Backtesting Performance with a Simple Trading Strategy using Market Orders

Yuanda Chen

Dec, 2016

Abstract

In this article we show the backtesting result using LOB data for INTC and MSFT traded on NASDAQ on 2012-06-21.

1 Testing a Simple Trading Strategy

In this section, we show the effectiveness of our proposed model by testing it with a simple-minded trading strategy. An analysis of the prediction accuracy does not necessarily suggest that our predictions are good enough to have any practical value, although the results are promising, for the following two reasons.

The first is related to the presence of the bid-ask spread. Notice that all transactions happen at the best prices (bid or ask) rather than the mid price. This means that if you immediately buy and sell 1 share of the same stock, you will lose the spread rather than at break even. As a consequence, an accuracy rate higher than 50% is needed to make sure one does not lose money in the long run and we need to assess if our model is accurate enough.

The second reason is related to the timing of the predictions. It is not surprising that the predictions are more accurate when they are closer to a price move. That is $\hat{p}$ approaches 1 (0, respectively) when the mid price actually moves up (down, respectively). This leads to a high rates of both signal triggering R_s and accuracy R_a and as a consequence a high rate of true signal R_T. On the other hand, in our experiment, a $\hat{p}$ is estimated for every testing sample. Recall that the testing samples correspond with the rows in the order book file, and the rows in the order book file are recorded every time when there is a new market event (corresponding to the rows in the message file). Usually there are more market activities when the mid price is about to change. Putting all these concerns together, there are likely to be more predictions made near a price change, most of which are accurate. However, predictions too close to a price move might be of little use in practice due to latency and slippage. It is hard to exclude the possibility that the high accuracy of our predictions are mainly contributed by the (not so useful) ones near a price move.

1.1 Strategy Design

To make sure our trading strategy is not overvalued, we choose to introduce a cool-down time of Δt seconds. The strategy goes into a cool-down phase right after a trading action is made and it only makes a trading action when it is off cool-down. This makes sure that signals generated from our model are used less frequently than every Δt seconds. To add some "randomness" we introduce a burn-up time of δt seconds at the start of the first testing period, i.e. the strategy starts at δt seconds past 11:00 a.m.. Suppose our portfolio at time t contains $C(t)$ dollars of cash and $H(t)$ shares of the stock, both of which can be negative. The value of this portfolio $V(t)$ is calculated as the sum of $C(t)$ and the value readily obtainable from the stock, i.e. the value at which the stock can be immediately traded. More precisely,

$$\begin{cases} V(t) = C(t) + H(t)p^b(t) & \text{if} \quad H(t) \geq 0 \\ V(t) = C(t) + H(t)p^a(t) & \text{if} \quad H(t) < 0 \end{cases}$$

Moreover, assume our model gives an instant prediction and our trading activities can be executed immediately and we are able to long or short 1 share of the stock at the best prices. Suppose further the predictions are made and signals are generated automatically whenever there is an update to the LOB, or a new event in the market. Again, this test is not meant to represent a realistic trading implementation, but rather a simple way to illustrate whether the model produces useful information in terms of predicting the future price movement. Starting at 11:00 a.m. with $C(0) = H(0) = 0$, our strategy automates trading activities according to the following systematic algorithm utilizing the signals generated by our model. This algorithm is also illustrated as a flow chart in Figure 1.

1. This strategy becomes active at δt seconds after 11:00 a.m., off cool-down.
2. Whenever there is a new signal at time t, do nothing if the strategy is on cool-down; otherwise do the following:
   (1) If it is a positive signal:
      a. If $H(t) \geq 0$ (in a long (no) position), long 1 (more) share;
      b. otherwise, we are in a short position with negative holdings $H(t)$, long $|H(t)|$ shares to close the position.
   (2) otherwise, it is a negative signal:
      a. If $H(t) \leq 0$ (in a short (no) position), short 1 (more) share;
      b. otherwise, we are in a long position with positive holdings $H(t)$, short $|H(t)|$ shares to close the position.
   (3) The strategy starts a Δt seconds cool-down.
3. If 15:30 (3:30 p.m.) is reached, close any remaining position; otherwise repeat step 2.

