Opportunistic Execution Report

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1. Overview

The purpose of this assignment is to find out if and when an order should be immediately executed by paying (half) the Bid/Offer spread, i.e, MT. Or if would be economically better to rest this order with the Bid/Offer spread for a period time to achieve possibly a better execution, i.e, OMM.

The data here we use is the price data of Gbp/Usd. It is a large set of tick data (for both Bid and Offer). Moreover, a set of orders covering the same time period was also given. Because of the price data minimum decimal is 0.1 bps, so we may set up a responding Stop Loss in the level of bps. Also, the tick interval is 1 second, so we may set up Time Limit in level of seconds as well.

2. Execution Methods

And during this assignment, we basically concern about three methods with those given orders. Because of the fact that execution immediately (MT) will always lose half of the B/O spread, we may want to be in OMM sometime to avoid that much loss.

2.1 Method1 : Market Taking (MT)

For each order, we will aggress the market immediately and therefore incur the (half) Bid/Offer spread. In this case, we buy at the latest Ask price and sell at the latest Bid price.

2.2 Opportunistic Market Making (OMM)

For each order, we will rest it within the Bid/Offer spread for a given amount of time waiting for its (possible) opportunistic execution. For both case, we set:
Time to Execution (TTE, TimeLimit): 15s
Stop Loss (SL): -0.0003 (-3 bps)
In our opinion, 15 second is an appropriate length because market Bid/Ask prices are updated frequently at most time. Besides, 3bps is also a good threshold to stop the trade during the short time period.

2.2.1 OMMSide

OMMSide means that we place the order on our chosen side, wait for the market to move toward us for completion. In this way, we would probably buy at Bid price and sell at Ask price.

2.2.2 OMMMid

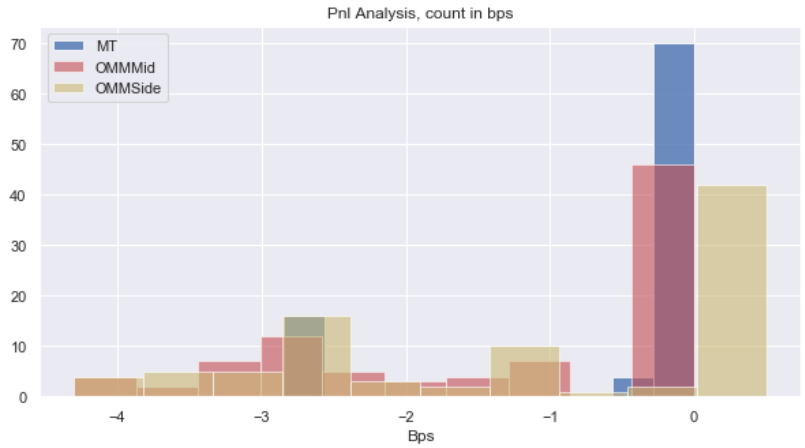
OMMMid means that we place the order on the mid-price, wait for the market to move toward us for completion. In this way, we would probably buy and sell at mid-price.

3. Analysis

3.1 Pnl Analysis

Here we first show some stats and histogram for the execution Pnl for all three methods.

	Pnl_min(bp)	Pnl_max(bp)	Pnl_mean(bp)	Pnl_median(bp)	Pnl_std(bp)
MT	-2.85	-0.0	-0.667	-0.200	1.023
OMMSide	-4.30	0.5	-1.196	-0.925	1.520
OMMMid	-4.30	0.0	-1.243	-0.125	1.437



We may see from the graph and the Pnl table:
min: MT > OMMSide = OMMMid
max: OMMSide > MT = OMMMid
mean: MT > OMMSide > OMMMid
median: OMMMid > MT > OMMSide
std: OMMSide > OMMMid > MT
And may also conclude that:
1. MT has the highest Pnl_mean, meaning that OMM doesn't always save our money, compared with direct MT.
2. MT has a higher Pnl_min since it doesn't need to wait, and never trigger TTE and SL.
3. OMMSide has the positive max, it is the only method that we could make a postive execution Pnl.
4. And OMMSide also gets the higher std, followed by OMMMid and MT, which means the more we want to save cost when placing an order, the more risk we take.

