

The Penn-Lehman Automated Trading Project

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Abstract:

The Penn-Lehman Automated Trading (PLAT) Project is an investigation of algorithms and strategies for automated trading in financial markets. The project makes use of the Penn Exchange Simulator (PXS), a simulator for automated trading that uses real-world and simulated stock market data available over modern Electronic Crossing Networks (ECNs). The final deliverable will be a stock-market trading program which will be used in a competition against other PLAT participants. The program will decide when to buy/sell stocks based on financial information with the goal of achieving the most profitability.

Related Work:

There are a tremendous amount of books and websites that deal with stock trading and stock trading strategies, though we found that the majority of these resources were not very helpful with this project. This is because we are dealing with a specific form of trading, day trading, and only specific strategies are useful in this environment. As shown in the References section, we consulted many of these resources and found them to be quite helpful. More specifically, there have even been a few papers written on the Penn-Lehman project itself. "Two Stock-Trading Agents: Market Making and Technical Analysis" by Yi Feng, Ronggang Yu, and Peter Stone, describes the market making agent strategy and the reverse technical analysis strategy (buying when the market is declining, and selling when it is on the rise). "Three Automated Stock-Trading Agents: A Comparative Study" by Alexander Sherstov and Peter Stone, which studies three trading algorithms: reinforcement learning, regression-based price prediction, and the market making agent. "News Mining Agent for Automated Stock Trading" by Gurushyam Hariharan describes trying to buy/sell based on news / press releases published during the trading day. "Evolutionary Algorithms in Optimization of Technical Rules for Automated Stock Trading" by Harish K Subramanian develops different trading systems using various indicator. There were other helpful articles as well, and they are described throughout this report where appropriate. Our stock-trading strategy takes into account the lessons learned from this previous research, and we have refined and improved some of their ideas and proposals. Because of this, we feel that our strategy will do a good job at accomplishing the assigned goal of beating the given five strategies.

Technical Approach:

There are two main goals of this project. The first goal, which is to be completed this semester, is to outperform five common trading strategies. These strategies are Moving Average, Channel Breakout, Momentum, Relative Strength Index, and Market Maker. We are competing against these strategies in a simulated environment, rather than using real-world data since our advisor feels that this will give a more accurate view of how the developed strategies would perform over the long-term. The second goal, which is for next semester, is to outperform the other groups in the competition.

Comparison of Given Strategies

In order to outperform the other strategies, one of the first things we did was to test the other strategies against each other to examine their strengths and weaknesses. For each pair of technical strategies, we ran multiple PXS simulations (using the symmetric background agent), recorded their results, and graphed their performance throughout the day. The specific numerical results are included in the appendix, as is a single testing of the market making strategy versus the other strategies. This is a summary of our findings (See also Exhibit 1):

Market Maker

- Exploits the price volatility of a stock, rather than predicting the direction of its movement. The agent we used in this comparison will simply put in a pair of buy and sell orders close to the bid/ask at each time interval.
- Produced a significant profit in all 15 tests, and always outperformed every other strategy. It also produced a profit when ran against itself. This was by far the most successful strategy.

Relative Strength Index

- Predicts the overbought/oversold market. The agent will record the number and the spans of Ups and Downs. To calculate the RSI value: $RSI = 100 - 100/(1+U/D)$ where U denotes the average value of Ups and D denotes the average value of Downs. Today most practitioners regard RSI over 70 indicating the market tops while below 30 indicating the bottoms. So the agent will buy when RSI crosses up the 30 threshold and sell when RSI crosses down the 70 threshold.
- Except against Market Maker, RSI consistently outperformed the other strategies. However, it mostly failed to make a profit. This means that it “outperformed” the other strategies by losing less money than they did, which does not exactly make it a “success”.

Moving Average

- Calculates the moving average for a certain time interval specified by the user. When the current price up-crosses the moving average, the agent will buy in; when it down-crosses the moving average, the agent will sell out.
- This strategy consistently lost a significant amount of money. However, relative to the other strategies, it significantly outperformed Channel Breakouts and was barely better than Momentum.

Momentum

- Compares the current price with the price at some user-defined time span ago. If the current price is higher, it buys in; otherwise, it sells out.
- Momentum almost never produced a profit, and it never outperformed any other strategy except for Channel Breakouts.

Channel Breakouts

- Records the highest and lowest prices for a certain time interval. When the current price goes higher than the highest price recorded, or lower than the lowest price recorded, there is a breakout of the channel, and a corresponding buy or sell order is placed in.
- This was the worst strategy relative to the other strategies. It never outperformed another strategy, and the only time it produced a profit was when it was ran against itself.

Market Maker was by far the most successful strategy, so we did further research on this strategy. We found that the market making strategy accumulates profit when the stock price has a lot of fluctuation during the day. If the end price for the day is close to its start price, then that is good for the market making strategy. However, if it moves drastically in one direction and doesn't return to its start position, that can result in losses. The market making strategy performed better than the other strategies because one can be fairly certain that the stock price will move up and down throughout the day, where as the specific cases required for the other strategies to do well turned out to be more rare. The "spread" for market making also contributed to its success. In our testing, the distance from the order price to the bid/ask was .02. This value is important; if it is too high then the orders are unlikely to get executed, but if it is too low then the profits could be reduced.

Microsoft is good stock for the market making strategy because on a daily basis, it tends to be pretty volatile due to its high profile and large volume traded. Millions of shares of MSFT are traded per day, as opposed to hundreds of thousands for other well-known companies such as Blockbuster or thousands per day for Coke. This high volume allows for a fluctuation in price. Also, MSFT has been relatively stable over the past couple years (with the stock price oscillating between 23 – 29) This is good for the market making agent, whereas a stock like netflix whose price has plunged from a price of 35 to 10 over the past 6 months could be bad for market maker.

