COMP 4971C – Independent Study (Summer 2016)

DEVELOPMENT AND ANALYSIS OF A TRADING ALGORITHM USING CANDLESTICK PATTERNS

By

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Development and Analysis of a Trading Algorithm using Candlestick Patterns

ABSTRACT

A custom algorithm was developed to analyse a candlestick chart patterns and colour code the candlesticks based on candlestick reversal patterns and price fluctuations. The colour codes were then used to set a buy or sell signal. The parameters of the custom algorithm were optimised with respect to the Buy & Hold strategy. The results of the algorithm were then tested against commonly used technical trading indicators such as 14-25 Moving Average and the 70-30 Relative Strength Indicator. Results indicate that the custom algorithm conforms with the financial theory of Risk/Return Trade-off. Moreover, the performance of the custom algorithm is on average better than the Buy & Hold strategy, and the commonly used technical trading indicators like the Moving Average and the Relative Strength Index.

INTRODUCTION

The purpose of this project was to analyse any given candlestick chart and to set a buy and sell order. This is done to provide an alternative method to the Buy & Hold Investment strategy. The Custom Algorithm (CA) was optimized with respect to the Buy and Hold (BH) and then compared with the results from already existing technical trading indicators such as the Moving Average (MA), and Relative Strength Index (RSI) methods.

Assumptions

1. All values mentioned in this report are quoted in USD.
2. The initial amount for investment in each scenario was $100,000.00.
3. The trading cost per trade was set at $10.00.
4. The applicability of this strategy is only tested for a short-term investment with a 1-year interval for 8 years. A short-term investment is assumed to be either:
    a. An investor puts in $100,000.00 at the beginning of a 1-year interval and then takes out the money at the end of the 1-year interval.
    b. The investor puts in $100,000.00 at the beginning and at the end of every 1-year interval, they make a decision to stay in and continue or to end the investment. If decided to stay, the value of $100,000.00 initial investment has to be matched for every 1-year interval by taking off or putting money into the investment.
5. The CA was tested against the benchmark BH and technical trading indicators (MA and RSI) only. The benchmark and technical trading indicators are good baseline to test the effectiveness of the CA outputs.
6. The MA [1] uses a 14-day and 25-day moving average crossings as an indicator to buy or sell trades. 14 and 25 are commonly used short term moving averages.

7. The RSI [2] uses a 70 and 30 as the limits beyond which an indicator is set to buy or sell trades.

For the purpose of this project, 9 Exchange Traded Funds (ETFs) were picked representing the various existing markets and their types. The following is the list, (Table 1), of ETFs picked for this project.

Table 1: List of ETFs chosen for this project

REGION	ETF (Country)	Description
ASIA	EWH (Hong Kong)	Home country
	EPI (India)	Developing country
	EWJ (Japan)	Developed country
EUROPE	EWG (Germany)	Developed country
	EWU (United Kingdom)	Developed country
	VGK	All European markets combined
AMERICA	SPY (S&P 500)	Top 500 American stocks
	VTI (All America)	Developed country (Largest market)
EMERGING	VWO	All Emerging markets combined

PROCESS FLOW

This project utilized the following steps in the following order (Figure 1).

1. Get data for all ETFs – manually done for this project; can be automated.
2. Colour code the candlestick chart
3. Set buy or sell signals. Also perform BH, MA, and RSI trading strategy in the same time horizon
4. Compare the results.

At first, all the relevant data was downloaded manually from Yahoo Finance. Then the candlestick chart was plotted with colour coding representing the trends. The changing colour codes (trends) was done using candlestick reversal patterns and price deviations from the standard deviations (SD). Once the candlestick was plotted with colour codes, the buy and sell order was then placed at trend changing locations defined by a specific combination of colour codes. Next, the same set of data was taken and a BH strategy was implemented. The BH strategy was the benchmark to test the CA. Moreover, to test the effectiveness of the CA, the MA and RSI methods were also implemented. In the end, the CA was optimised with respect to BH and compared to the MA and RSI to test its effectiveness.

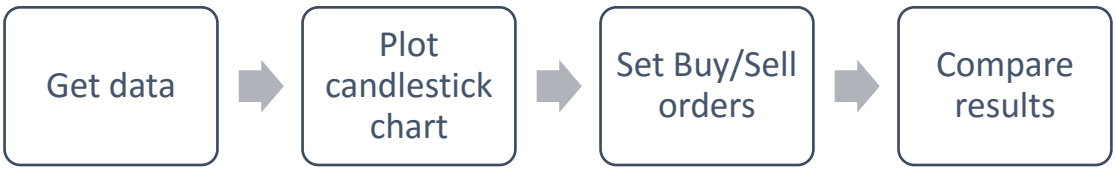


Figure 1: Process flow of the steps involved in the project

GETTING DATA

The data for all the ETFs were downloaded from Yahoo Finance. Data can be directly utilized from Yahoo Finance Chart API links [3]. But for the reasons of very large number of requests, constant internet connection, and running time for the research aspect of this project, direct utilization of data from Chart API was not used in this project. Instead, the data was downloaded beforehand (as a .csv file). Since the data was downloaded from the Yahoo Finance, the data had a set time frame. Based on the available data for each of the ETFs, an 8-year data set was found to be the largest common data range. Hence, the data ranges from 26th July 2008 to 25th July 2016.

Assumptions

1. A 1-year time horizon consists of 252 trading days [4] (accounting for holidays).
2. An 8 x 1-year interval was chosen based on the ETFs used for this project.
3. This project used daily data for the actual trading days only.

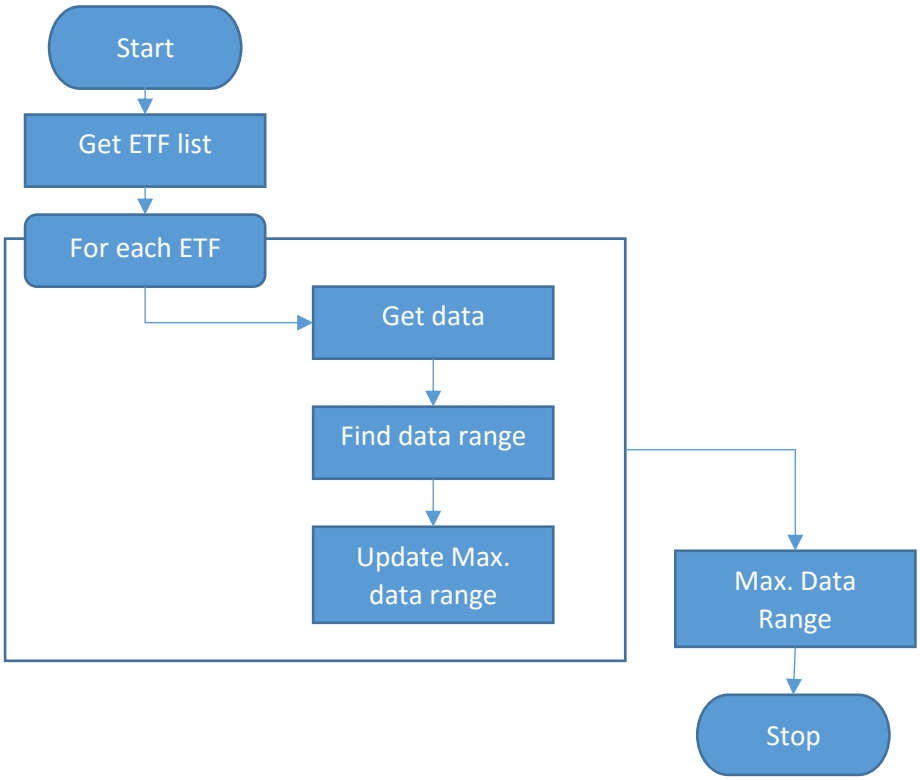


Figure 2: Flowchart for obtaining data and finding maximum common data range

COLOUR CODING THE CANDLESTICK CHART

A candlestick chart was used to plot the data obtained for each ETF. The candlestick chart was a convenient way to display the comprehensive information about the price of an instrument and how it moved along time. Moreover, candlesticks also have the ability to display reversal patterns [5] that were studied by researchers. These reversal patterns help identify moments of expected change in trends. The candlestick is plotted using 4 points per day: open price, close price, high price and low price.

The candlestick chart is colour coded to indicate the trend and performance of the prices. The following colour codes are being used in the candlestick charting.