3.2 Duration, Trigger Times Analysis

These two parameters are used for both methods in OMM.

	Duration_mean	Duration_median
OMMSide	8.97	9.0
OMMMid	8.32	7.0

We may see from the table that OMMSide has longer mean Duration than that of OMMMid. Same for median. This is because for OMMSide, we place the order more favorable for us, and thus need more time to wait for the price to reach our order price.

We also show the Trigger Times table below to display how may times that TTE or SL happen during both OMM methods.

	TTE_count	SL_count	Success_count
OMMSide	39	10	41
OMMMid	35	10	45

The table shows that both OMM Methods are more likely to be triggered by Time Limit. Market Bid/Ask prices are updated frequently at most time, so it's less likely to trigger the SL .
In addition, OMMSide method incurs more Time Limit and same in Stop Loss trigger times compared to OMMMid method because the former's condition is harder for the price to reach.

Now we add them up, showing them in a summary table below:

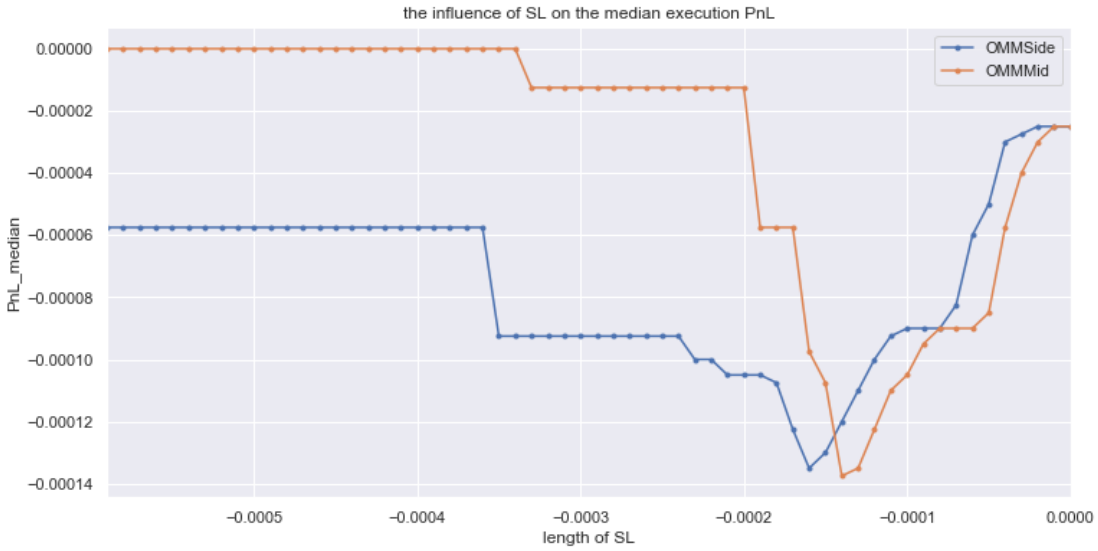
	Pnl_min(bp)	Pnl_max(bp)	Pnl_mean(bp)	Pnl_median(bp)	Pnl_std(bp)	Duration_mean	Duration_median	TTE_count	SL_count	Success_count
MT	-2.85	-0.0	-0.667	-0.200	1.023	NaN	NaN	NaN	NaN	NaN
OMMSide	-4.30	0.5	-1.196	-0.925	1.520	8.97	9.0	39.0	10.0	41.0
OMMMid	-4.30	0.0	-1.243	-0.125	1.437	8.32	7.0	35.0	10.0	45.0

We may learn from the Summary Table that:
MT Method has a less risky Pnl because it's less possible to be exposed to the market move. OMM Method has larger volatility since the market move during the waiting time period. And thus OMMSide is more risky since the harder the condition can be realized, the more profit we can gain and the longer TTE we have to wait.