The market making strategy produced a significant profit every time. The other strategies almost always resulted in a loss. This is because the specific cases required for them to make a profit did not occur very often. According to the data collected from our simulations, it appears that all of the other strategies are horrible ideas, and that the market making agent miraculously makes a profit every time. We would caution against making this absolute conclusion though. The other strategies are well-known theoretical ideas which in other cases have performed well, so perhaps a reason they performed so poorly in this simulation was because the arguments passed into them were not the optimal values, a string of bad luck occurred during these tests, or the simulated normal distribution files used were not enough like real-world data.

Alternative Trading Strategies Researched

Price Percentage Gainers and Losers

Each day in the Wall Street Journal there is a section of the day's biggest percentage gainers and losers. Often these stocks move up or down 20% in one day. With such a dramatic change in price, we decided to investigate how these stocks performed over the next couple days and over the next week. The initial hypothesis was that the market over-reacted, so, for example, if a stock decreased 25% in one day, it would correct itself and increase in value by a little the next day.

For each day over a one-week period (January 31, 2005 to February 7, 2005) we gathered the stock data for 3 of the biggest gainers and 3 of the biggest losers. The 3 selected for each were:

1. the top gainer and loser
2. the next highest that had a stock price greater than \$5 (didn't want to look at penny stocks) and volume over 100k (to make sure there was decent liquidity and to make sure it was a fairly popular stock)
3. out of these three stocks we wanted at least one from the NYSE and one from the NASDAQ, so if this requirement hadn't been met we chose the highest from the exchange we didn't have yet

The data collected includes: the stock ticker, its closing price on the day that it made its big move, the percentage it lost or gained, and then its stock movement over the next two days and a week later. (See Exhibit II.) After analyzing the data (Exhibit III), it turned out that there was not a pattern to how the stocks performed the next day after a big move. The big gainers lost value the next day 61% (11 out of 18 times) of the time, and the big losers gained value the next day 53% (8 out of 15 times) of the time. Though both of these values are above 50%, it is not significant enough to call it a pattern, especially with a sample size this small.

Since the next day's closing price was not predictable, volatility was another option to look at. After a big moving day, it would make sense that the next couple days would be more volatile as the price adjusts to its new level. The range between the high and low for the next day was substantial and averaged 8% of the stock price. The average increase between the opening price and the day's high for the big percentage losers was 4.27%. So, a possible strategy is to buy the biggest losers at the beginning of the day, and sell them when the stock increases by 3%. If it doesn't happen the first day, hold onto the stock for a week to see if it can increase by at least 1%, since the stock's increased volatility should have it hit that value at some point during the week. If the stock starts going down however, the strategy needs to cut its losses before the stock tumbles more. The value that is not too restraining but not too lenient for this data is having a stop-loss value of 6%. This means that once the stock has decreased in value by 6%, the strategy will sell it, thereby avoiding any further losses.

The expected value for this strategy of selling at 3% the first day (which happened 8 times), then selling at 1% for the rest of the week (happened 2 times), and cutting the losses at 6% (which happened 3 times) yields an expected value of:

$$3(8/15) + 1(2/15) + -6(3/15) = .5333.$$

You would need to lower this value a bit for the stocks that didn't match any of these criteria. A half of a percent is a pretty good return for one day's work, and there could be ways to tweak the strategy to get it higher.

Opening Price Relative to High and Low Price for the Day

While looking at daily historical data for MSFT, we noticed something interesting. According to the data on finance.yahoo.com, the opening price was often in between (and not equal to) the high and low price for the day. In fact, from February 1, 2004 to February 1, 2005, the opening price was in between the high and low price 96.6% of the trading days. This is significant because that means that at at least one point during the day, the stock price is going to cross the opening day's price. A trading strategy could take advantage of this. If the stock is decreasing in value at the beginning of the day, the strategy would buy stock. The further it continues to decrease, the more stock it would buy, as long as the price hadn't crossed the opening price yet. This is a good strategy because according to the historical data, the price is going to rise in value at some point later in the day when it crosses the opening price, at which point the strategy would sell its stock. So, the strategy buys low, and sells high. The opposite would be true if the stock price is increasing at the beginning of the day, at which point the strategy would short stock as it increases, and clear its position when it decreases to its opening price.

The next question is how much stock to buy/short and how often to do it. Looking at the daily stock movement graphs for each day between December 30,2004 and February 11, 2005, we analyzed how much the stock would increase/decrease before it crossed its opening price. (See Exhibit IV.) It moved an average of .068 points (or about .25%) away from its opening price before crossing it again. On 28 of the 31 days, it moved at least .03 points away. On 18 of 31 reached at least .06 points, and 8 of the 31 reached at least .09 points. So, at each increment of .03 points, the strategy should buy/short X number of shares (X depends on how much money there is to invest) until it crosses the opening price.

Once the price crosses the opening price, the strategy would clear its position (sell all the stock it is holding, or buy back all of the stock it shorted), thereby locking in the profits. This clearing strategy can be greatly improved, though more analysis and data collection would be needed. For example, instead of the strategy clearing all of its stock when the stock crosses its opening price, perhaps it would only sell 50% and wait to see if the price moves further in that direction. Perhaps when it reaches .03 points beyond its opening price (without crossing the opening price again) it clears 25% more of its position, and if it reaches .03 points beyond that, it clears the remaining 25%. As long as the stock price does not cross back over it opening price (which would mean there is the risk of actually

losing money), this alternative cleaning strategy is very safe. If the stock does not continue in that direction and instead reaches its opening price again, the strategy would quickly clear all of its position, still ensuring a profit. The numbers used in this example (50%, .03 points, 25%), are merely examples, and more research is needed in order to find the best values to maximize profit.