1. A solid fill candlestick – The closing price is higher than the opening price
2. A transparent fill candlestick – The closing price is lower than the opening price
3. Green – Up-trend
4. Red – Down-trend
5. Yellow – Sideways movement or closing price within ± (multiplier*SD)

The following (Table 2) lists the candlestick reversal patterns [5] along with all their accepted variations were used in this project:

Table 2: Candlestick Reversal Patterns used in this project

Bearish Pattern	Bullish Pattern
Hanging Man	Hammer
Shooting Star	Inverted Hammer
Doji (northern)	Doji (southern)
Dark Cloud Cover	Piercing Pattern
Bearish Engulfing	Bullish Engulfing
Bearish Harami	Bullish Harami
Evening Star	Morning Star

Candlestick reversal patterns only indicate a potential change in trend (Green or Red to Yellow). Another indicator was decided to indicate if we should continue with Yellow, Green, or Red depending on the trend. For this, a recent 50-day data was used to compute a SD. When the trend changes from Yellow to Green or Red, Green to Green, or Red to Red, the SD is recomputed. The allowable range of price fluctuations is the closing price of that day plus-minus a multiplier times the SD. The usage of this SD will be mentioned in the following sections of this report.

Assumptions

1. The starting candlestick was set to Yellow colour and was the initial baseline to judge the next candlestick.
2. A 50-day data was used to calculate the SD. 10-day, 21-day, 63-day [6] were also used to find the best number of days to calculate the SD. In the numbers tested, the 50-day SD gave the best results.
3. Since the volatility of each stock was different, to accommodate this fluctuation, a multiplier was introduced to the SD to accommodate the daily price volatility. This project puts a focus on finding the best SD multiplier for each ETF based on a custom algorithm. This algorithm will be discussed in great detail in the following sections.

Colour coding algorithm

The colour coding worked in the following way:

1. Yellow can change to Green, Red, or remain as Yellow.

2. Green can change to Yellow or remain as Green.
3. Red can change to Yellow or remain as Red.
4. Green and Red cannot change colours to each other without changing to Yellow.

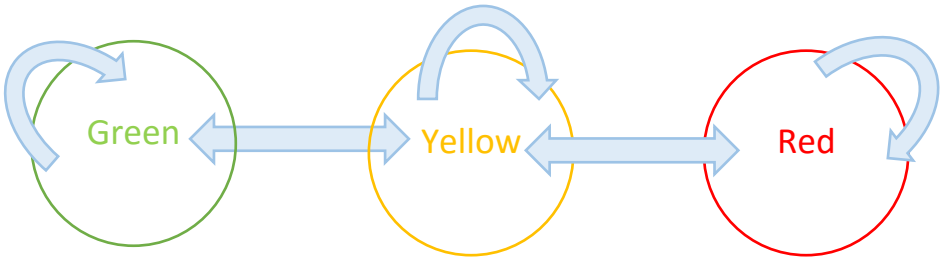


Figure 3: Possible change of colour code directions

The following rules were followed in order to change colours indicated by the above picture (Figure 3). When the SD was recomputed, the closing price of that day is defined as sdClosingPrice. The previous days candlestick colour was define as trendColour.

Yellow to Green

1. currentClosingPrice ≥ sdClosingPrice + (multiplier * SD)

Yellow to Red

1. currentClosingPrice ≤ sdClosingPrice – (multiplier * SD)

Green to Yellow

1. Current candlestick is a Bullish Pattern Reversal
   OR
2. currentClosingPrice ≤ sdClosingPrice – (multiplier * SD)

Red to Yellow

1. Current candlestick is a Bearish Pattern Reversal
   OR
2. currentClosingPrice ≥ sdClosingPrice + (multiplier * SD)

Green to Green

1. Current candlestick is not a pattern reversal
   AND
2. currentClosingPrice ≥ sdClosingPrice – (multiplier * SD)

Red to Red

1. Current candlestick is not a pattern reversal
   AND
2. currentClosingPrice ≤ sdClosingPrice + (multiplier * SD)

The following diagram (Figure 4) illustrates the algorithm. Legends used:- cCP : currentClosingPrice | sdCP : sdClosingPrice | tC : trendColour | y : yellow | g : green | r : red | O/P : output | m(SD) : multiplier * SD.

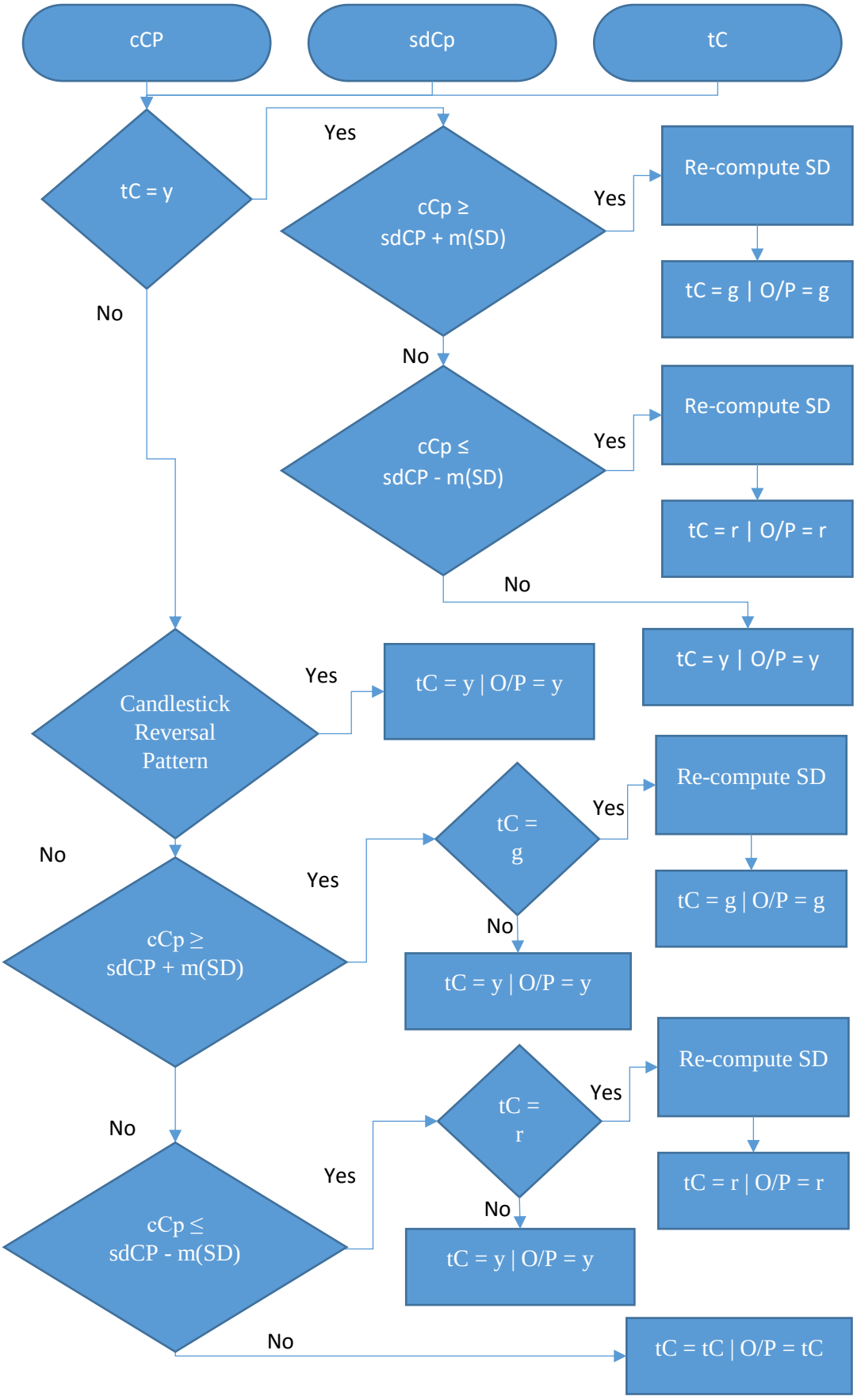


Figure 4: Flowchart for the Colour Changing Algorithm where O/P is the output returned

Setting the Buy and Sell order

Once the candlestick chart was colour coded, the buy and sell order was set up.

Assumptions

1. The very first order has to be a buy order.
2. When a buy order was set, the entire amount-at-hand to spend was spent on purchasing the maximum quantity of ETF at the closing price of that day.
3. When a sell order was set, the entire quantity of ETF purchased was sold at the closing price of that day.
4. Quantities are positive integers only.
5. When a buy order has been set, the next order has to be a sell order. Conversely, when a sell order is set, the next order has to be a buy order.
6. At a buy order, a stop- loss condition was set. For this project, the stop-loss was at 80% of the purchase price. This merely reflects the users risk-aversion level and the value will differ for different investors. The meaning of this was that the price of an equity can fall 20% below its purchase price before the stop-loss order was initiated.

The criteria that decided when to set a buy and sell order is explained in the following points.

1. A buy order was executed when the colour code changed from Red to Yellow, and when the previous signal was sell.
2. A sell order was executed when the colour code changed from Green to Yellow, and when the previous signal was buy.
3. At the very beginning, if the Yellow trend changed to a Green, a buy order was executed.

The order to buy or sell was executed as soon as the colour changed from Green/Red to Yellow and not when the colour changed later from Yellow to Red/Green respectively. This is because the Green/Red to Yellow indicated a pattern reversal. Through such an indicator, the trader/investor was hoping that the pattern indeed changed and the subsequent trend would be opposite to the trend before the pattern reversal. A short-coming of this algorithm is when the trend does not change after the pattern reversal is identified.