1.2 Performance when $\Delta t = 30$, $\delta t = 0$

Figure 2 shows the performance of our systematic trading strategy, with a cool-down time $\Delta t = 30$ seconds and a burn-up time $\delta t = 0$, against the INTC LOB data on 2012-06-21. The strategy runs from 11:00 a.m. to 3:30 p.m. and the value of the portfolio $V(t)$, or the accumulated profit and loss, is shown as the blue curve in the top panel (left y-axis). The black curve shows the mid price (right y-axis) along which markers are placed. The upward-pointing triangles (green) represents the positive signals and the downward-pointing ones (red) the negative signals. Both the green and red triangles are sub-categorized as the darker ones and the brighter ones, representing the true and false signals, respectively. In the bottom panel the holdings $H(t)$ is shown as vertical bars and dots on the horizontal line $y = 0$ correspond to the moments when $H(t) = 0$.

We now take a closer look at what happened in the first 5 minutes in Figure 3. Table 1 lists the trades generated by our trading algorithm, with detailed information about the transaction size $\Delta H(t)$, the resulting holding $H(t)$, the best ask $p^a(t)$ and bid $p^b(t)$ prices when the trade happens, the change in cash $\Delta C(t)$, the resulting total cash $C(t)$ and the resulting total value of the portfolio (cash and stock) $V(t)$.

There is a total of 292 signals generated in our test for INTC from 11:00 a.m. to 3:30 p.m., which further breaks down to the four categories, yielding an accuracy rate of 89.38%. The signals are generated 11.5207 seconds prior to the actual price changes on average. There are 204 round-trip trades, defined below in Definition 1.1, completed (with 2 shares shorted at the end of the trading period to close the remaining position) and the average holding time of each share is 120.5267 seconds, with the minimum (excluding the last 2 completed at the end due to position closing) and maximum being 30.0005 and 463.8187 seconds, respectively. The largest short/long positions are $H(t) = -9$ (short position of 9 shares) and $H(t) = 6$ (long position of 6 shares) with an average holding of -0.6246 share and a standard deviation of 2.2791 shares. The distribution of the round-trip profit and loss is shown by the histogram in Figure 4, where the red is due to the position closing at the end of the trading period. The total profit is \$1.39 and the average profit is 0.6912 tick per round-trip trade with a standard deviation of 1.9846 ticks. There are 92 winning round-trip trades and 50 losing ones resulting in a winning ratio (percentage of winning ones among all round-trip trades) of 45.10% and a win-to-loss ratio of 1.84.