This strategy, like the market making strategy, exploits the volatility of a stock. However, unlike market-maker, this strategy executes fewer trades which would save on real-world trading costs (since each trade costs around \$7 to execute in the real-world). Like market maker, this strategy will perform horribly if the stock continues in one direction, or in this case if it continually moves away from its opening price and never crosses it again. That is why it is so important that MSFT crosses its opening price 96.6% of the time.

A problem with MSFT however, is that it doesn't move large percentage points throughout the day. With the .03 points incremental trading strategy, the strategy would gain 3 cents each time, but 3 cents is only .11% of MSFT's \$26 stock price. It would be better to find a stock that has more dramatic volatility during the day, but still crosses its opening price over 90% of the time.

Here is an example to illustrate how trading costs are so important in the real world. Let's go on the assumption that the strategy clears 100% of its position when it crosses the opening price (the simpler though less profitable clearing method). For the month and half between Dec 30 and Feb 11, the strategy would make an average of 1.89 per share during that month and a half (according to the data in the table). If the strategy was investing \$1000, with each share of MSFT stock priced around \$26.65, it would be trading with 28 shares ($\$1000 / \26.65 per share). During the month and a half, it would make \$52.92 ($28 * \1.89). Assuming that the month and a half data is similar to how the stock would perform the rest of the year, it would make \$432.36 per year ($52.92 * 8$). A 43% return over a year is really good.

This return ignores the trading fees, and it doesn't factor in the occasional loss of money for when the stock does not cross its opening price. For the trading fees, over the month and a half the strategy would have to make 94 trades (one trade for each .03 incremental purchase and one trade for selling all the stock when it crosses the opening price). Assuming it is \$7 per trade in the real world, the strategy would spend \$658 on trades alone during the month and a half, and that would greatly dwarf the \$52.92 profit it made. So, in order to use this strategy, one would need to work with tens of thousands of dollars in order to make the trading costs less significant, or increase the amount of return each trade would make. If one was trading with \$50,000 instead, the strategy would have an annual return of 47.1% ($(\$50,000 / \$26.25 \text{ per share} * \$1.89 \text{ profit per 1.5 months per share} * 8 \text{ 1.5 months/year} - \$658 \text{ trading fees} * 8) / \$50,000 \text{ initial investment}$). A return like this is very impressive, though it doesn't include the possible losses of when the stock doesn't cross its opening price. However, modifying the clearing strategy could make up for those losses.

Improving the Market Making Agent

We decided to do more in-depth research on market maker specifically. There has actually not been a lot of research done on it, though we did find a couple research papers. The most significant paper though was “Automated Market Making” by Yuriy Nevmyvaka. In it he talked about some fundamental concepts of markets and trading, running simulations, related literature, different theories and models, and prior work.

Specifically we employed his research on the idea of inventory management. An ideal scenario for a market-making agent would have the exact same number of buy and sell orders filled, resulting in the fluctuation of a long and short position, centered around zero. But this does not always work out in practice. If, for example, a stock price is going up consistently, the ask price gets hit more often than the bid. This can result in the accumulation of a large short position in the rising stock. The opposite scenario can also occur and is equally as negative.

When a large stock position occurs, there are several options to help reduce the position and prevent the further increase in the inventory. We could have attempted to directly change the volumes being traded, but as the author suggests, resizing the spread can have the same effect.

We attempt to mitigate the inventory effects by dynamically resizing the spread according to the following formula

Distance from the inside market = $\text{MinimumDistance} + \alpha * \max(0, \text{Inventory} - \text{InitialLimit}) / \text{Inventory} * \text{MinimumDistance}$.

Analysis of First Semester Competition

Once the data from the results of the December presentation were analyzed, we were quite happy with our findings. We state two of our assumptions before presenting our analysis:

1. We used the “before penalty” values because seven of the eight competing groups had anomalies within the “after penalty” results, most likely due to liquidation problems.
2. We excluded the asymmetric background agent simulations, again because seven of the groups had anomalies within these results, even before penalty. This is most likely a result of not testing these cases extensively before the competition, as they were not provided until just before the competition.

Based on data from the competition, these two issues of effective liquidation and profitability under an asymmetric background, are the most important to be addressed. A more aggressive liquidation algorithm is needed to deal with the first issue. Extensive

testing and modification of our strategy to identify and react to an asymmetric background case would address the second issue.

To identify the asymmetric case, we could, for a set period of time, analyze the current price and, if trending up or down, determine which asymmetric background agent is in place. Following this, we could adjust our bid/ask spread accordingly.

Some of the positive results we found for our strategy (based on results before penalty):

- The highest average value and a competitive Sharpe Ratio when run along with the given strategies and the symmetric background agent. (See Exhibit V)
- By far the best Sharpe Ratio when run using historical data. (See Exhibit VI)
- A positive and somewhat competitive value when run along with all the other groups strategies. (See Exhibit VII)

Overall, we have a somewhat un-impressive Sharpe Ratio of 0.74, but are somewhat close to the highest Sharpe Ratio of 0.85. Our second highest average value of \$4436 is 40% greater than the two strategies with higher Sharpe Ratios, but 33% less than that of the leader in this category, who had the fourth highest Sharpe Ratio, at 0.68 (See Exhibit VIII). In a less risk-averse assessment (based more on average gain and less on volatility) the latter of these strategies along with our strategy, would be higher valued than the other strategies.