Finding the multiplier for the SD

Allowing the price to move within 1 SD of the sdClosingPrice does not take into account the historical volatility of the respective ETFs, and hence may produce undesirable results. To account for the volatility of the respective ETFs, a range of multipliers were used to find the multiplier that maximises the output of the program. The range of multipliers is from 0.0 to 3.0 (both inclusive) at 0.1 intervals.

To find the SD multiplier that produces the maximum output, the Net Asset Value (NAV) was computed for each ETF from the 8 x 1-year intervals for each SD multiplier in the above said range. This lead to a 3-D array of size (31,8,9). 30 was for the number of multiplier that the algorithm has to go through, 8 was the number of yearly intervals

used in this project, and 9 was the number of ETFs used to test the algorithm. In the pythonic language, the array is an numpy.array((31,8,9)). There were four such 3-D arrays, one for each CA, BH, MA, and RSI.

[m1, yr1, ETF1]	[m1, yr1, ETF2]	…	[m1, yr1, ETF9]
[m1, yr2, ETF1]	[m1, yr2, ETF2]	…	[m1, yr2, ETF9]
…	…	…	…
[m1, yr8, ETF1]	[m1, yr8, ETF2]	…	[m1, yr8, ETF9]
[m2, yr1, ETF1]	[m2, yr1, ETF2]	…	[m2, yr1, ETF9]
[m2, yr2, ETF1]	[m2, yr2, ETF2]	…	[m2, yr2, ETF9]
…	…	…	…
[m2, yr8, ETF1]	[m2, yr8, ETF2]	…	[m2, yr8, ETF9]
…	…	…	…
[m31, yr1, ETF1]	[m31, yr1, ETF2]	…	[m31, yr1, ETF9]
[m31, yr2, ETF1]	[m31, yr2, ETF2]	…	[m31, yr2, ETF9]
…	…	…	…
[m31, yr8, ETF1]	[m31, yr8, ETF2]	…	[m31, yr8, ETF9]

Figure 5: Diagram showing a 3D numpy array and the 1D array used for NAV calculations

In the diagram above (Figure 5), 'mX' stands for SD multiplier, 'yrX' stands for which yearly interval, and 'ETFX' stands for the ETFs. Each red circle contains a 1-D array which were used to calculate the NAV for the corresponding ETF for the corresponding SD multiplier.The performance was calculated by using the 1-D array marked by the red circles for each ETFs and for each multiplier for each trading strategy (like CA, BH, MA, RSI) and, the following formula.

Performance = NAV(1-D array of CA) – NAV(1-D array of BH)

The calculation of the difference of the NAV of the CA and BH for each ETFs for each multiplier reduces the 3-D array to a 2-D array of size (31,9). 30 was the number of multipliers and 9 was the number of ETFs. In pythonic language the array is a numpy.array((31,9)). Using the same notation as the above diagram, we have the following representation of the array.

[m1, ETF1]	[m1, ETF2]	…	[m1, ETF9]
[m2, ETF1]	[m2, ETF2]	…	[m2, ETF9]
…	…	…	…
[m31, ETF1]	[m31, ETF2]	…	[m31, ETF9]

Figure 6: Diagram of the 2D array with values of the performance of CA

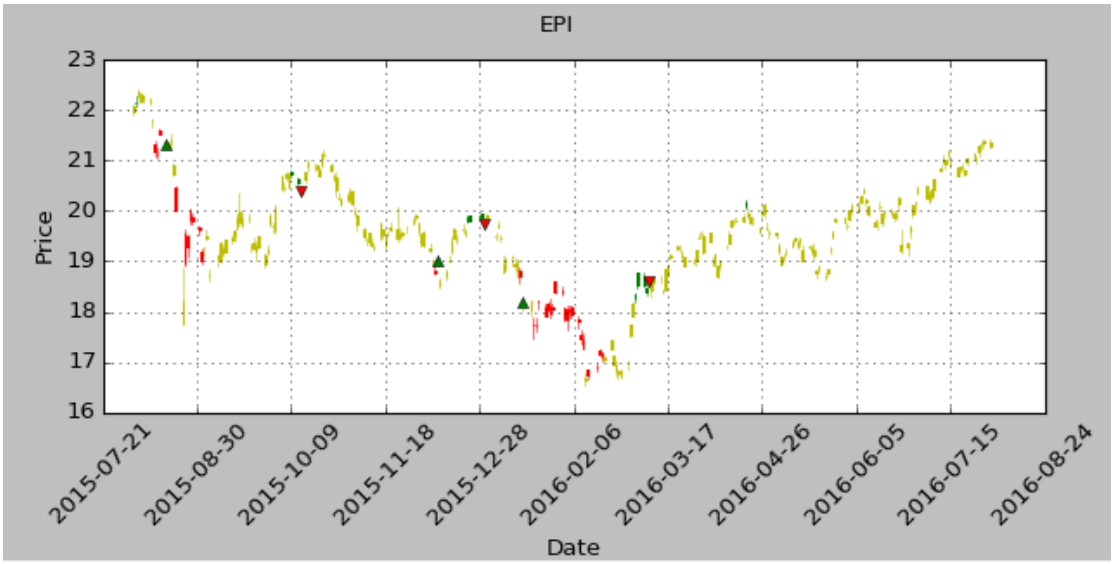
From the given 2-D array (Figure 6), the best outperforming SD multiplier for each ETFs was the SD multiplier that corresponds to the maximum value in each column respectively. Once the best SD multipliers were found for each ETFs, the values were then re-input into the program to give the best performance of the buy and sell signal with respect to the buy and hold strategy.