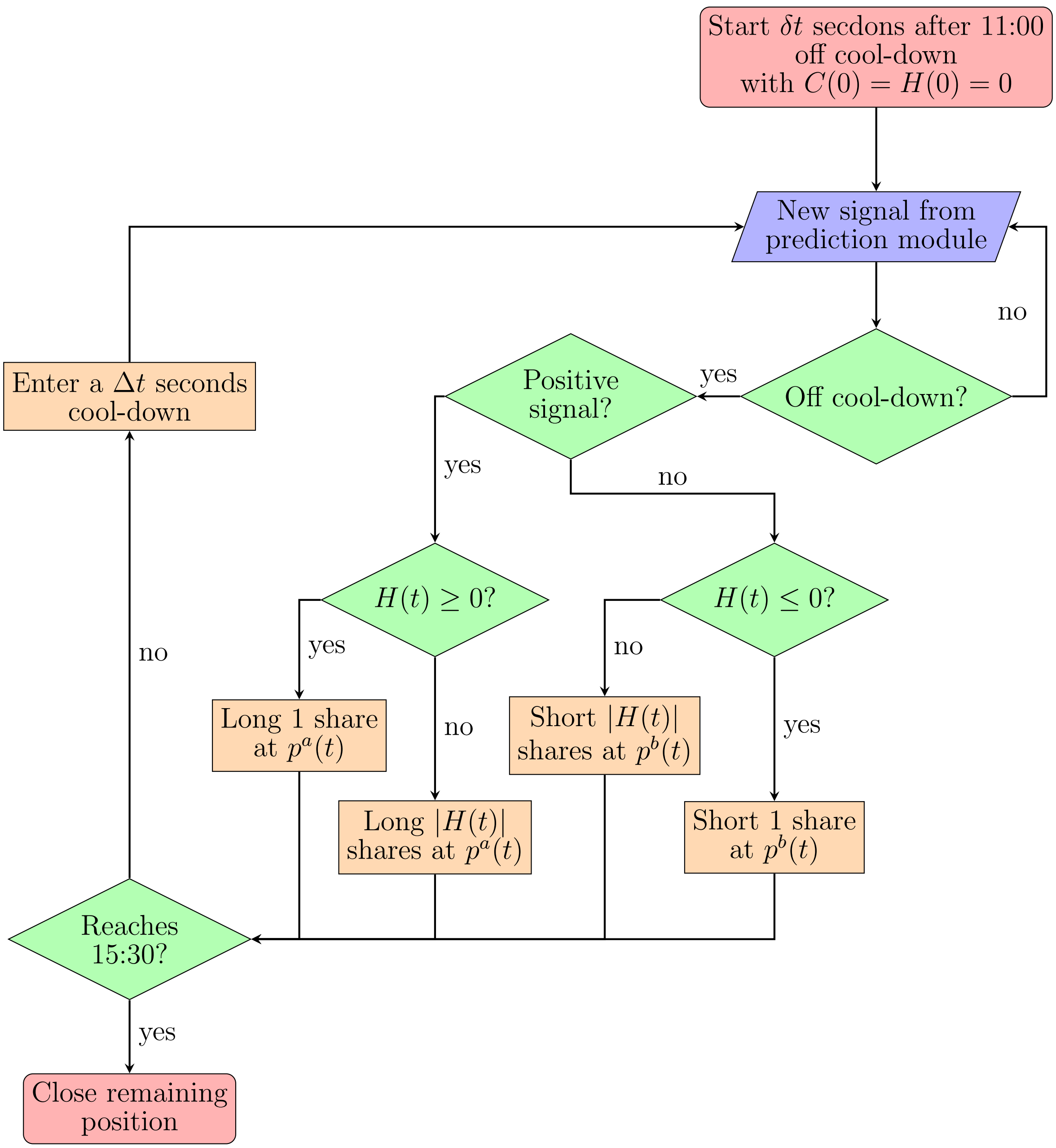

Figure 1: Flow chart showing the design of our algorithmic trading strategy. The top right red rectangle marks the start of the strategy at time δt seconds after 11:00, with initial cash \$0 and no position in the stock. The purple trapezoid is a module that produces signals using our model. At each green diamond a decision is made based on the nature of the signal, the cool-down state of the strategy, the current holdings of the stock $H(t)$ where t is the time elapsed from 11:00 in seconds, and the current time. At each orange rectangle an action is made changing $H(t)$ or the cool-down state. The bottom left red rectangle is the terminal node where the remaining position will be closed.

