickdata
    bidorder, askorder = calculate bid ask
    if no orders in the book then
        Quote bid and ask prices
    end if
    if exist one or many orders in the book then
        for list waiting orders do
            cancel unfilled order if excess waiting time
        end for
    end if
    if current time - previous order time > waiting time then
        Quote bid-ask spread
    end if
end while
```

2.2 Avellaneda and Stoikov Models

We utilize the optimal market making model created by Avellaneda and Stoikov (2008) for setting our bid and ask quotes. This model is designed for a utility-maximizing market maker operating within a limit order book. In this section, we provide a concise overview of the model. Our goal is to maximize the expected exponential utility based on our profit and loss at the terminal time T. With the assumption of a zero risk-free rate and the mid-price of a stock following a standard Brownian motion $dS_t = \sigma dW_t$ with an initial value $S_0 = s$ and standard deviation σ, Avellaneda and Stoikov (2008) formulate the market maker's problem as follows:

$$u(s,x,q,t) = max_{\delta^a,\delta^b} E_t[-e^{-\gamma(X_T+q_T+S_T)}] \tag{1}$$

where δ^a, δ^b are the bid and ask spreads
γ is a risk aversion parameters
X_T is the cash at time T
q_T is the inventory at time T
S_T is the stock price at time T

Several assumptions are necessary before addressing the stochastic optimal control problem. Firstly, inventory must be modeled as a stochastic process because order fills are inherently random variables. Hence, we can model:

$$q_t = N_t^a - N_t^b \tag{2}$$

where N_t^a and N_t^b is the amount of stock sold and buy respectively.

Avellaneda and Stoikov [1] propose two terms in field market making, which help maximize utility function. This results in the pricing equations that are used in our algorithm:

$$r(s,t) = s - q\gamma\sigma^2(T-t) -> \text{Indifference price} \tag{3}$$

$$\delta^a + \delta^b = \gamma\sigma^2(T-t) + ln(1+\frac{\gamma}{\kappa}) -> \text{Spread around r(s,t)} \tag{4}$$

It is important to observe that, since Avellaneda and Stoikov (2008) define T as the terminal time at which the trader optimizes their expected utility, the spread equation can be viewed as a linear function of $(T-t)$ given by:

$$\delta^a + \delta^b = \gamma\sigma^2(T-t) + ln(1+\frac{\gamma}{\kappa}) \tag{5}$$

where $\gamma\sigma^2$ is the slope of spread equation, and $ln(1+\frac{\gamma}{\kappa})$ is the closing spread when $t = T$

If $\gamma > 0$, the spread equation becomes a decreasing function of time. The rationale for this optimal strategy is that a tighter spread allows the market maker to liquidate their position before the market closes, thereby closing all positions by the maturity date. To implement the framework developed by Avellaneda and Stoikov (2008), we must calculate our indifference price and set an optimal spread around it using these two equations. We leverage the linearity of the spread equation and our market data to adjust our spread to align with the best bid-ask spread dynamics. The calibration strategy is detailed in the Experiments section of the paper.

2.3 Estimating when a tick will arrive

Avellaneda and Stoikov's model was tested using a simulator. According to their framework, this Poisson process should also depend on the market depth of our quote. However, in real data, the number of ticks arriving is not stable; hence, we formulate the arrival of ticks as follows:

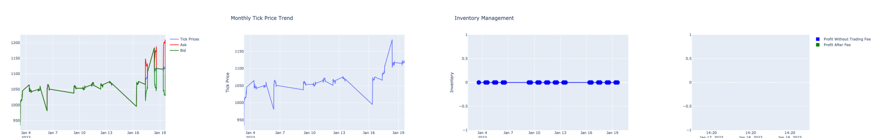
$$\hat{T} = \frac{\lambda}{\lambda + N} \tag{6}$$

where N is the number of tick data arrived, λ is the average duration trading time from the starting time to the current time.

3 Experimental Setup

We choose the range time from Jan 1 2023 to Oct 19 2023 with VN30F2301 to VN30F2310 respectively for in-sample dataset. And outsample from Oct 20 2023 to Dec 21 2023, and trade from 09:00am - 02:20pm each day. With the technique described in section 2, the parameters are calibrated using the average of the opening and closing spreads from VN30Index in the previous days. The maximum inventory is set to 35. The parameters are set to $\kappa = 0.5$, $\gamma = 0.2$, history window size = 10 days, waiting time = 5 seconds.