Improving the Simulator for Second Semester

Our ability to improve the simulator for second semester was severely limited by PLAT not being operational for a good part of the semester. So while we thought of ways to improve it throughout the semester, the actual coding could not take place until slightly before the competition. There were two areas which we wanted to improve: the liquidation and dealing with the asymmetric agent.

The liquidation turned out to be more difficult than initially expected. This is because of the provided code and the way the system worked, not because of a lack of ideas on how to liquidate. The first idea was to modify the value of the “liquidation” variable given in the code. Its default value was around 180. After running simulations with it changed to 50 and 400, it turns out that this variable controls how fast the liquidation occurs. For example, the position was cleared at 3:46 pm with liquidation equal to 400 and at 3:38 with it equal to 50. The problem is what occurred after these times. Though the position was cleared, the program continued to buy stock. By the end of the liquidation period, liquidation equal to 400 had bought 26,273 shares and liquidation equal to 50 had bought 61,500 shares. We also tried to implement a liquidation strategy that sells all of its position at once, but we came across the same problem of it continuing to buy/sell stock after it reached a share position of zero. Because of the limited time, we were not able to diagnose why it was doing this or what part of the code made it continue to buy stock, since there wasn’t any code in the liquidation section that made it behave this way.

The other aspect was handling the asymmetric agent. Though the idea we had was solid, again implementing it took longer than expected and we were unable to implement it in time for the final competition. The basic idea is to monitor the stock price for the first forty-five minutes and see if it is behaving in an asymmetric way. If it is, the strategy stops the modified market-maker strategy and buys/shorts a large amount of stock, depending on the direction of the stock price. It then clears its position at the end of the day, making a good profit. Code for this strategy is included in Exhibit IX.

Conclusion

The market making strategy is a very profitable strategy, though it does not always give a strong Sharpe Ratio. After doing extensive analysis of the first competition (see Exhibits the below), we were very pleased that our custom day-trading strategy was so successful in the areas we planned for. It was unfortunate that the PLAT server was down for a significant part of the second semester, however this allowed us to explore real-world day trading strategies which have a good possibility of being successful. This project has been very fun and interesting, and we plan on doing more testing and implementing the improvements mentioned above to our custom strategy before the competition now that PLAT is working again.

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Exhibit I: Comparison of given basic strategies:

Exhibit Comparison of strategies

	ds	ra	vsra	ra	vsb	df	ra	vsro	df	ra	vsis	df	ra	vsrn	df
	1	(404)	(169)	43	(325)	1372	(252)	(301)	353	(318)	(337)	(81)	(278)	216	(352)
ra	3	(382)	(152)	53	(1084)	1242	(210)	(467)	283	(423)	272	(63)	(316)	(836)	(365)
	9	(223)	(153)	61	(728)	637	(212)	(523)	732	(512)	(154)	(441)	(414)	(378)	(304)
	aq	(184)	(498)	(367)	319	(657)	(667)	(319)	(651)	(465)	(431)	(718)	(314)	(462)	(712)
	db	vsra	df	db	vsb		db	vsro	df	db	vsis	df	db	vsrn	df
	1	(325)	43	(372)	37	(99)	(319)	214	(213)	(1344)	223	(262)	(94)	(215)	(381)
db	3	(1084)	53	(1242)	(316)	(102)	(668)	(314)	(423)	(66)	(327)	(473)	(1734)	(542)	(1306)
	9	(728)	61	(637)	(705)	(428)	(2257)	(637)	(2424)	(668)	(63)	(651)	(337)	(534)	(1494)
	aq	(657)	319	(667)	(213)	(738)	(267)	(1083)	(318)	(185)	(122)	(54)	(154)	(92)	(541)
	ro	vsra	df	ro	vsb	df	ro	vsro		ro	vsis	df	ro	vsrn	df
	1	(301)	(252)	(375)	214	(318)	213	218	(43)	(65)	(31)	(167)	(44)	(195)	
ro	3	(467)	(210)	(283)	(314)	(338)	423	(312)	(308)	(57)	(36)	(24)	(82)	(31)	(167)
	9	(523)	(212)	(732)	(637)	(2157)	2424	(314)	(66)	(332)	(314)	(32)	(414)	(316)	(122)
	aq	(651)	(319)	(465)	(319)	(1083)	(185)	(316)	(224)	(277)	(45)	(32)	(31)	(34)	(133)
	is	vsra	df	is	vsb	df	is	vsro	df	is	vsis		is	vsrn	df
	1	(317)	(318)	81	223	(1344)	2123	(65)	(431)	317	37	(15)	(132)	(36)	(45)
is	3	272	(423)	(63)	(31)	(66)	973	(368)	(63)	213	(312)	(26)	(116)	(21)	(136)
	9	(154)	(312)	(441)	(63)	(66)	(31)	(734)	(332)	(33)	217	(154)	(67)	(41)	(133)
	aq	(718)	(431)	(314)	(41)	(122)	(154)	(32)	(45)	(312)	(15)	(31)	(67)	(67)	(132)
	rn	vsra	df	rn	vsb	df	rn	vsro	df	rn	vsis	df	rn	vsrn	
	1	(216)	(278)	(352)	(215)	(314)	(163)	(44)	(167)	193	(36)	(132)	(4)	(45)	(42)
rn	3	(636)	(316)	(952)	(1734)	(1306)	(314)	(852)	(167)	(21)	(116)	(136)	(45)	(43)	
	9	(378)	(414)	(1384)	(534)	(337)	(414)	(316)	(414)	(22)	(41)	(67)	(131)	(43)	
	aq	(712)	(462)	(274)	(321)	(923)	(541)	(315)	(34)	(133)	(47)	(67)	(133)	(43)	(45)

Exhibit II: the stock ticker, its closing price on the day that it made its big move, the percentage it lost or gained, and then its stock movement over the next two days and a week later.