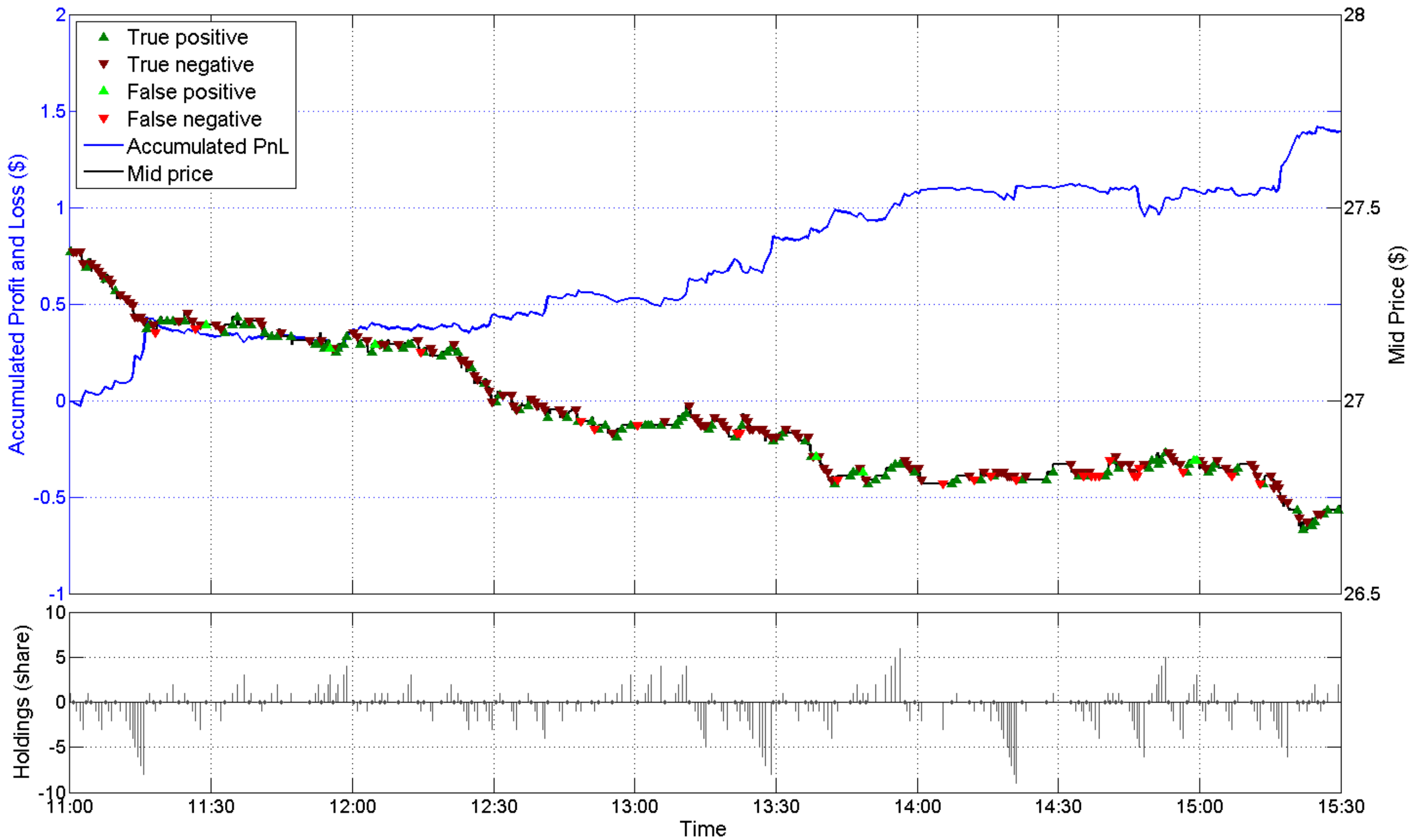

Figure 2: Performance of the systematic trading strategy using signals generated by our model (with $\eta = 0.9$) against the INTC LOB data on 2012-06-21, with $\Delta t = 30$ and $\delta t = 0$. In the top panel, the accumulated profit and loss, or $V(t)$ is shown as the blue curve (left y-axis) and the mid price the black (right y-axis) along which markers are placed. Positive (negative) signals are shown by the upward (downward)-pointing triangles, with the darker (brighter) ones correspond to the true (false) signals. In the bottom panel the holding, or $H(t)$ is shown as vertical bars, with and dots on the horizontal line $y = 0$ correspond to the moments when $H(t) = 0$.

Figure 3: A zoomed-in version of Figure 2 with the best bid (red) and ask (green) prices plotted, showing the trades generated by our systematic trading algorithm during the first 5 minutes when running against the INTC LOB data on 2012-06-21.

Table 1: Trades generated by our systematic trading algorithm during the first 5 minutes when applied against the INTC LOB data on 2012-06-21, with $\eta = 0.9$, $\Delta t = 30$ and $\delta t = 0$.

Trades	$\Delta H(t)$	H(t)	$p^a(t)$	$p^b(t)$	$\Delta C(t)$	$C(t)$	$V(t)$
long	1	1	27.39	27.38	-27.39	-27.39	-27.39+ (1)(27.38) $= -0.01$
short	-1	0	27.39	27.38	27.38	-0.01	-0.01+ 0 $= -0.01$
short	-1	-1	27.39	27.38	27.38	27.37	27.37+(-1)(27.39) $= -0.02$
short	-1	-2	27.39	27.38	27.38	54.75	54.75+(-2)(27.39) $= -0.03$
short	-1	-3	27.36	27.35	27.35	82.10	82.10+(-3)(27.36) $= +0.02$
long	3	0	27.35	27.34	-82.05	0.05	0.05+ 0 $= +0.05$
long	1	1	27.36	27.35	-27.36	-27.31	-27.31+ (1)(27.35) $= +0.04$
short	-1	0	27.36	27.35	27.35	0.04	0.04+ 0 $= +0.04$