4. Further Analysis

4.1 The influence of SL

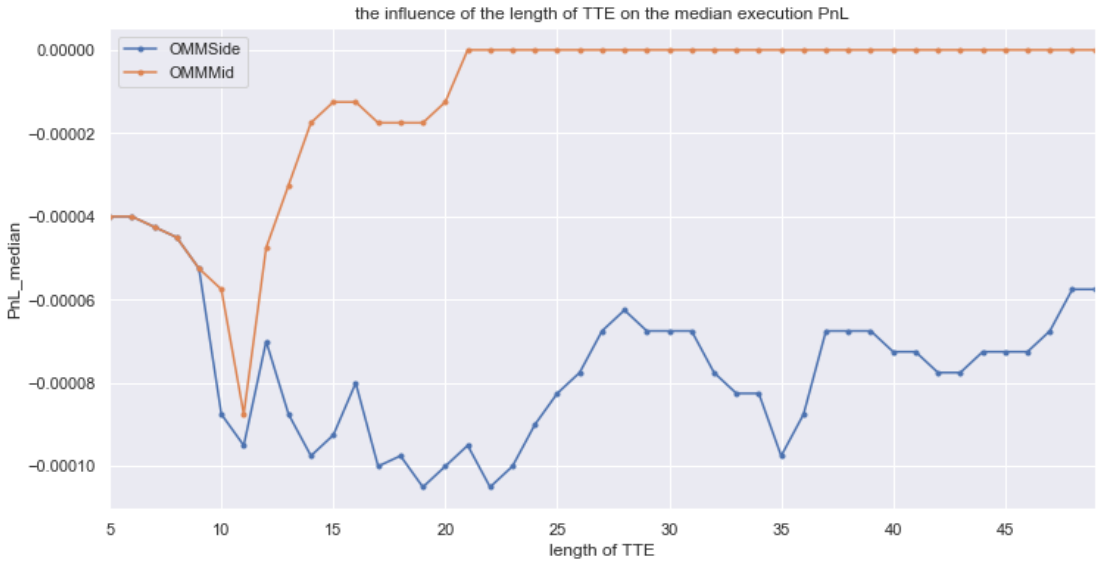
Here we fix the TimeLimt (TTE) to be 15, and try SL from -6bps to 0. The result is shown below:



We may conclude from the graph that although OMMMid gets a higher Pnl median most of the time, but when SL is close to 0 (from -1.5bps to 0), OMMSide actually gets a higher Pnl median. And overall, Pnl median reaches its lowest when SL is set around -1.5bps, and increases on both sides. In this sense, we may want to use a tighter or fatter SL threshold but not the one in the middle.

4.2 The influence of the length of TTE

Here we fix the StopLoss(SL) to be -3bps, and try length of TimeLimit (TTE) from 5 to 50. The result is shown below:



We may conclude from the graph that OMMMid gets a higher Pnl median all the time and it reaches zero-level after TTE is set to be 20. And for OMMSide, its Pnl median is volatile and does not follow certain trend.

4.3 Annex: Trade Table

The trade table list all the orders, with their PnL, time to execution and whether SL or TTE has been triggered, for all three execution methods.