Big One-Day Gainers and Losers

chose top gainer and loser, then the 2nd and 3rd highest as long as price > \$5 and volume > 100k; had to be at least one from NYSE and Nq if possible

Date (printed in WSJ one day later)	Company (WSJ name)	Exchange	Ticker	Day's Close	Percent +/-	open	high	low	close	open	high	low	close	price	week's high	week's low		
31-Jan	Aviall N	AVL	28.81	21.6	1-Feb	28.81	28.84	27.68	28.19	2-Feb	27.65	29.45	26.7	29.32	7-Feb	29.78	30.4	26.7
	NovenPhai Nq	NOVN	18.22	18.3		18.4	18.45	17.66	17.76		17.85	18.05	17.55	17.96		17.86	18.45	16.42
	IntrikElctr Nq	LINK	8.41	13.6		8.5	8.52	7.85	8.04		7.85	8.3	7.7	7.7		7.82	8.52	7.44
	Sirva N	SIR	8.86	-38.5		8.86	9.17	7.78	8		8.06	9.11	7.85	9.02		9.21	9.58	7.78
	MS GibOp N		11.95	-9.1														
1-Feb	Santarus Nq	SNTS	6.36	-8.9		6.35	6.78	6.35	6.7		6.6	7.24	6.6	7.17		7.64	8.15	6.35
	DanlsnHdq A	DHC	10.2	24.8	2-Feb	10.15	11.94	9.9	11.7	3-Feb	11.7	14.25	11.7	12.78	8-Feb	13.12	14.25	9.9
	AlincSang N	AGI	11.64	18.8		11.84	11.86	11.13	11.23		11.24	11.37	10.92	11.01		11.32	11.86	10.92
	CTMolecir Nq	CTMI	17.36	17.9		17.28	17.59	16.62	16.96		16.9	17.76	16.65	17.61		18	18.95	16.62
	Arba Nq	ARBA	9.38	-32.4		9.43	9.79	9.25	9.64		9.62	9.72	9.39	9.68		8.04	9.9	7.69
2-Feb	DscrvYLbs Nq	DSCO	6.07	-22.1		6.03	6.23	5.92	6.17		6.2	6.2	5.99	6.1		5.9	6.29	5.79
	ManPower N	MAN	43.36	-10.9		44.45	45.33	44.25	44.6		44.45	44.45	43.51	43.86		44.9	45.33	43.51
	Accelr8Tct A	AXK	2.64	32	3-Feb	2.95	3.35	2.7	2.92	4-Feb	3	3.1	3	3	9-Feb	2.49	3.35	2.4
	Myogen Nq	MYOG	9	27.3		7.22	7.66	6.97	7.08		7.14	7.3	6.9	6.9		7.95	8.04	6.9
	NewRvrPh Nq	NRPH	30.1	19.8		30.4	32.11	30.36	31		30.98	31.99	30.77	30.99		29.99	32.11	28.25
3-Feb	Candela Nq	CLZR	9.6	-20.7		9.62	9.62	9.15	9.15		9.13	9.42	9.06	9.37		9.18	9.87	9.06
	HaggarCp Nq	HGGR	18.78	-15.5		18.25	19.2	18.25	19		19	19.03	18.34	18.91		18.99	19.2	18.14
	AlamoGp N	ALG	23.6	-8.8		23.61	25.65	23.61	25.95		25.49	25.73	25.19	25.69		25.5	25.75	23.61
	Cyberonics Nq	CYBX	39.01	-42	4-Feb	38.44	40.33	38.16	38.78	7-Feb	39.91	40.94	38.88	39.35	10-Feb	43.36	45.03	35.8
	WPT Ent Nq	WPTE	16.87	29.7		16.59	16.66	15.38	16.14		16.1	16.1	15.02	15.71		17.5	17.86	15.02
4-Feb	CarMax Nq	KMX	33.35	12.9		33.44	34.13	32.66	33.05		33.1	33.35	32.48	32.6		32.5	34.13	32.4
	USConcret Nq	RMIX	6.6	-24.1		6.71	6.71	5.75	5.95		6.05	6.27	5.95	6.18		6.46	6.27	5.75
	Myogen Nq	MYOG	7.08	-21.3		7.14	7.3	6.9	6.9		7	7.39	7	7.39		8.09	8.35	6.9
	Garter N		9.41	-17.9														
	Gurunet A	GRU	22.98	35.8	7-Feb	25.7	28.5	22.81	26.45	8-Feb	25.75	25.75	20	20.51	11-Feb	21.19	28.5	18.25
7-Feb	PegasCom Nq	PGTV	15.12	24.8		15	15.76	14.5	15.32		15.27	16.7	14.6	15.08		13.81	15.76	13
	TempInlan N	TIN	75.75	16.4		78	78.85	75.49	75.75		76.5	77.19	75.77	76.75		74.5	78.85	75.94
	HrsIntrctv Nq	HPOL	5.18	-27.7		5.3	5.3	5.09	5.19		5.24	5.25	5.13	5.17		4.99	5.3	4.97
	Shoppng.co Nq	SHOP	18.94	-16.4		19.01	19.2	18.5	18.89		18.98	19	17.63	18.1		17.75	19.2	16.08
	Alliance		12.04	-12.4														
7-Feb	IbisTch Nq	IBIS	3.97	41.8	8-Feb	4.05	4.14	3.42	3.43	9-Feb	3.35	3.53	3.08	3.1	14-Feb	3.57	4.14	3.03
	RealNtwks Nq	RNWK	6.83	20.7		6.77	6.89	6.63	6.68		6.95	6.98	6.57	6.6		6.08	7.08	6.55
	OshBG A Nq	GOSHA	27.63	20.4		25.85	27.47	25.69	26.19		25.8	27.44	25.78	26.93		27.25	27.39	25.4
	RofinSinar Nq	RSTI	34.8	-17.4		36.03	37.89	35.55	36.64		37.43	37.43	35.04	35.1		36.99	37.89	35.04
	Synaptics Nq	SYNA	33.3	-15.8		33.8	34.88	33.13	33.31		32.29	32.53	25.47	25.88		23.15	23.25	21.5
QwestCom N	Q	4.39	-9.5		4.35	4.47	4.22	4.38		4.48	4.48	4.24	4.28		3.98	4.1	3.74	