Definition 1.1. *A round-trip trade is a pair of trades, one of which opens a position for one share and the other closes the position.*

The performance of applying our trading algorithm against the MSFT LOB data on 2012-06-21 is shown in Figure 5 and Figure 6 with signals broken down in Table 3. A total of 373 signals are generated, 12.5459 seconds prior to the actual price changes on average, with a rate of accuracy of 88.47% (details shown in Table 3). There are 279 round-trip trades with 1 share longed at the end of the trading period to close the remaining position. The average holding time of each share is 124.0531 seconds with a minimum (excluding

Table 2: Breakdown of the 262 signals shown in Figure 2 for INTC with an accuracy rate of 89.38%.

	Positive	Negative	Total
True	118	143	261
False	7	24	31
Total	125	167	292

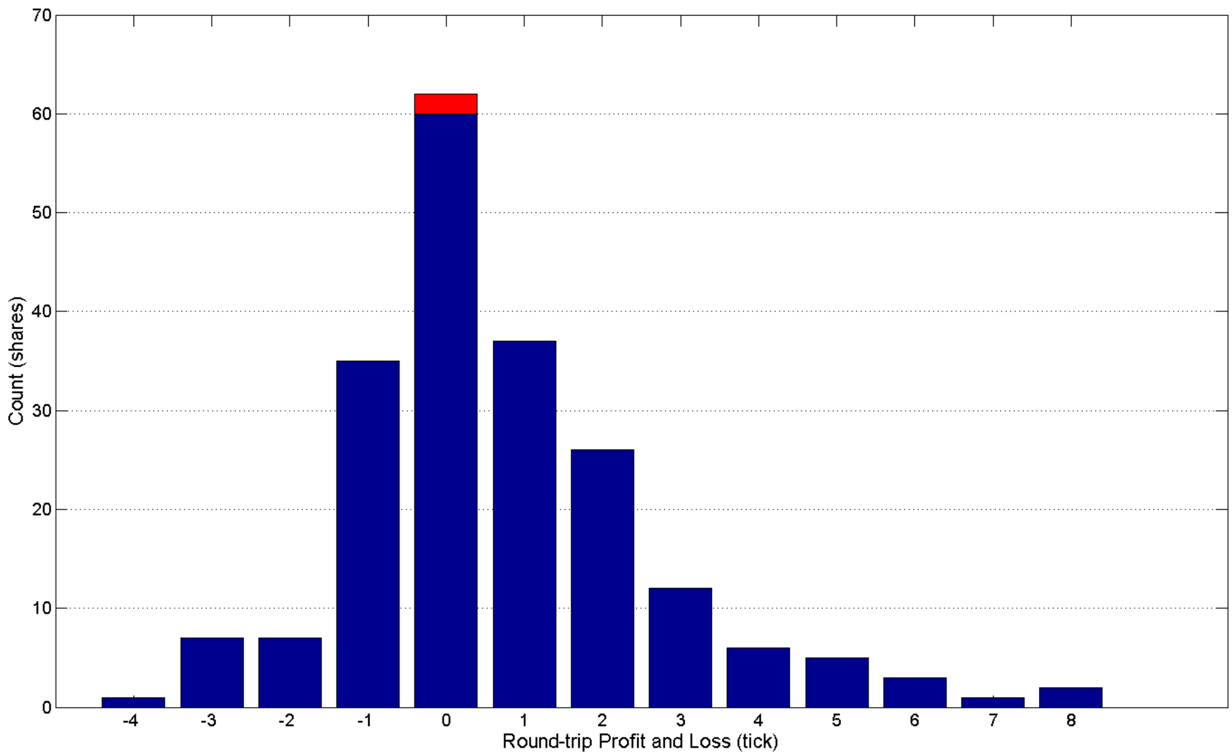

Figure 4: Distribution of the round-trip profit and loss from running our systematic trading algorithm against the INTC LOB data on 2012-06-21, with $\eta = 0.9$, $\Delta t = 30$ and $\delta t = 0$. The two shares shown as red are due to the closing of remaining position at the end of the trading period. The average profit and loss is 0.6912 ticks per round-trip trade with a standard deviation of 1.9846 ticks. There are 92 winning round-trip trades and 50 losing ones resulting in a winning ratio (percentage of winning ones among all round-trip trades) of 45.10% and a win-to-loss ratio of 1.84.

the last 1 completed at the end due to position closing) and maximum of 30.0109 and 499.1807 seconds, respectively. The largest short/long positions are a short of 12 shares and a long of 4 shares with an average holding of -1.8984 and a standard deviation of 2.8502 shares. The total profit is \$3.56 and the average profit is 1.2760 ticks per round-trip trade with a standard deviation of 3.3316 ticks. There are 150 winning round-trip trades and 74 losing ones resulting in a winning ratio (percentage of winning ones among all round-trip trades) of 40.21% and a win-to-loss ratio of 2.027.