	Side	MT_Pnl (bp)	OMMSide_Pnl (bp)	OMMSide_TE	OMMSide_	OMMMid_Pnl (bp)	OMMMid_TE	OMMMid_I
0	B	-2.85	-2.85	15	TTE	-2.85	15	TTE
1	S	-2.85	-2.85	15	TTE	-2.85	15	TTE
2	B	-2.85	-2.85	15	TTE	-2.85	15	TTE
3	S	-2.85	-2.85	15	TTE	-2.85	15	TTE
4	B	-2.85	-2.85	15	TTE	-2.85	15	TTE
5	B	-2.85	-2.85	15	TTE	-2.85	15	TTE
6	B	-2.85	-2.85	15	TTE	-2.85	15	TTE
7	S	-2.85	-2.85	15	TTE	-2.85	15	TTE
8	S	-2.85	-2.85	15	TTE	-2.85	15	TTE
9	S	-2.85	-2.85	15	TTE	-2.85	15	TTE
10	S	-2.85	-2.85	15	TTE	-2.85	15	TTE
11	B	-2.85	-2.85	15	TTE	-2.85	15	TTE
12	S	-2.85	-2.45	15	TTE	-2.45	15	TTE
13	S	-2.85	-2.45	15	TTE	-2.45	15	TTE
14	B	-2.85	-3.35	15	TTE	-3.35	15	TTE
15	B	-2.85	-3.35	15	TTE	-3.35	15	TTE
16	B	-0.25	-0.25	15	TTE	-0.25	15	TTE
17	S	-0.15	-1.35	15	TTE	-1.35	15	TTE
18	B	-0.2	0.2	9	Success	0	8	Success
19	S	-0.25	-1.45	15	TTE	-1.45	15	TTE
20	B	-0.2	0.2	7	Success	0	6	Success
21	B	-0.2	0.2	6	Success	0	5	Success
22	B	-0.2	0.2	5	Success	0	4	Success
23	S	-0.2	-2.5	15	TTE	-2.5	15	TTE
24	S	-0.2	-2.4	15	TTE	-2.4	15	TTE
25	S	-0.2	-2.1	15	TTE	-2.1	15	TTE
26	S	-0.2	-2	15	TTE	-2	15	TTE
27	B	-0.1	0.1	1	Success	0	1	Success

28	S	-0.2	-1.2	15	TTE	-1.2	15	TTE
29	S	-0.15	-1.05	15	TTE	-1.05	15	TTE
30	B	-0.25	0.25	7	Success	0	7	Success
31	B	-0.2	0.2	6	Success	0	6	Success
32	B	-0.25	-3.05	15	TTE	-3.05	15	TTE
33	S	-0.15	0.15	3	Success	0	3	Success
34	B	-0.2	-4.1	13	SL	-4.1	13	SL
35	B	-0.2	-4	11	SL	-4	11	SL
36	B	-0.15	-4.05	9	SL	-4.05	9	SL
37	B	0	-3.7	7	SL	-3.7	7	SL
38	B	-0.1	0.1	1	Success	0	1	Success
39	B	-0.15	-3.55	3	SL	-3.55	3	SL
40	B	-0.2	-4.3	3	SL	-4.3	3	SL
41	B	-0.15	-3.35	2	SL	-3.35	2	SL
42	B	-0.2	-3.3	3	SL	-3.3	3	SL
43	B	-0.15	-3.25	1	SL	-3.25	1	SL
44	B	-0.5	0.5	2	Success	0	1	Success
45	B	-0.15	0.15	3	Success	0	3	Success
46	B	-0.15	0.15	1	Success	0	1	Success
47	S	-0.15	0.15	4	Success	0	2	Success
48	S	-0.15	0.15	2	Success	0	2	Success
49	S	-0.25	0.25	1	Success	0	1	Success
50	S	-0.2	0.2	9	Success	0	9	Success
51	S	-0.35	0.35	9	Success	0	9	Success
52	S	-0.25	0.25	3	Success	0	1	Success
53	S	-0.3	0.3	1	Success	0	1	Success
54	S	-0.2	0.2	3	Success	0	1	Success
55	B	-0.25	-2.25	15	TTE	-2.25	15	TTE
56	S	-0.2	0.2	6	Success	0	4	Success
57	S	-0.2	0.2	2	Success	0	2	Success
58	B	-0.1	-1.9	15	TTE	-1.9	15	TTE
59	B	-0.15	-0.95	15	TTE	-0.95	15	TTE
60	B	-0.15	0.15	3	Success	0	3	Success
61	B	-0.25	0.25	1	Success	0	1	Success
62	B	-0.15	0.15	2	Success	0	1	Success
63	B	-0.25	-2.95	15	TTE	0	8	Success
64	B	-0.2	0.2	6	Success	0	1	Success
65	B	-0.2	0.2	6	Success	0	5	Success
66	S	-0.15	0.15	6	Success	0	6	Success
67	S	-0.2	0.2	3	Success	0	3	Success
68	S	0	0	1	Success	0	1	Success
69	B	-0.2	0.2	4	Success	0	4	Success
70	S	-0.25	-3.25	5	SL	-3.25	5	SL
71	B	-0.25	0.25	2	Success	0	2	Success
72	S	-0.25	0.25	11	Success	0	7	Success
73	S	-0.15	0.15	3	Success	0	3	Success
74	S	-0.05	0.05	4	Success	0	4	Success
75	S	-0.2	0.2	4	Success	0	4	Success
76	B	-0.1	0.1	1	Success	0	1	Success
77	B	-0.2	0.1	15	TTE	0	14	Success
78	B	-0.2	0.2	12	Success	0	12	Success
79	B	-0.2	0.2	1	Success	0	1	Success
80	B	-0.2	0.2	2	Success	0	2	Success
81	B	-0.2	0.2	2	Success	0	1	Success
82	B	-0.2	0.2	15	TTE	0	2	Success
83	S	-0.25	-1.05	15	TTE	0	3	Success
84	S	-0.3	-1.3	15	TTE	-1.3	15	TTE
85	S	-0.2	-1.3	15	TTE	-1.3	15	TTE
86	S	-0.2	-0.9	15	TTE	-0.9	15	TTE
87	S	-0.25	-1.15	15	TTE	-1.15	15	TTE
88	S	-0.2	-1.1	15	TTE	-1.1	15	TTE
89	S	-0.25	-1.05	15	TTE	-1.05	15	TTE