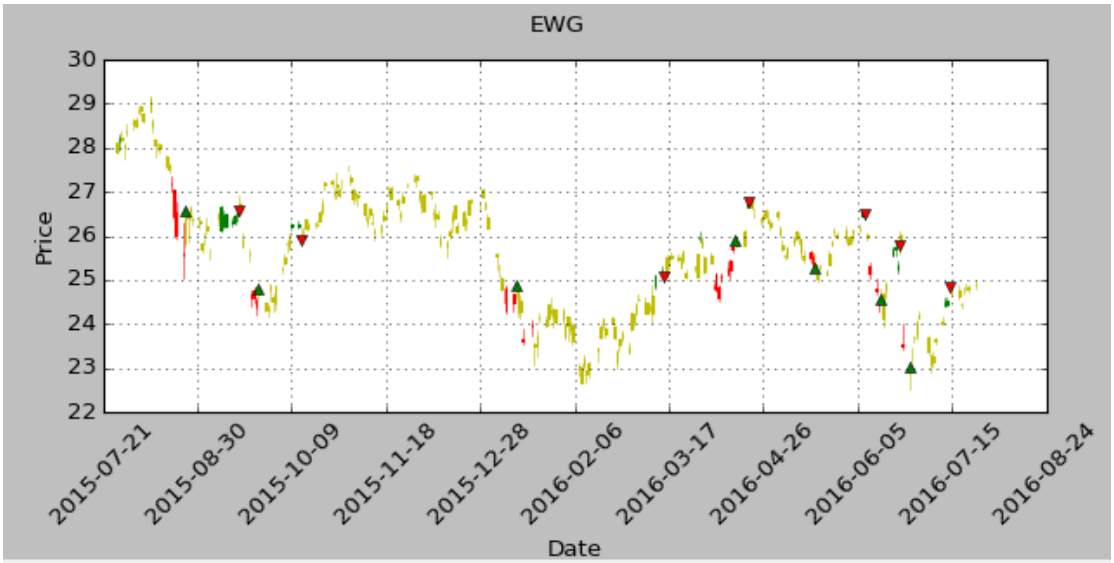
RESULTS

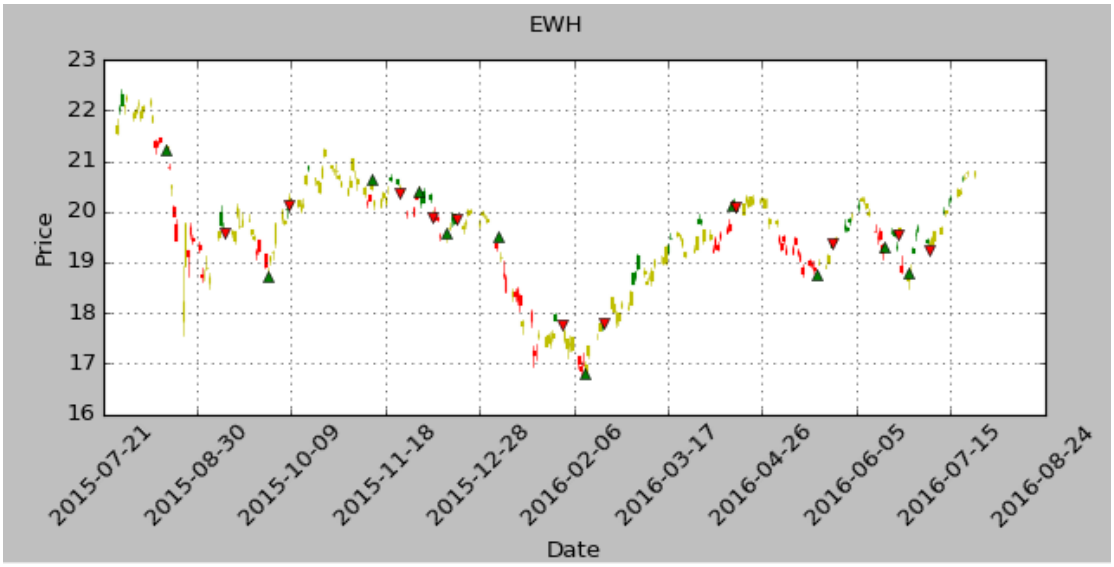
The Custom Algorithm (CA) was optimized for the Buy & Hold (BH) strategy and then compared with two technical trading indicators: Moving Average (MA) and Relative Strength Index (RSI). The performance of CA in the following conclusion is relative to the performance of BH. 100% means the performance of CA equals that of BH (there is no added advantage), lower than 100% indicates lower performance (the investor is better off using a BH strategy), and above 100% indicates higher performance (the investor gains using the CA strategy).

Colour coded candlestick chart

When the above algorithm was used in producing a candlestick chart, the following style of charts was obtained (Figure 7). The graphs have incorporated their best performing SD multiplier and is plotted for a sample 1-year interval (1st 252 data points only; which indicates 1 year of trading dates). The green arrows (up arrow) are indicators of a buy signal, while the red (down arrow) are indicators of a sell signal.






EWH
Price
23
22
21
20
19
18
17
16
2015-07-21
2015-08-30
2015-10-09
2015-11-18
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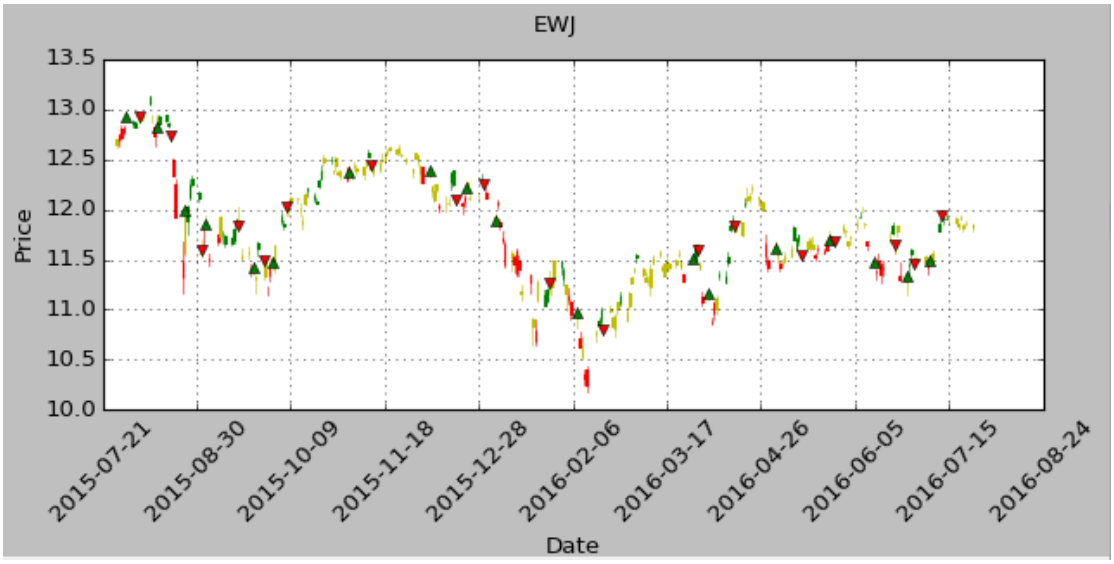
2016-04-26
2016-06-05
2016-07-15
2016-08-24
Date


EWJ
Price
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13.0
12.5
12.0
11.5
11.0
10.5
10.0
2015-07-21
2015-08-30
2015-10-09
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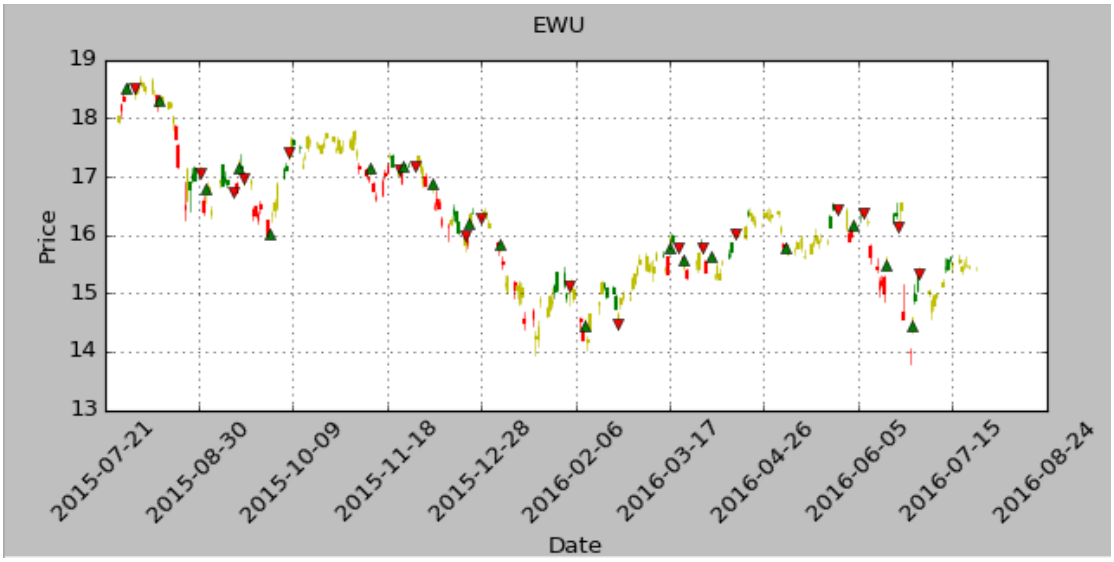
2016-06-05
2016-07-15
2016-08-24
Date


EWU
Price
19
18
17
16
15
14
13
2015-07-21
2015-08-30
2015-10-09
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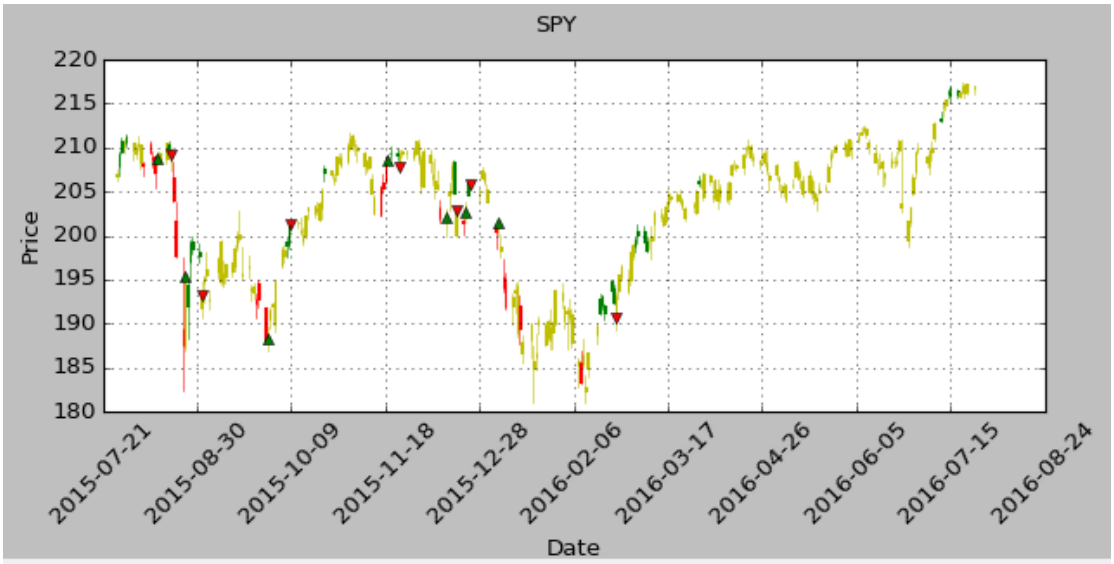
2016-07-15
2016-08-24
Date