Table 4 and Table 5 summarize the performance statistics obtained from the tests in this section.

Figure 5: Performance of the systematic trading strategy using signals generated by our model (with $\eta = 0.9$) against the MSFT LOB data on 2012-06-21, with $\Delta t = 30$ and $\delta t = 0$, similar to Figure 2. A total of 373 signals are generated, 12.5459 seconds prior to the actual price changes on average, with a rate of accuracy of 88.47% (details shown in Table 3). There are 279 round-trip trades with 1 share longed at the end of the trading period to close the remaining position. The average holding time of each share is 124.0531 seconds with a minimum (excluding the last 1 completed at the end due to position closing) and maximum of 30.0109 and 499.1807 seconds, respectively. The largest short/long positions are a short of 12 shares and a long of 4 shares with an average holding of -1.8984 shares and a standard deviation of 2.8502 shares.

Table 3: Breakdown of the 262 signals shown in Figure 5 for MSFT with an accuracy rate of 88.47%.

	Positive	Negative	Total
True	110	220	330
False	2	41	43
Total	112	261	373

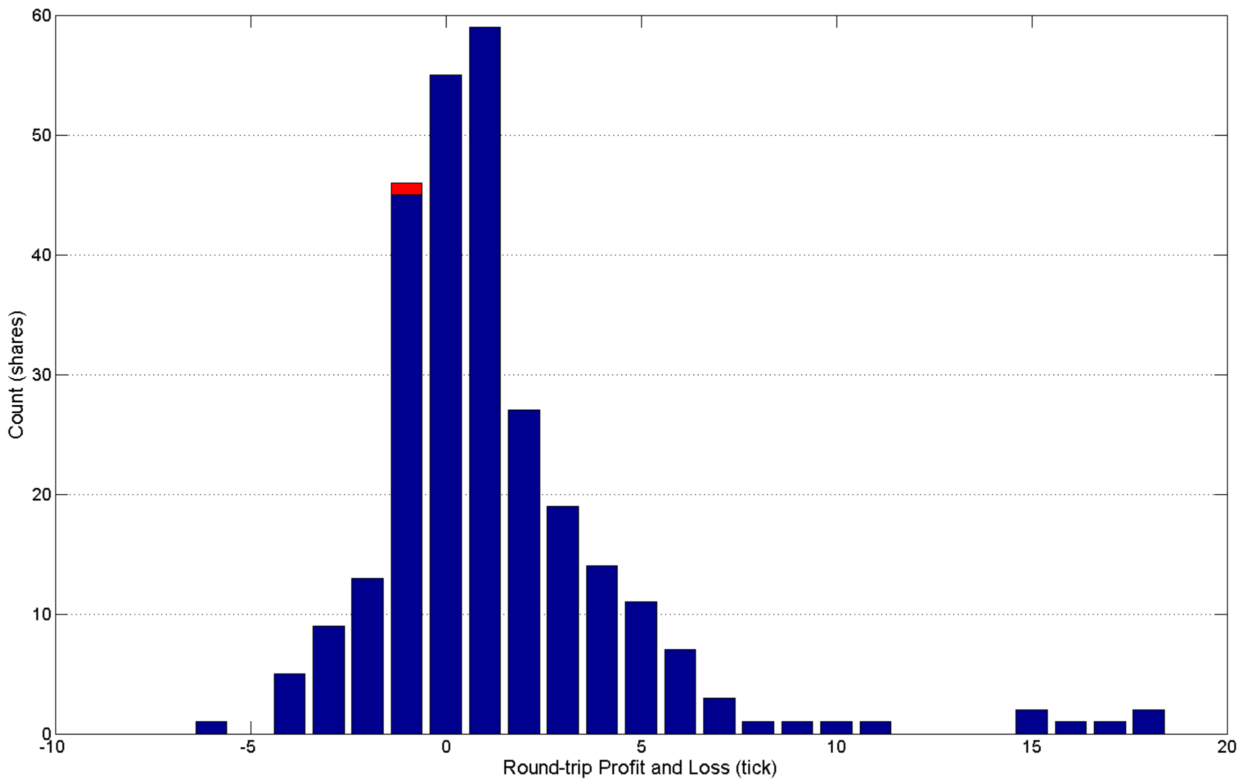

Figure 6: Distribution of the round-trip profit and loss from running our systematic trading algorithm against the MSFT LOB data on 2012-06-21, with $\eta = 0.9$, $\Delta t = 30$ and $\delta t = 0$. The one share shown as red is due to the closing of remaining position at the end of the trading period. The average profit and loss is 1.2760 ticks per round-trip trade with a standard deviation of 3.3316 ticks. There are 150 winning round-trip trades and 74 losing ones resulting in a winning ratio (percentage of winning ones among all round-trip trades) of 40.21% and a win-to-loss ratio of 2.027.

1.3 Varying Δt