4.4 Choose Execution Methods

First, we may need to define out in-sample data and out-of-sample data set. Here we use first half of our Orderset to be in-sample data, and we try on different strategies with different parameters on this set, then we move on to test our strategies in out sample Orderset.

And because of the goal is to save as much as possible when execution, so the sum of execution Pnl is the stat that we consider to be the most important one. And we construct our decision strategy in this way:

First of all, just from an intuition sense, with a given lookback period (lb) before an order, we may want to check if the price is in certain state (Eg. Mean-Reversion or Break-out Trend). Let's assume we are facing with a "Buy" order, then same process can be replicated for "Sell" order.

For a "Buy":

1. If the price in the lookback period is in an increasing trend, then the best way to execution is MT, since to wait in the market is more dangerous when the price enjoys an uptrend move.
2. If the price in the lookback period is in a decreasing trend, then the best way to execution is OMMSide, since the downtrend move of the price is more likely to reach our "Side".
3. Or if the price in the lookback period is more likely to be mean reverting, then the best way to execution should be OMMMide, since it may save us some cost and also the condition is more likely for a fluctuating price level to reach.

Given these thoughts, we may need to define how we identify these trend or state during the lookback period, the stats we compute in this period are:

1. Range of mid price: max – min, and call it "range"
2. Std
3. Difference between the earliest mid price of the period and the current mid price. And call it "diff"

When:

$$\text{abs(diff)} < \text{range} - N * \text{std}$$

we may judge it to be in the state of Mean-Reversion, so then we use OMMMide.