SPY
Price
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215
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205
200
195
190
185
180
2015-07-21
2015-08-30
2015-10-09
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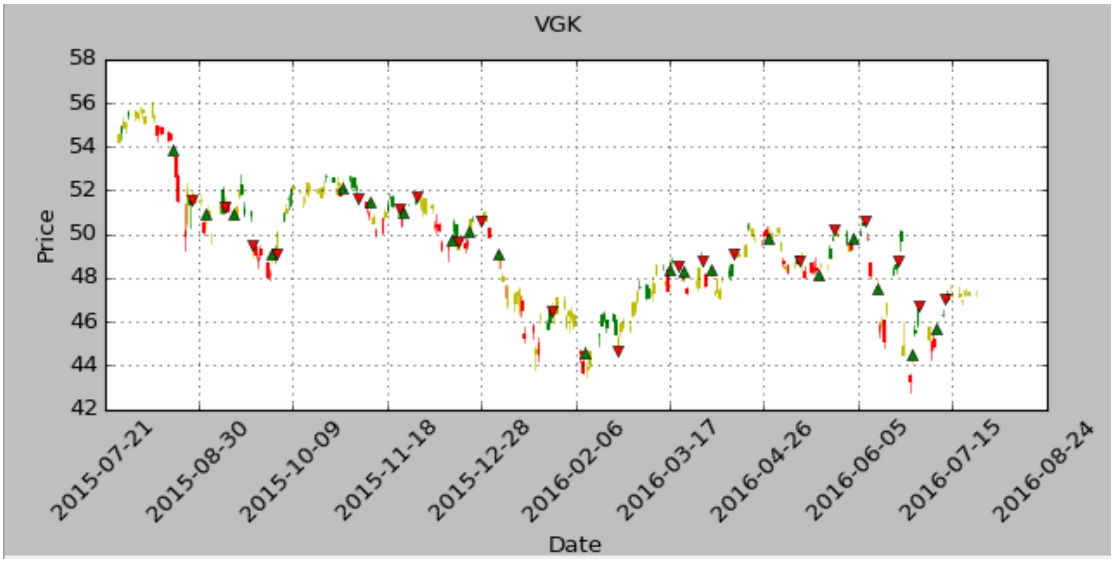
2016-08-24
Date


VGK
Price
58
56
54
52
50
48
46
44
42
2015-07-21
2015-08-30
2015-10-09
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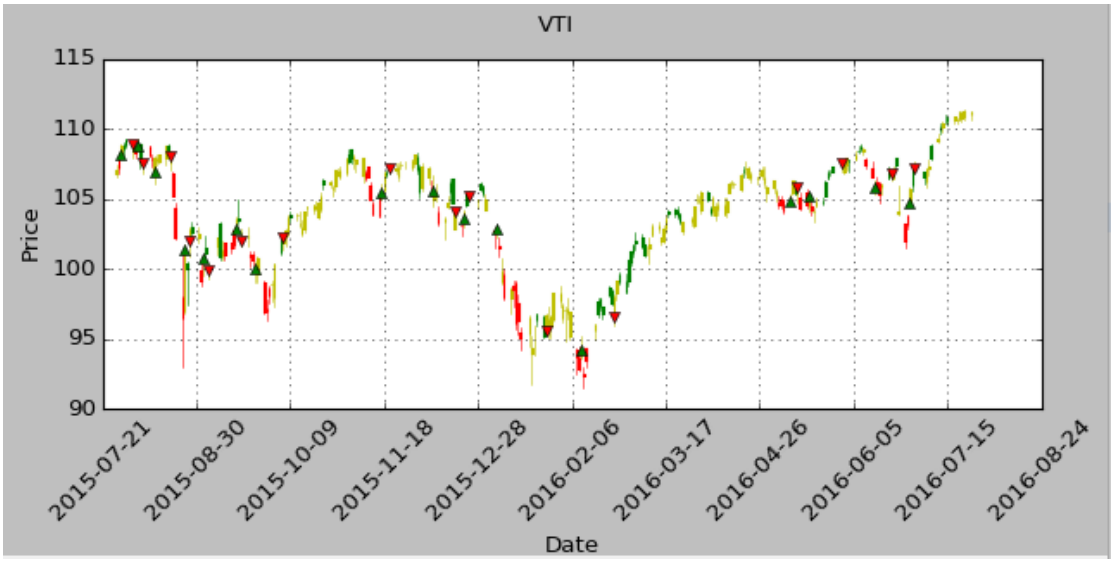
2016-07-15
2016-08-24
Date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Price
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110
105
100
95
90
2015-07-21
2015-08-30
2015-10-09
2015-11-18
2015-12-28
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2016-06-05
2016-07-15
2016-08-24
Date

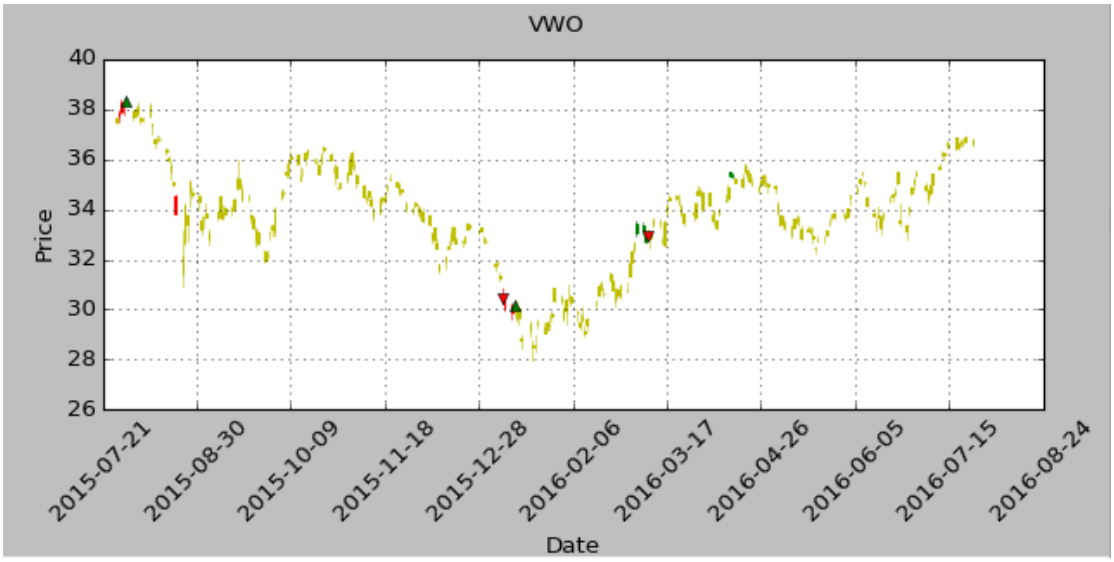


Figure 7: The candlestick charts plotted and incorporating the colour codes

Best Performing SD Multiplier and Outputs of CA

Below (Figure 8) is the plot of the 2-D array to find the best performing SD Multiplier.

