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To sell or not to sell: that is the question

Artemy Sazonov and Danil Legenkiy

Student Research Group «Currency Market Making»

Supervisors: Anton Filatov, Vadim Mescheryakov

Introduction

Optimal trade execution is crucial in currency markets due to their high liquidity, continuous trading, and significant price impact. By studying and developing optimal execution approaches, researchers aim to provide practical tools and insights to enhance traders' performance, improve trade outcomes, and strengthen risk management capabilities in these fast-paced and global markets.

Optimal execution problem statement

Liquidate the position by minimizing the functional of the price impact and the market risk.

Objectives

Here are the key steps of our research:

- Implement the MOEX L3 order book;
- Calculate price-by-volume for the book;
- Implement TWAP, AC and GLOBE;
- Calculate the price impact metrics for the algorithms;
- Compare the results.

Data collection and the OrderBook implementation

We obtained the L3 quote data for the four currency pairs from the MOEX:

1. USD/RUB;
2. EUR/RUB;
3. CHN/RUB;
4. EUR/USD.

We implemented the order book in Rust using the B-tree as a base data structure. To our knowledge, the ring buffer is considered to be the best practice in the industrial tasks for the order book storing, but we used the B-tree due to the ease of the implementation.

Online ML

Online machine learning, also known as incremental or streaming machine learning, allows for the learning process to occur as new data becomes available. Unlike batch learning, where the algorithm is trained on a fixed dataset, online learning algorithms update their models iteratively, dynamically incorporating new observations into the learning process. This flexibility makes online machine learning well-suited for trade execution, where market conditions change rapidly and the ability to adapt quickly is crucial.

Methods

We used *Time-Weighted Average Price* (TWAP) as a baseline model.

- AC: introduced in [AC00]. We used the modification with linear impact functions when the closed-form solution for the optimal trading strategy is known.
- GLOBE: introduced in [ATS18]. We used the custom-made modification which could be found by scanning the QR code. The original one has *incredibly* many restrictions and complications.

Did you really believe it's going to be that simple?

1. Both AC and GLOBE have *significant* price impact *restrictions*.
2. The current order book implementation is *static*.
3. Because of 1 and 2, the proper backtest is restricted to *mid-frequency execution only*.
4. Because of 2 and 3, we need to write a *virtual MOEX simulator*.
5. Because of 1 and 3, we need to *find a way to adapt* these algorithms to HFE.