Exhibit III: analysis of above data

Ticker	ONE DAY LATER				TWO DAYS LATER		ONE WEEK LATER		ONE WEEK USING CLOSING PR			
	*all numbers are percentages											
	increase from opening to high price	same but just for gainers	decrease same but for losers	decrease from opening to low price	same but just for losers	increase from first day's opening price to second day's high	increase from week's opening price to week's high	decrease from week's opening price to week's low	same but just for losers	from closing price to max during week	same but just for gainers	
31-Jan AVL	0.104			3.922		2.221	5.519	7.324		5.519		
NOVN	0.272			4.022		-1.902	0.272	10.761		1.262		
LINK	0.235			7.647		-2.353	0.235	12.471		1.308		
SIR	3.499			12.19		2.822	8.126	12.19		8.126		
SNTS	6.772			0		14.016	28.346	0		28.145		
1-Feb DHC	17.635			2.463		40.394	40.394	2.463		39.706		
AGI	0.169			5.997		-3.97	0.169	7.77		0.169		
CTMI	1.794			3.819		2.778	9.664	3.819		9.159		
ARBA	3.818			1.909		3.075	4.984	18.452		5.544		
DSCO	3.317			1.824		2.819	4.312	3.98		3.624		
MAN	1.98			0.45		0	1.98	2.115		4.543		
2-Feb AXK	13.559			8.475		5.085	13.559	18.644		26.894		
MYOG	6.094			3.463		1.108	11.357	4.432		-10.667		
NRPH	5.625			0.132		5.23	5.625	7.072		6.678		
CLZR	0			4.886		-2.079	2.599	5.821		2.813		
HGGR	5.205			0		4.274	5.205	0.603		2.236		
ALG	8.64			0		8.979	9.064	0		9.11		
3-Feb CYBX	4.917			0.728		6.243	17.144	6.868		15.432		
WPTE	0.422			7.294		-2.954	7.655	9.464		5.868		
KMX	2.063			2.333		-0.269	2.063	3.11		2.339		
RMIX	0			14.307		-6.557	-6.557	14.307		-5		
MYOG	2.241			3.361		3.501	16.947	3.361		17.938		
4-Feb GRU	10.895			11.245		0.195	10.895	28.988		24.021		
PGTV	5.067			3.333		4.667	5.067	13.333		4.233		
TIN	1.09			3.218		-1.038	1.09	2.641		4.092		
HPOL	0			3.962		-0.943	0	6.226		2.317		
SHOP	0.999			2.683		-0.053	0.999	15.413		1.373		
7-Feb IBIS	2.222			15.556		-12.84	2.222	25.185		4.282		
RNWK	1.773			2.068		3.102	4.579	3.25		3.66		
GOSHA	6.267			0.619		6.151	5.957	1.741		-0.869		
RSTI	5.162			1.332		3.886	5.162	2.748		8.879		
SYNA	3.195			1.982		-3.757	-31.213	36.391		-30.18		
Q	2.759			2.989		2.989	-5.747	14.023		-6.606		
Average	3.87242424	4.455722	4.2774	4.188152	3.458333		5.687061	7.970333	9.241394	9.042	5.937818	7.949222

Exhibit IV: amount MSFT would increase/decrease before it crossed its opening price

Amount MSFT increased / decreased before it crossed its opening price

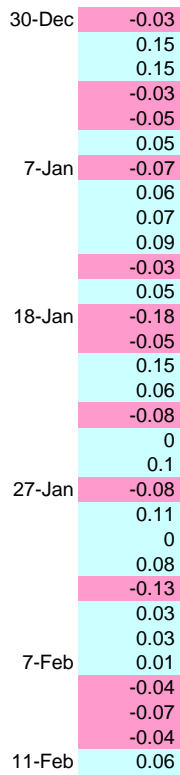
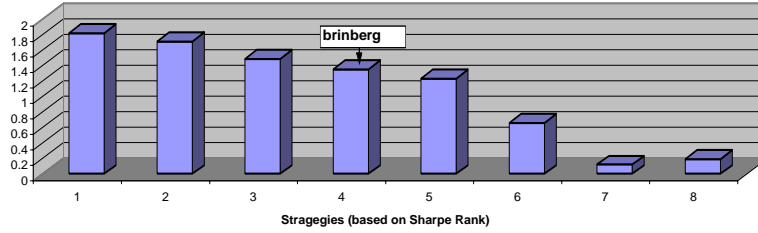


Exhibit V: Our strategy when run along with the given strategies:

Value of group's stratgy (before penalty), ran with syetric background agent and:	jung	hashmi	kumar	brinberg	kanon	veal	sohn	ricketts
Channel Breakouts (CB)	625	906	319	1384	2607	-402	1568	93
Moving Averagen (MA)	1330	1072	373	1398	1145	785	1203	-13
Market Maker (MM)	1353	510	257	1514	-204	894	0	319
Momentum (MO)	424	1127	461	1306	2967	544	2130	-358
Realitive Stregnth Index (RSI)	691	731	403	383	364	-32	-6284	84
another copy of Groups Strategy	690	637	35	683	1854	210	0	0
CB, MA, MM, MO, RSI	257	2328	10	3814	1162	128	4116	149
Average	767.1428571	1044.428571	265.4285714	1497.428571	1413.571429	303.8571429	390.4285714	39.14285714
Average Rank (out of 8)	4	3	7	1	2	6	5	8
Average value relative to brinberg's	51%	70%	18%	100%	94%	20%	26%	3%
Standard Deviation	422.2919324	608.8439475	177.9642821	1105.397343	1146.36714	463.3581871	3261.02754	207.072796
Sharpe Ratio	1.816617364	1.715429012	1.491471031	1.354651864	1.233087882	0.655771607	0.119725628	0.189029452
Sharpe Rank (out of 8)	1	2	3	4	5	6	7	8
Sharpe relative to brinberg's	1.341021566	1.266324624	1.100999505	1	0.910261828	0.484088661	0.088381105	0.139540982

Sharpe Ratio



Value

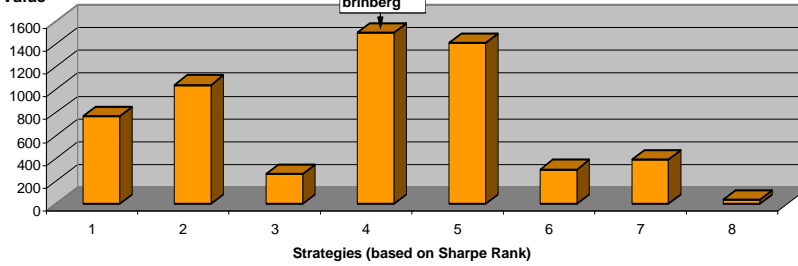


Exhibit VI: Our strategy when run along with the historical background agent:

Value of group's stratgy (before penalty), ran with real background agent:	brinberg	sohn	kanon	jung	hashmi	veal	ricketts	kumar
REALBG_dell	6611	9220	7462	8645	10968	6693	3727	2778
REALBG_msft	7783	6444	15487	17857	26525	15158	25127	2792
REALBG_yhoo	8438	5455	13930	12473	16950	8524	14639	-1478
Average	7,610.67	7,039.67	12,293.00	12,991.67	18,147.67	10,125.00	14,497.67	1,364.00
Average Rank (out of 8)	6	7	4	3	1	5	2	8
Average value relative to brinberg's	100%	92%	162%	171%	238%	133%	190%	18%
Standard Deviation	925.61133	1951.90172	4255.582569	4627.85018	7847.34773	4453.81376	10700.7	2461.25415
Sharpe Ratio	8.2223136	3.60656819	2.88867618	2.80727901	2.31258602	2.2733326	1.35483348	0.55418901
Sharpe Rank (out of 8)	1	2	3	4	5	6	7	8
Sharpe relative to brinberg's	100%	44%	35%	34%	28%	28%	16%	7%

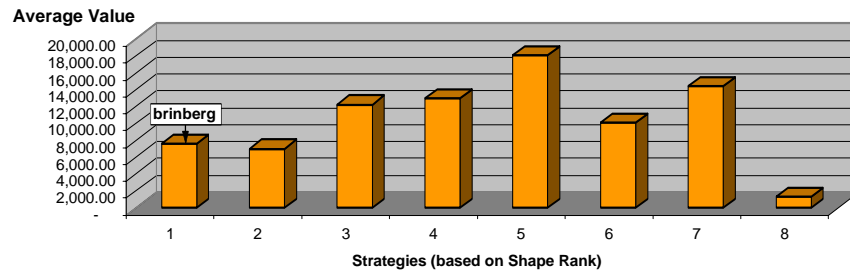
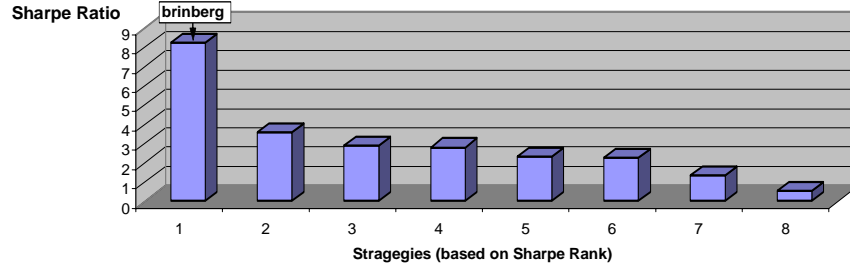


Exhibit VII: Our strategy when run along with the other groups' strategies:

Value of group's stratgy (before penalty), ran with symmetric background agent and:	kumar	ricketts	brinberg	veal	hashmi	jung	sohn	kanon
All other group's strategies	399	341	72	8	0	-9	-300	-652
rank	1	2	3	4	5	6	7	8
Value relative to brinberg's	5.54	4.74	1.00	0.11	-	(0.13)	(4.17)	(9.06)