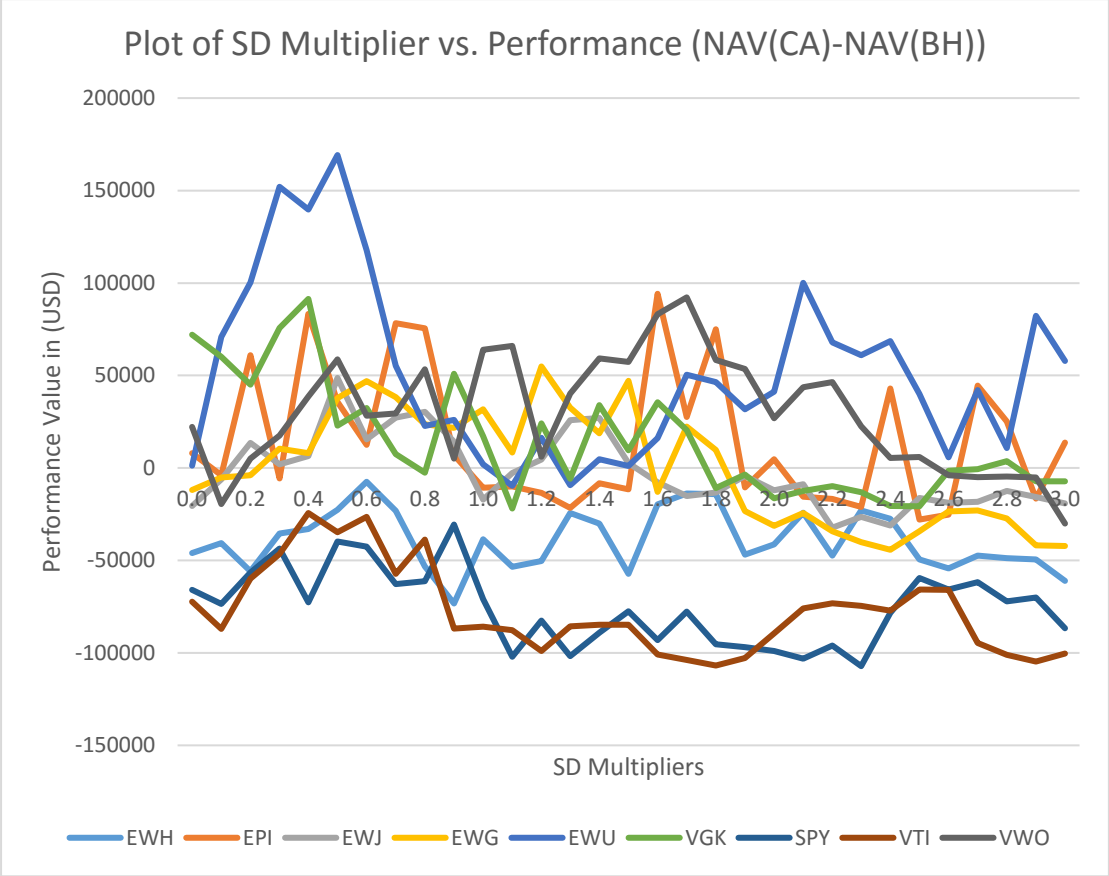


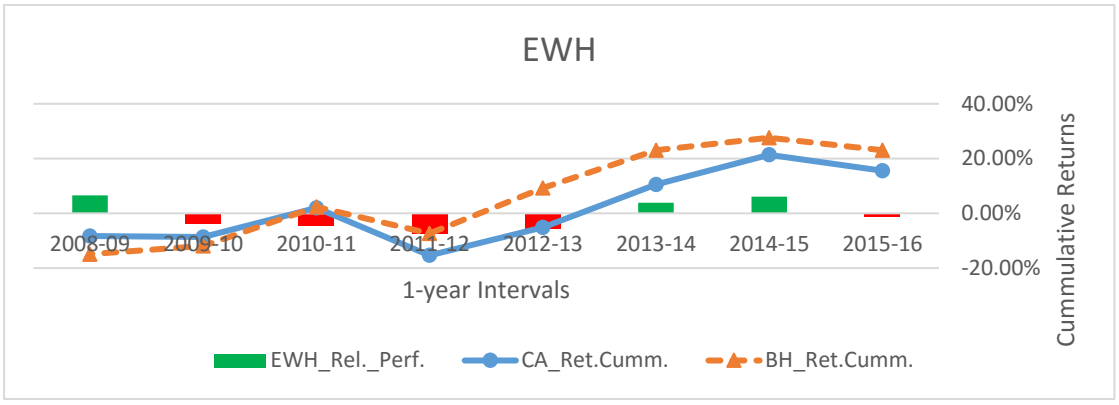
Figure 8:Plot of SD multiplier versus performance of CA against BH

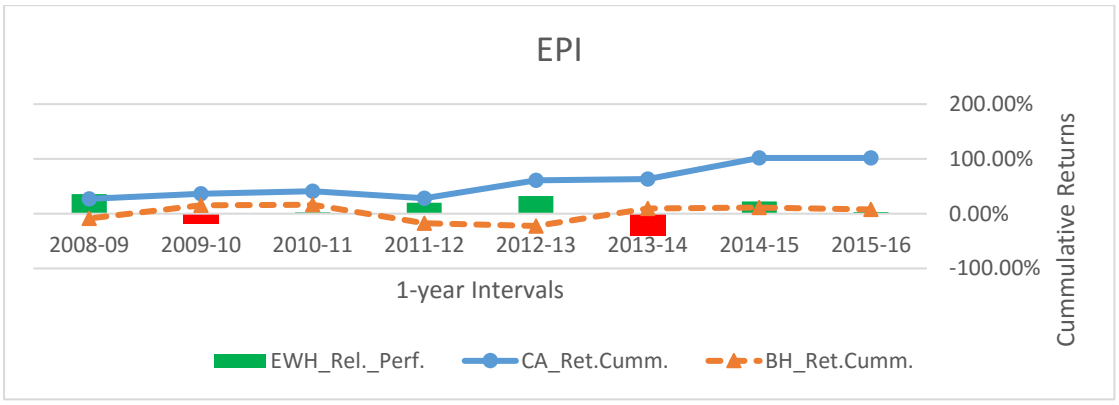
The highest performing SD multiplier for each ETFs is given in the table below (Table 3).

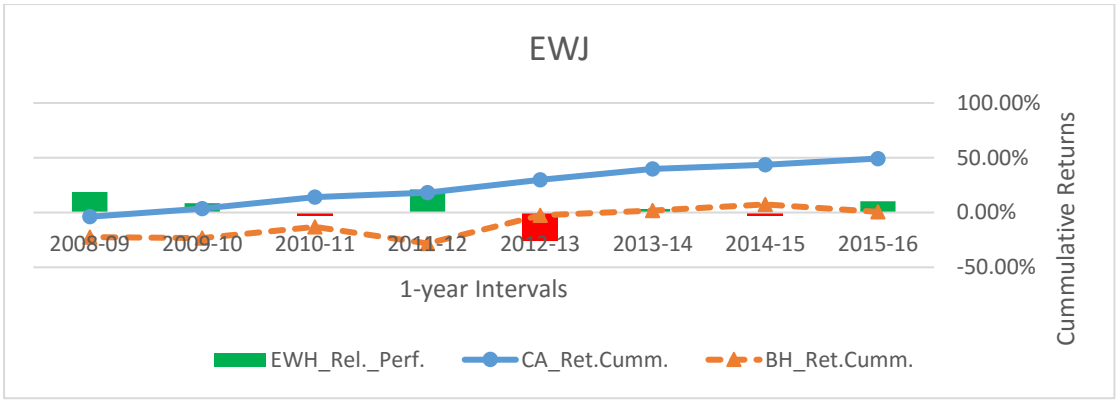
Table 3: ETFs and its corresponding best performing SD multiplier

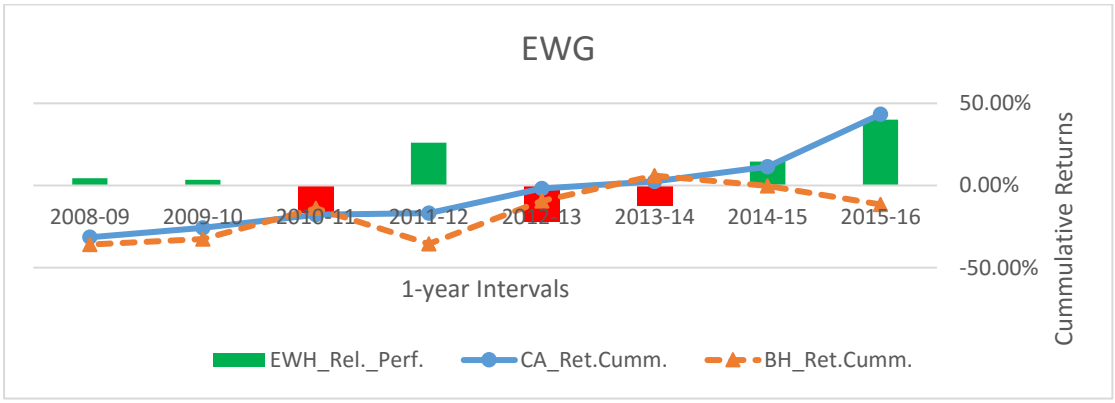
ETF	SD Multiplier
EWH	0.6
EPI	1.6
EWJ	0.5
EWG	1.2
EWU	0.5
VGK	0.4
SPY	0.9
VTI	0.4
VWO	1.7

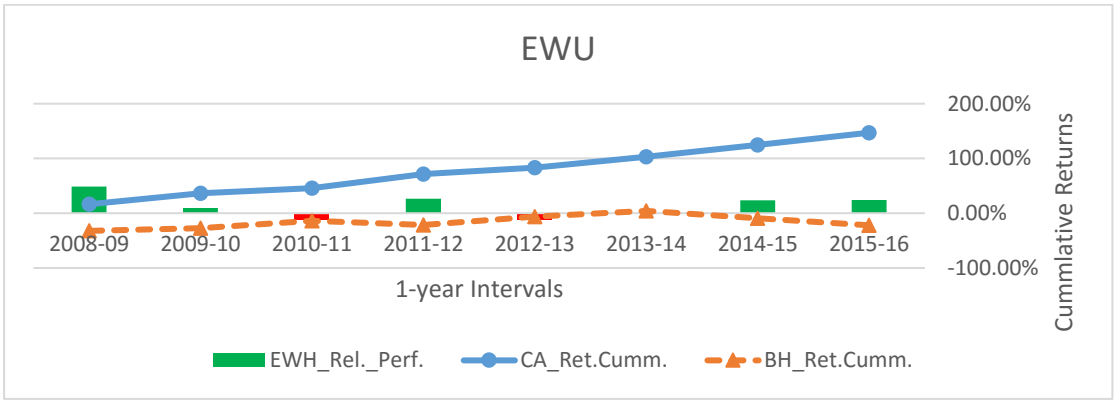
Given the best performing SD multiplier, the multipliers were used to generate the output of the CA. The graphs below (Figure 8) show the relative performance (cumulative) of the CA with respect to the BH. In the graphs, a plot of the individual year interval performance is also given. This was to show the yearly performance of the CA. If it was green, the CA outperformed the BH, else if red, the CA underperformed the BH.