In Table 6 and Table 7 we show the performance statistics similar to Table 4 and Table 5 but with varying Δt from 5 to 120 seconds. We observe that the number of signals decreases as expected when Δt increases while the rate of accuracy has a tendency to slightly increase. There are profits made for all of them except when $\Delta t = 95$ for INTC.

Table 4: Performance statistics of the systematic trading algorithm applied against the INTC LOB data on 2012-06-21, with $\eta = 0.9$, $\Delta t = 30$ and $\delta t = 0$.

Signals						
Positive		Negative		Total	Rate of accuracy	Average seconds prior to price change
True	False	True	False			
118	7	143	24	292	89.38%	11.5207
Holding Time			**Positions**			
Min	Max	Average	Largest		Average	Strand deviation
			long	short		
30.0005	463.8187	120.5267	6	9	-0.6246	2.2791
Profit and loss (ticks)			**Round-trip trades**			
Total	Average per round-trip	Standard deviation	Wins	Losses	Win ratio	Win-to-loss Ratio
139	0.6912	1.9846	92	50	45.10%	1.84

Table 5: Performance statistics of the systematic trading algorithm applied against the MSFT LOB data on 2012-06-21, with $\eta = 0.9$, $\Delta t = 30$ and $\delta t = 0$.

Signals						
Positive		Negative		Total	Rate of accuracy	Average seconds prior to price change
True	False	True	False			
110	2	220	41	373	88.47%	12.5459
Holding Time			**Positions**			
Min	Max	Average	Largest		Average	Strand deviation
			long	short		
30.0109	499.1807	124.0531	4	12	-1.8984	2.8502
Profit and loss (ticks)			**Round-trip trades**			
Total	Average per round-trip	Standard deviation	Wins	Losses	Win ratio	Win-to-loss Ratio
356	1.2760	3.3316	150	74	40.21%	2.027

1.4 Varying δt

In this section we show that similar performance will be achieved with varying δt values. We fix $\Delta = 30$ for easier comparison. 100 randomly (uniformly) chosen values for δt between 0 and 3600 seconds will be used,

Table 6: Performance statistics for the algorithmic trading strategy as described in Section 1.1 against the INTC LOB data on 2012-06-21, with $\eta = 0.9$, $\delta t = 0$ and varying Δt values.