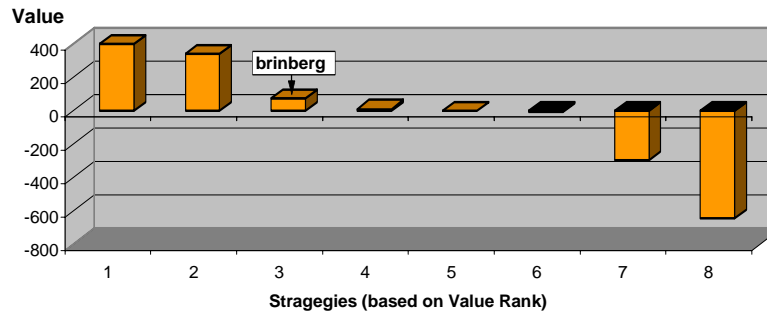
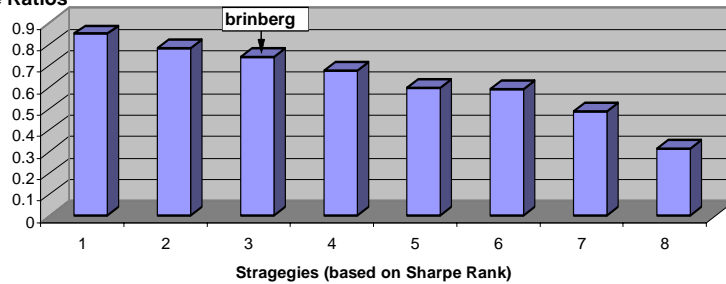


Exhibit VIII: Overall Performance:

Value of group's strategy (before penalty), ran with:	hashmi	jung	brinberg	kanon	veal	kumar	sohn	ricketts
Symetric BG, Channel Breakouts (CB)	906	625	1384	2607	-402	319	1568	93
Symetric BG, Moving Averagen (MA)	1072	1330	1398	1145	785	373	1203	-13
Symetric BG, Market Maker (MM)	510	1353	1514	-204	894	257	0	319
Symetric BG, Momentum (MO)	1127	424	1306	2967	544	461	2130	-358
Symetric BG, Realitive Stregnth Index (RSI)	731	691	383	364	-32	403	-6284	84
Symetric BG, another copy of Groups Strategy	637	690	683	1854	210	35	0	0
Symetric BG, CB, MA, MM, MO, RSI	2328	257	3814	1162	128	10	4116	149
Symetric BG, all groups' strategies	0	72	-652	399	341	-9	-300	8
REALBG_dell	9220	6611	8645	10968	6693	7462	3727	2778
REALBG_msft	6444	7783	17857	26525	15158	15487	25127	2792
REALBG_yhoo	5455	8438	12473	16950	8524	13930	14639	-1478
Average Value	2584.55	2570.36	4436.82	5885.18	2985.73	3520.73	4175.09	397.64
Average Rank (out of 8)	6	7	2	1	5	4	3	8
Average value relative to brinberg's	58%	58%	100%	133%	67%	79%	94%	9%
Standard Deviation	3044.206	3286.343	5967.394	8673.048	5012.089	5949	8560.225	1273.807
Sharpe Ratio	0.849005	0.782135	0.74351	0.67856	0.595705	0.591818	0.487731	0.312164
Sharpe Rank (out of 8)	1	2	3	4	5	6	7	8
Sharpe relative to brinberg's	114%	105%	100%	91%	80%	80%	66%	42%

Sharpe Ratios



Average Value

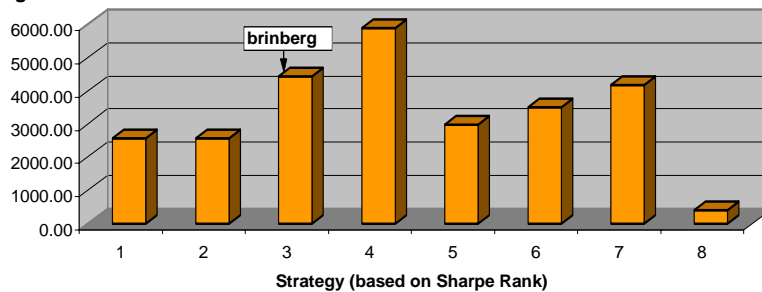


Exhibit IX: Asymmetric trial code

```

if (currentTime> 34210 && do_once==0){
    opening_price = getSimLastPrice(mState);
    do_once=1;
}

```

```

//checking to see if it's assymetric between 9:30 and 10:15
if (currentTime>34200 && currentTime<36900){
    if (getSimLastPrice(mState) > opening_price) num_higher++;
    else if (getSimLastPrice(mState) < opening_price) num_lower++;
}

```



```

    printf("\nopening price = %d  currentPrice = %d\n", opening_price,
getSimLastPrice(mState));
    printf("\n\n num_higher = %d  num_lower = %d \n\n", num_higher, num_lower);
}

//change is_a_agent to 1 if necessary
if(currentTime>36900 && do_once2 ==0){

    printf("\n\n checking to see if is_a_agent\n\n");
    if (num_higher > num_lower && num_higher/num_lower>4){
        is_a_agent=1;
        buyOrder(getSimLastPrice(mState), 10000, cState, mState);
        printf("\nyes it's incr asym with high = %d and low = %d\n\n", num_higher,
num_lower);

    }
    else if(num_lower>num_higher && num_lower/num_higher >4){
        is_a_agent=1;
        sellOrder(getSimLastPrice(mState), 10000, cState, mState);
        printf("\nyes it's decr asym with low = %d and high = %d\n\n", num_lower,
num_higher);
    }
    do_once2=1;
}
//given code
if(currentTime<55800 && is_a_agent==0)

```