But when:

$$\text{abs(diff)} >= \text{range} - N * \text{std}$$

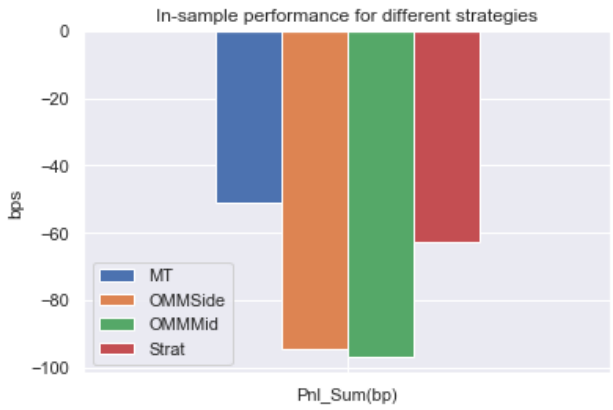
we may think the price level is in certain trend and then we look at the sign of "diff", positive for uptrend and negative for downtrend. Then we use MT or OMMSide for a "Buy" order respectively.

Basically, this strategy contains two parameters: lookback period (lb) and Number of std (N). So we first do a grid search in the in-sample data, here shows the result, the number in the grid table is the sum of strategy execution Pnl, counts in bps:

	15	20	25	30	35	40	45
0.5	-66	-66.7	-63.8	-63.9	-63.9	-62.7	-65.6
1.0	-62.7	-63.4	-63.9	-63.9	-63.9	-63.9	-63.9
1.5	-62.7	-63.4	-63.9	-63.9	-63.9	-64.35	-64.35
2.0	-62.7	-63.4	-64.15	-64.35	-64.35	-64.35	-64.35
2.5	-62.7	-63.85	-63.95	-64.35	-64.35	-64.35	-64.35
3.0	-62.95	-63.85	-63.95	-64.35	-64.35	-64.35	-64.35
3.5	-62.95	-63.85	-63.95	-64.35	-64.35	-64.35	-64.35
4.0	-62.95	-63.85	-63.95	-64.35	-64.35	-64.35	-64.35

While the result from in-sample grid search is not that disperse, we may see that the maximum of the result lies in when lb=15 and N=1.0 to 2.5. We first compare their total Pnl with three-method-only execution strategies to see if it works during the in-sample data. Here is the result:

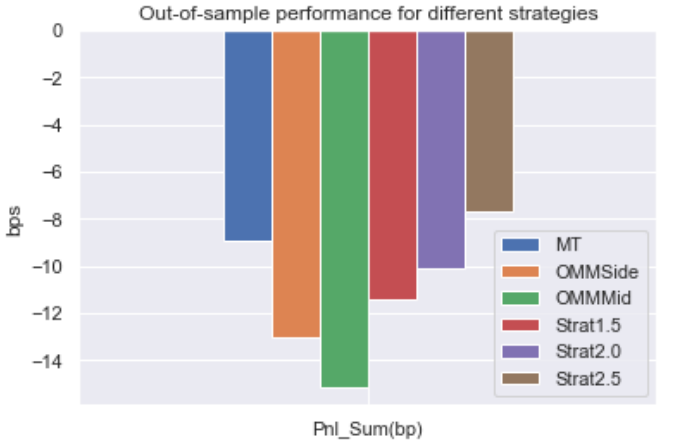
	MT	OMMSide	OMMMid	Strat
Pnl_Sum(bp)	-51.15	-94.65	-96.75	-62.7



We may see that our strategies is better than OMM methods but worse than MT methods, but they are close to each other.

Then we go back to the grid search, however, when N falls down to 0.5, the result suffers a lot to -66bps. Since we want the parameter to be stable for the shifting, so we here chose the lb=15 and consider N equal from 1.5, 2.0, 2.5, then we test their efficacy in out-sample data. The results are shown below:

	MT	OMMSide	OMMMid	Strat1.5	Strat2.0	Strat2.5
Pnl_Sum(bp)	-8.9	-13.0	-15.15	-11.45	-10.1	-7.7



During the out-of-sample period, we can see that our strategies are all better than OMM methods but only Strat with N = 2.5 beat the MT, improving it by around 1.2 bps, but the other two Strats, with N =2.0 and 1.5, cannot win MT method.