3.1 In-sample data results

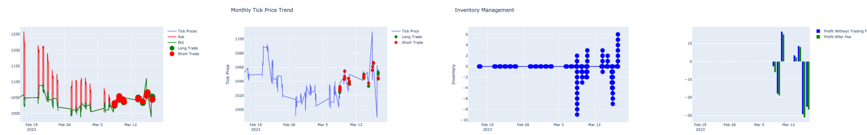


(a) Bid-Ask spreads (b) Trends (c) Inventory (d) Profit

Fig. 1: VN30F2301

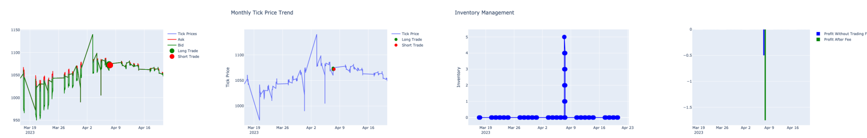
(a) Bid-Ask spreads (b) Trends (c) Inventory (d) Profit

Fig. 2: VN30F2302



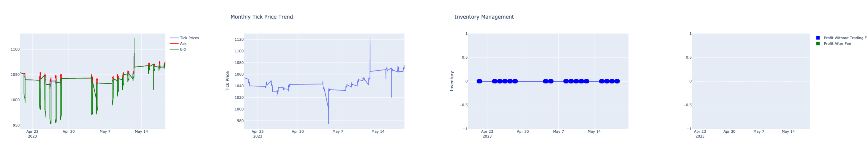
(a) Bid-Ask spreads (b) Trends (c) Inventory (d) Profit

Fig. 3: VN30F2303



(a) Bid-Ask spreads (b) Trends (c) Inventory (d) Profit

Fig. 4: VN30F2304

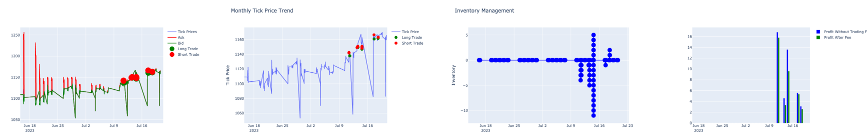


(a) Bid-Ask spreads (b) Trends (c) Inventory (d) Profit

Fig. 5: VN30F2305

(a) Bid-Ask spreads (b) Trends (c) Inventory (d) Profit

Fig. 6: VN30F2306



(a) Bid-Ask spreads (b) Trends (c) Inventory (d) Profit

Fig. 7: VN30F2307

(a) Bid-Ask spreads (b) Trends (c) Inventory (d) Profit

Fig. 8: VN30F2308

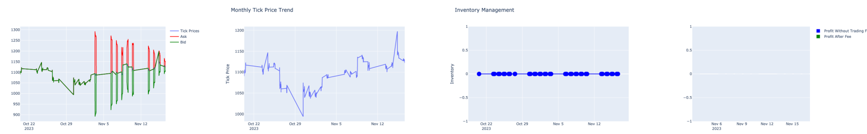
(a) Bid-Ask spreads (b) Trends (c) Inventory (d) Profit

Fig. 9: VN30F2309

(a) Bid-Ask spreads (b) Trends (c) Inventory (d) Profit

Fig. 10: VN30F2310

3.2 Out-sample data results



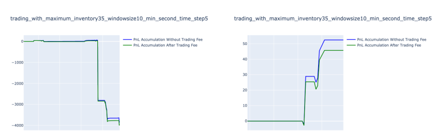
(a) Bid-Ask spreads (b) Trends (c) Inventory (d) Profit

Fig. 11: VN30F2311

(a) Bid-Ask spreads (b) Trends (c) Inventory (d) Profit

Fig. 12: VN30F2312

3.3 Summary results



(a) In-sample data PnL (b) Out-sample data PnL

Fig. 13: Visualize PnL over training and validation set

Datasets	Returns	Sharpe
In-sample	-3919.8	-1.51
Out-sample	45.75	3.63

4 Conclusion

Market making models offer several advantages and disadvantages. One major advantage is their ability to provide liquidity to the market, facilitating smoother transactions and potentially earning profits through the bid-ask spread. These models, such as the one developed by Avellaneda and Stoikov, can effectively adjust spreads based on market conditions, which can be advantageous during volatile periods. However, a significant drawback is that these models are often neutral, not favoring buying or selling. This neutrality can be a limitation since markets tend to have a long-term upward trend due to economic growth.

Moreover, the performance of market making algorithms often depends on market bursts, trading only during periods of significant volatility, which may occur just a few times each month. This behavior is similar to the Algotrade market maker, which operates in bursts, aligning with the observed results. One area for future improvement is incorporating a bias towards the prevailing market trend into the algorithm. By adjusting the model to favor upward trends, reflecting long-term economic growth, the algorithm could potentially reduce losses and enhance overall performance.

References

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