Δt	Signals	Rate of accuracy	PnL	PnL per round-trip	Wins	Losses	Win ratio	Win-to-loss ratio
5	685	0.8482	217	0.4071	214	119	0.4015	1.7983
10	502	0.8685	215	0.5703	162	84	0.4297	1.9286
15	418	0.8732	155	0.5049	128	78	0.4169	1.6410
20	358	0.8799	136	0.5191	112	76	0.4275	1.4737
25	315	0.9048	128	0.5689	105	54	0.4667	1.9444
30	292	0.8938	141	0.6912	92	50	0.4510	1.8400
35	262	0.8931	84	0.4565	78	48	0.4239	1.6250
40	239	0.8954	89	0.5329	62	48	0.3713	1.2917
45	219	0.9132	10	0.0658	53	50	0.3487	1.0600
50	204	0.9118	15	0.1056	55	53	0.3873	1.0377
55	194	0.9021	29	0.2214	58	45	0.4427	1.2889
60	189	0.8836	44	0.3438	55	44	0.4297	1.2500
65	177	0.8983	99	0.7920	53	44	0.4140	1.2045
70	171	0.9123	123	1.0336	60	32	0.5042	1.8750
75	159	0.9119	127	1.1239	62	26	0.5487	2.3846
80	152	0.9079	48	0.4660	48	33	0.4660	1.4545
85	141	0.9149	28	0.3011	45	34	0.4839	1.3235
90	136	0.9265	30	0.3261	40	33	0.4348	1.2121
95	129	0.9147	-6	-0.0682	38	35	0.4318	1.0857
100	122	0.9262	59	0.7195	40	29	0.4878	1.3793
105	119	0.9328	89	1.0854	37	26	0.4512	1.4231
110	117	0.9402	140	1.7073	44	23	0.5366	1.9130
115	110	0.9364	80	1.0667	38	20	0.5067	1.9000
120	108	0.9167	43	0.5733	27	24	0.3600	1.1250

Table 7: Similar to Table 6, but against the MSFT LOB data on 2012-06-21.

Δt	Signals	Rate of accuracy	PnL (ticks)	PnL per round-trip	Wins	Losses	Win ratio	Win-to-loss ratio
5	1129	0.8406	740	0.7923	460	221	0.4925	2.0814
10	758	0.8575	523	0.8760	312	135	0.5226	2.3111
15	591	0.8731	430	0.9492	239	103	0.5276	2.3204
20	493	0.8763	416	1.1153	205	92	0.5496	2.2283
25	424	0.8821	347	1.0981	182	81	0.5759	2.2469
30	373	0.8847	356	1.2760	150	74	0.5376	2.0270
35	332	0.8825	238	0.9714	136	65	0.5551	2.0923
40	300	0.8833	159	0.7361	103	72	0.4769	1.4306
45	269	0.8885	182	0.8922	108	57	0.5294	1.8947
50	252	0.9048	145	0.7672	94	54	0.4974	1.7407
55	236	0.8644	73	0.4195	78	68	0.4483	1.1471
60	224	0.9107	197	1.1796	89	47	0.5329	1.8936
65	209	0.9378	239	1.5724	101	26	0.6645	3.8846
70	192	0.8646	287	1.9931	88	33	0.6111	2.6667
75	184	0.8804	241	1.8258	82	31	0.6212	2.6452
80	173	0.8786	249	2.1282	74	26	0.6325	2.8462
85	164	0.8902	150	1.2500	59	32	0.4917	1.8438
90	157	0.8917	96	0.8496	58	36	0.5133	1.6111
95	149	0.8993	236	2.1852	66	32	0.6111	2.0625
100	140	0.8786	185	1.7453	59	27	0.5566	2.1852
105	134	0.9403	166	1.6939	52	34	0.5306	1.5294
110	132	0.9091	87	0.8878	50	32	0.5102	1.5625
115	123	0.9187	146	1.5699	46	32	0.4946	1.4375
120	121	0.8926	209	2.2473	57	26	0.6129	2.1923

and the associated minimum, maximum, mean and standard deviation of profit and loss per round-trip, win ratio and win-to-loss ratio among the 100 independent tests will be shown in Table 8 for both INTC and MSFT. It is evident that the trading strategy is robust with changing values of δt and the performance will be similar to the ones shown in Table 4 and Table 5.

Table 8: The minimum, maximum, mean and standard deviation of profit and loss per round-trip, win ratio and win-to-loss ratio among 100 independent tests with δt uniformly distributed in between 0 and 3600 seconds, against both the INTC and MSFT LOB data on 2012-06-21. Other parameters are fixed at $\eta = 0.9$ and $\Delta t = 30$.

	INTC			MSFT		
	PnL per round-trip	Win ratio	Win-to-loss ratio	PnL per round-trip	Win ratio	Win-to-loss ratio
Min	0.5134	0.4171	1.5918	1.2327	0.5285	1.8971
Max	0.7114	0.4548	2.0000	1.3506	0.5541	2.0704
Mean	0.6269	0.4401	1.8269	1.2797	0.5398	1.9785
Std.	0.0450	0.0106	0.0782	0.0261	0.0058	0.0439