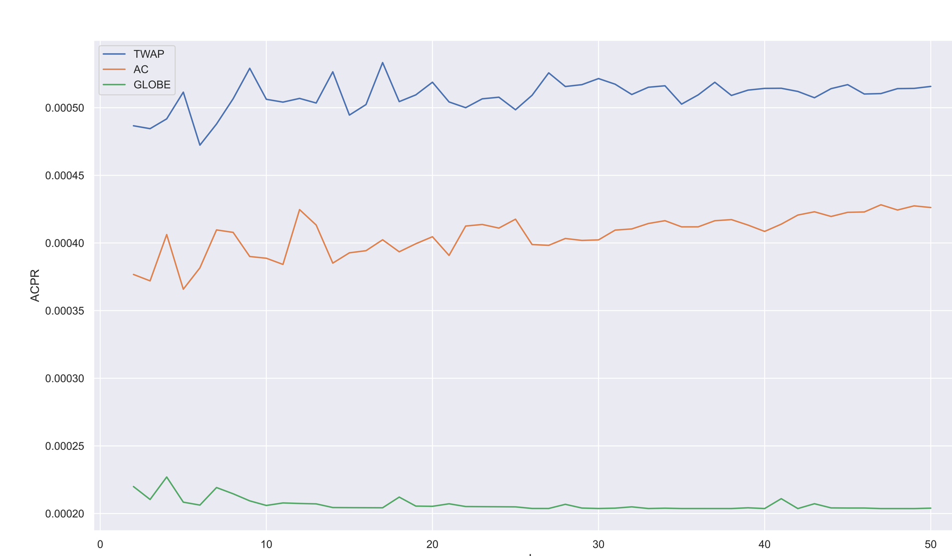
A crash-course into HFT

We can divide all orders to the two groups: *market orders* (MO) and *limit orders* (LO). The LOs are *passive*, the MOs are *aggressive*. There is a thing called *price impact* and it is the main reason why we should need to optimize the trade execution. We have a trade-off between the price impact and the market risk. The *trading trajectory* is a process $(w_k)_{k=0,\dots,L}$, where w_k is a number of lots we still posess at time t_k. Alternatively, we can define the *trade list* $n_k = \Delta w_k$, $k = 1, \dots, L$ as a number of lots we sell at time t_k. The *trading strategy* is a rule for determining n_k given the information avaliable at time t_k. Mathematically speaking,

$$\hat{n}_k = \mathbb{E}^{\nu}\left[n_k | \mathcal{F}_{t_{k-1}}\right].$$

We can divide the strategies to *static* (deterministic, all the parameters are known upon the start of the execution) and *dynamic* (stochastic).

Results



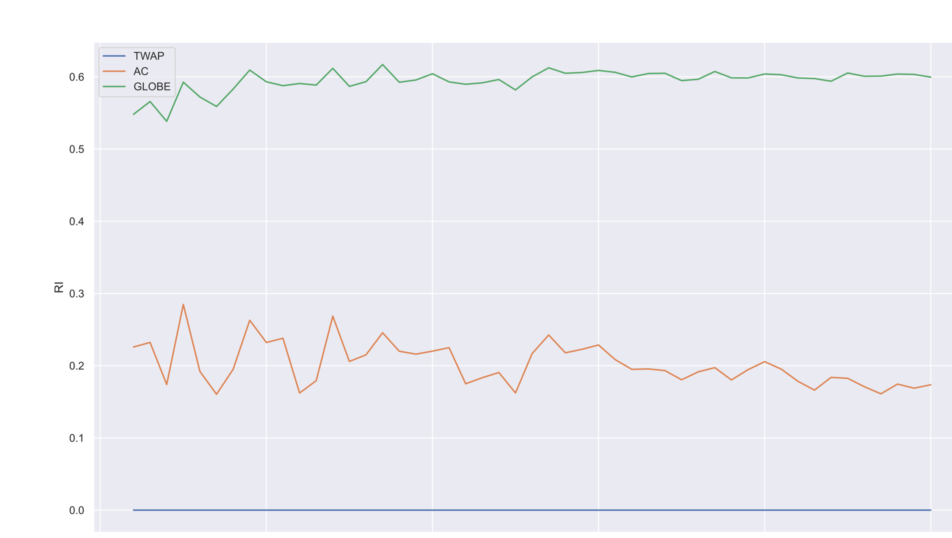


Figure 1: ACPR and RI with TWAP as a baseline

Conclusion

During the semester we studied various books and articles about the market microstructure, high-frequency trading and market making. It is worth noticing that these topics are not usually covered by any standart courses or books. We implemented three trade execution algorithms:

1. Time-Weighted Average Price;
2. Almgren-Chriss model with linear impact functions;
3. Greedy exploration in Limit Order Book Execution.

We found out that TWAP is the most versatile of them all, but is far from being the optimal one. The AC model has the closed-form solution for the strategy only in case of the linear price impact functions, and it's optimal strategy is deterministic. The underlying assumptions of the GLOBE algorithm do not allow us to use it for the high-frequency trading, and in addition to that, the authors of this model stronly rely on the AC assumptions, which are not too realistic.

References

[AC00] Robert Almgren and Neil Chriss. *Optimal Execution of Portfolio Transactions*. 2000.

[ATS18] Nima Akbarzadeh, Cem Tekin, and Mihaela Van Der Schaar. "Online Learning in Limit Order Book Trade Execution". In: *IEEE Transactions on Signal Processing* 66 (17 2018), pp. 4626–4641.

[Bou+18] Jean-Philippe Bouchaud et al. *Trades, Quotes and Prices: Financial Markets Under the Microscope*. Cambridge University Press, 2018, pp. 5–19, 44–72, 208–224, 384–403. ISBN: 9781107156050.