EWJ
100.00%
50.00%
0.00%
-50.00%
2008-09
2009-10
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
1-year Intervals
Cummulative Returns
EWH_Rel._Perf.
CA_Ret.Cumm.
BH_Ret.Cumm.


EWG
50.00%
0.00%
-50.00%
2008-09
2009-10
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
1-year Intervals
Cummulative Returns
EWH_Rel._Perf.
CA_Ret.Cumm.
BH_Ret.Cumm.


EWU
200.00%
100.00%
0.00%
-100.00%
2008-09
2009-10
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
1-year Intervals
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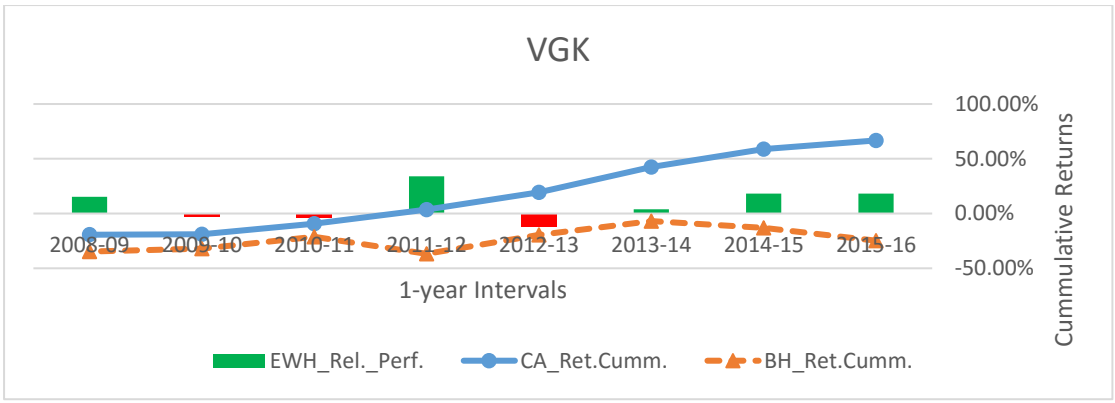
EWH_Rel._Perf.
CA_Ret.Cumm.
BH_Ret.Cumm.


VGK
100.00%
50.00%
0.00%
-50.00%
2008-09
2009-10
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
1-year Intervals
Cummulative Returns
EWH_Rel._Perf.
CA_Ret.Cumm.
BH_Ret.Cumm.

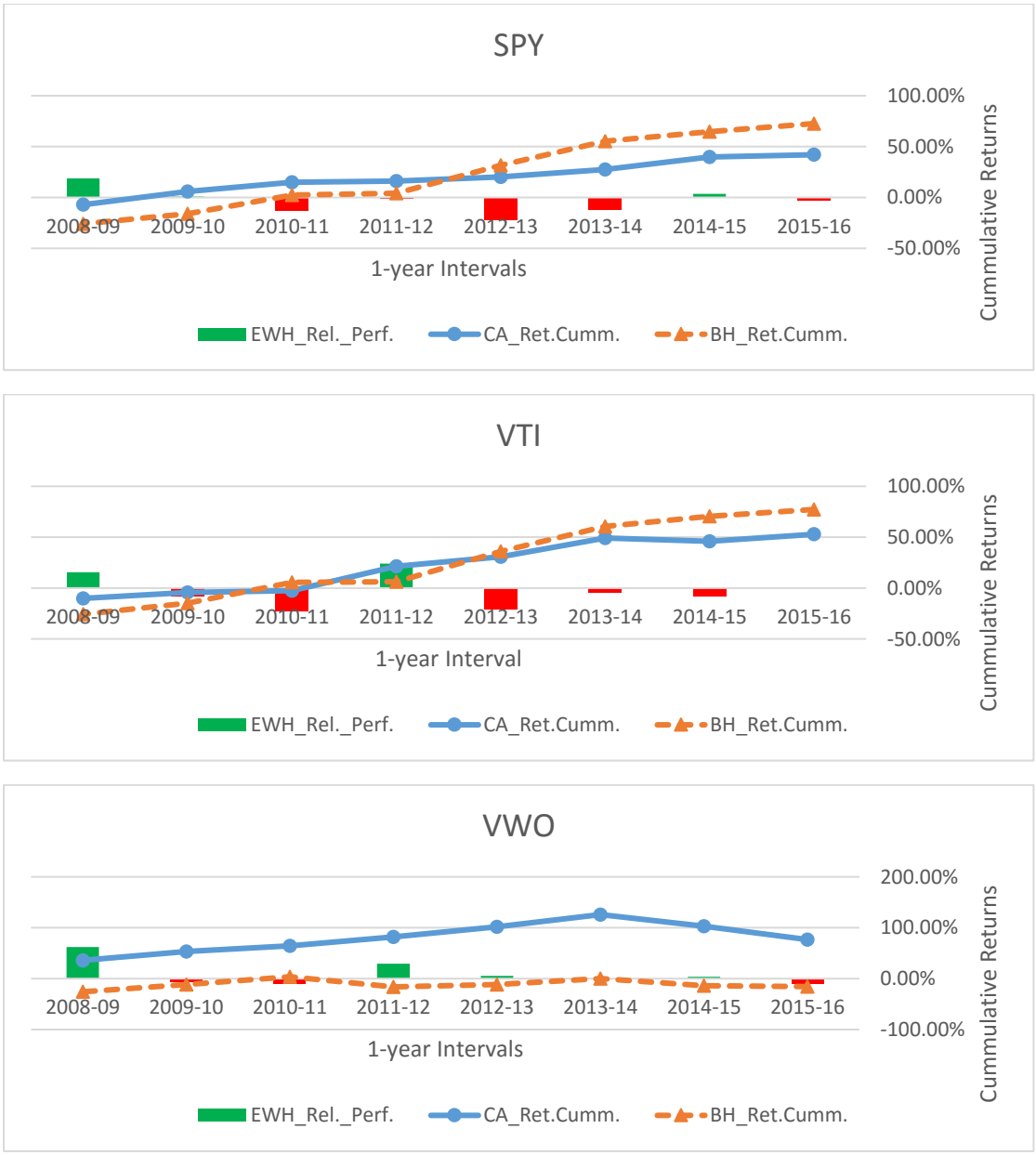


Figure 9: Plots of the Cumulative returns of CA versus the BH incorporating the stand alone yearly performance

Comparing results

The results were then compared to the MA and RSI technical trading methods. The results are summarized in the following (Table 4).

Table 4: Tabulating the #Trades and comparing results of CA with respect to BH, MA, and RSI

ETF	SD Multiplier	# Trades	% NAV(BH) Captured by CA	% NAV(MA) Captured by CA	% NAV(RSI) Captured by CA
EWH	0.6	22	93.91%	89.48%	117.89%
EPI	1.6	6	187.55%	176.76%	214.89%
EWJ	0.5	36	148.42%	126.00%	174.73%
EWG	1.2	14	162.06%	159.44%	148.65%
EWU	0.5	36	317.41%	375.55%	306.15%
VGK	0.4	40	221.29%	194.81%	212.21%
SPY	0.9	14	82.27%	122.86%	94.10%
VTI	0.4	32	86.24%	119.47%	123.41%
VWO	1.7	4	209.50%	144.72%	172.20%
Average			167.63%	167.68%	173.80%

The above (Table 4) shows that the CA was able to outperform the BH majority of the time. With the SD multiplier optimized for the BH, the CA was able to outperform the MA and RSI indicators. This can indicate the CA was outperforming the MA and RSI, but it could also indicate that the MA and the RSI were not optimal and needs to be optimised for the BH. While using the average MA and RSI indicators, the CA was performing better.

Theoretical Confirmation

Financial theory (Risk/Return Trade-off) [7] regarding the volatility of an equity states that as the volatility increases the return on that investment must increase. The increase in return is to compensate for the risk the investor had to take in the investment. To verify if the output of the CA follows the Risk/Return Trade-off, the volatility (annualized) for each ETF is computed and a table is tabulated to check for the signs of verification.

Table 5: Tabulating the Volatility versus % of NAV(BH) captured by CA

ETFs	Volatility (Annualized) (%)	% of BH_NAV captured by CA (100% equals BH performance)
SPY	21.14	93.91%
VTI	21.79	187.55%
EWJ	22.12	148.42%
EWH	24.71	162.06%
EWU	26.83	317.41%
VGK	26.88	221.29%
VWO	28.74	82.27%
EPI	29.96	86.24%
EWG	30.99	209.50%

Plotting a graph (Figure 10) of the Volatility versus the percentage of NAV(BH) captured by the CA is given below. The volatility was plotted in an ascending order with corresponding output performance. A line of best fit was plotted for the volatility and the percentage of NAV(BH) captured by the CA. This line of best fit is the general trend of the plot. The line of best fit is indicated by a dotted line and titled as linear in the legends.

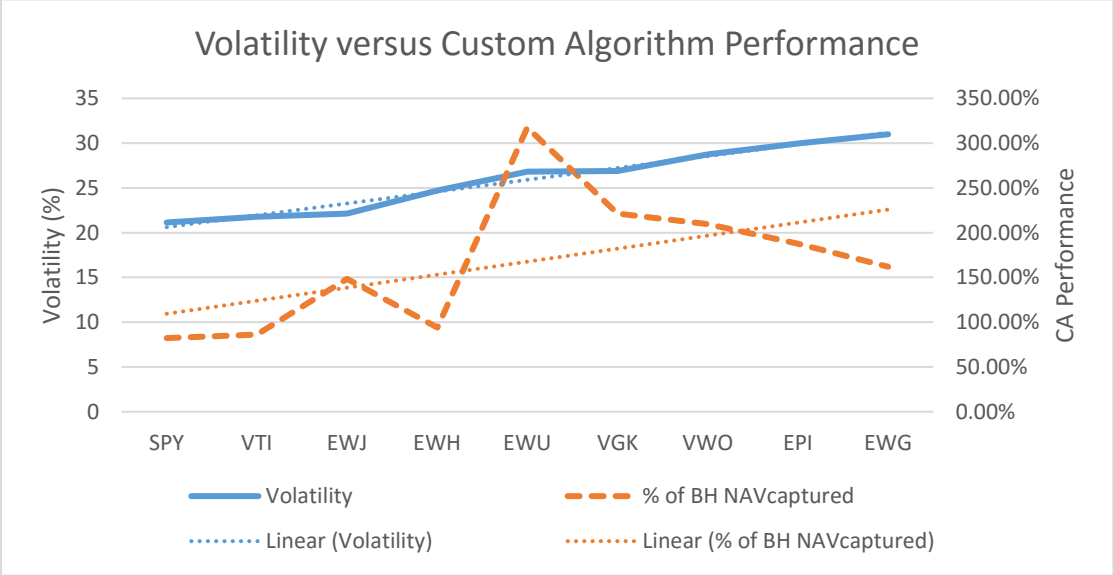


Figure 10: Plot of table 5. Volatility versus CA Performance

The output performance was showing a fluctuation, but when a linear line fit was fitted to the CA Performance chart, an upward trend (given by the dotted orange line) is seen. Similarly, if the linear fit line for the volatility (given by the blue dotted line) is plotted, an upward trend is seen. A quick glance at the linear line fit plots, we can see that as the volatility increases the performance increases. Hence, the performance of the CA (Returns) is proportional to the volatility of the equity can be concluded. Hence the CA verifies and abides by the financial theory of Risk/Return Trade-off.

The volatility was also plotted against the SD multiplier to check if any conclusion to be drawn from it. The table is tabulated below (Table 6).

Table 6: Tabulation of Volatility versus SD multiplier and Number of trades

ETFs	Volatility (Annualized) (%)	SD Multiplier	Number of Trades
SPY	21.14	0.6	14
VTI	21.79	1.6	32
EWJ	22.12	0.5	36
EWH	24.71	1.2	22
EWU	26.83	0.5	36
VGK	26.88	0.4	40
VWO	28.74	0.9	4
EPI	29.96	0.4	6
EWG	30.99	1.7	14

The graphs (Figure 11,12) of Volatility versus SD Multiplier and Number of Trades are plotted below, respectively.

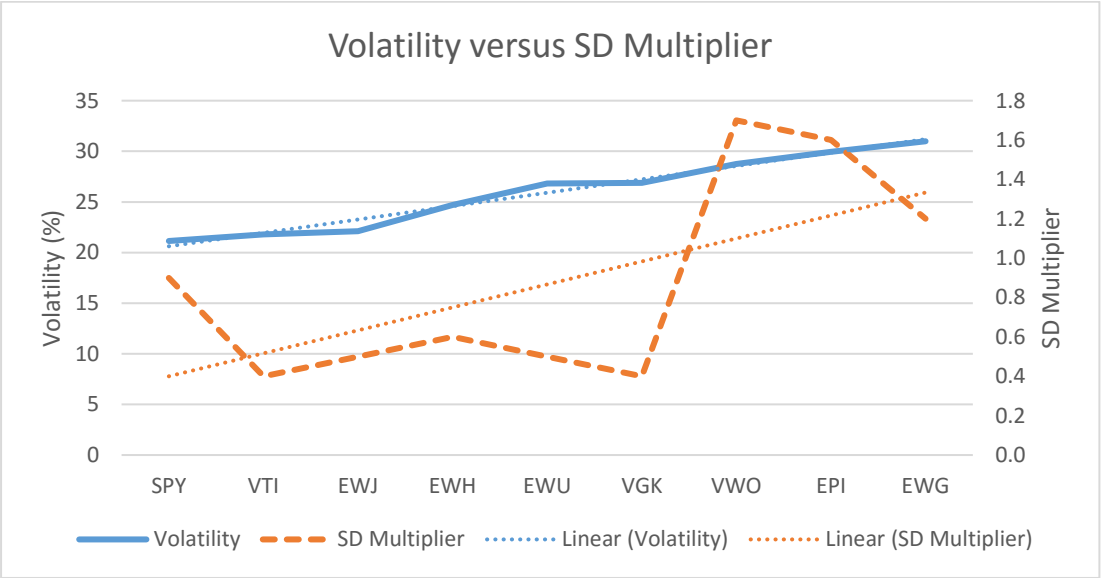


Figure 11: Plot of table 6. Volatility versus SD multiplier

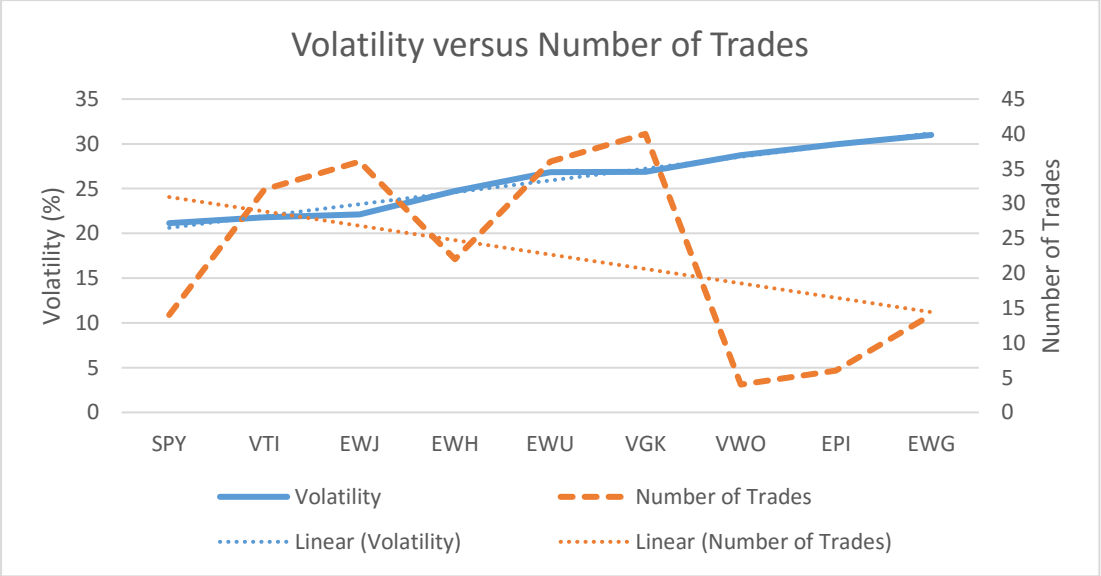


Figure 12: Plot of table 6. Volatility versus Number of trades

As we can see from the charts above (Figure 11,12), the linear line fits (the linear legend) indicate that as the Volatility increases, the SD multiplier increases. When the volatility is low, a smaller SD multiplier is sufficient to initiate trade. This ensures that the price fluctuations are optimal to initiating a buy or sell signal. When the volatility is high, a larger SD multiplier is needed to stop frequent trades. This ensures that the price can fluctuate a larger range before initiating the trades and reducing the trading costs.

CONCLUSION

A custom algorithm was developed to analyse a candlestick chart patterns and colour code the candlesticks based on candlestick reversal patterns and price fluctuations. The colour codes were then used to set a buy or sell signal. The parameters of the custom algorithm were optimised with respect to the Buy and Hold strategy. The results of the algorithm were then tested against commonly used technical trading indicators such as 14-25 days Moving average and the 70-30 Relative Strength Indicator. Results show that the Custom Algorithm was able to capture 167.63%, on average, of the Buy & Hold strategy, and captured 167.68% and 173.80%, on average, of the 14-25 days Moving Average and the 70-30 RSI indicators respectively. Furthermore, results indicate that the custom algorithm conforms with the financial theory of Risk/Return Trade-off (returns being proportional to the volatility).

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