Usage of the Hurst Exponent for Short Term Trading Strategies.

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Abstract

The goal of this research paper is to build trend following strategies for intraday trading by using the Hurst Exponent and combining it with technical indicators such as the SuperTrend indicators. First, we attempt to minimize the white noise effect of the Hurst Exponent using Kalman Filter. Going further, we will use the Hurst Exponent to identify trending and mean-reverting time series, based on this we will use the signals of the SuperTrend indicator to enter into position. We will use backtader.py for back testing on Index ETFs such as SPY and QQQ, on 60 minute, and daily timeframes.

Keywords: *Trading Strategies, Hurst Exponent, SuperTrend indicator, Day Trading, Trend following, Mean-Reversion, Kalman Filter, Fast Fourier Transform denoiser, Bollinger bands, Technical indicators*

Introduction

There two main categories of trading strategies, trend following and mean-reverting. The main assumption of trend following strategy is that the trend will continue, either up or down and mean-reverting assumes that a time series will revert to its mean, so the price will return to its previous level. In order to be able to decide which strategy can be winning at the time the Hurst Exponent can be useful as it can indicate whether a time series or a share price trending, mean-reverting or follows random walk otherwise white noise. The Hurst Exponent measures the long-term memory of a time series. First it was discovered by H.E. Hurst while he was working on determining the right dam size for the river Nile, and he published his book in 1951 called "Long-term storage capacity of reservoirs". The Hurst Exponent ranges from 0 to 1, and in the range of 0.5 – 1 indicates that there is a good chance in the series that high value will be followed by high value, in the range of 0 – 0.5 a low value will be followed by low value and if the value is at 0.5 it means that the series are uncorrelated. In trading, we can say if the value is between 0.5 and 1, then the prices are trending, if the values are between 0 and 0.5 the prices are mean-reverting, and if the value is equal to 0.5 then the prices follow random walk, meaning the price movement cannot be predicted.

In this research, we intend to reduce/remove white noise from time series (using mathematical models). Identify trending markets using the Hurst Exponent and take buy or sell signals using technical indicators such as the SuperTrend indicator in order to generate alpha. The SuperTrend indicator is a trend following indicator displayed on a chart and if the price is above the lower band the trend is bullish if the price is below the upper band the trend is bearish. It has two parameters the period and the multiplier; these are calculated using the average true range or ATR indicator. The period indicates the time period employed for the ATR and the value of the multiplier is multiplied by the ATR.

Data & Development Environment

The strategy development was done in python environment, to backtest the strategies backtrader.py (https://www.backtrader.com/) was utilized, as it is a python library which allows us to focus on writing reusable trading strategies, indicators and analyzers instead of having to spend time building infrastructure. Backtrader is an event driven backtest framework, which means that different parts of code (strategies, indicators, analyzers etc.) communicate continuously with each other by emitting and consuming events that represent some change in state. Thanks to event driven architecture, we were able to implement realistic scenarios about how order will be executed, and those scenarios were easily configurable. Secondly, it was easy to avoid look-ahead bias because market data receipt is treated as an "event" that must be acted upon.[10]

Historical prices were download from AmeriTrade is brokerage firm located in US and they are providing historical data for almost all equities in US Stock Exchange market in different timeframes. Therefore, AmeriTrade API is utilized to download historical data for our chosen ETFs, namely SPY (SPDR S&P 500 ETF Trust) & QQQ (Invesco QQQ Trust). We downloaded 60 minute and daily price data of SPY & QQQ from June of 2021 till October 2022 and from 2019 till 2022 October respectively. With the daily price data, we wanted to illustrate trading environment during the Covid crash, to see how our system performs under different market conditions. Furthermore, in order to consider realistic trading scenarios, buy and sell signals are executed on the next bar at market price on the best bid/ask available, also broker commissions are included in the final results.

During development, we firstly focused developing the methods to download historical data, thanks to those methods we can download historical price data of an equity in different time frames and periods. Secondly, we developed an abstract base strategy class which allows defining generic methods like stop loss, logs, trade notification etc., that can be used in any strategy. Then, we developed our main strategy class which is derived from base strategy class. The strategy includes the method for the indicators (HE and SuperTrend) and for buy/sell signal logic. It is a configurable strategy which accepts different parameters; thus, we had an opportunity to backtest different scenarios easily by sending different variables to the strategy. Finally, we setup Backtrader engine to run backtest different strategies for our ETFs, engine accepts price data, filtered price data and strategy as inputs and returns backtest results (profit rate, strike rate, PnL, max drawdown and sharpe ratio). Also, it shows a graphical representation of our trading on price data.

Reducing White Noise

Basically if a time series has white noise then it`s not predictable otherwise follows random walk. White noise has three conditions, which are the mean has to be zero, the standard deviation of time series has to be constant, so no change in the value, and the correlation between time series and its lagged version isn`t significant. Whether a time series has white noise it can be tested checking for autocorrelation using ACF plots in python and studying the autocorrelation plots. As explained earlier, The Hurst Exponent also shows if a time series has white noise when its value is around 0.5.

For any kind of trading strategy one of the obstacles is to reduce the impact of white noise on indicators that are used to measure either trending or mean-reverting behavior. The failure to do so results in poor trading results due to false signals, and these kinds of false signals most probably will result in trading loss. Therefore, it is crucial to minimize the white noise effect.

There two techniques which can reduce white noise in a time series namely Fast Fourier Transform denoiser and Kalman filter. The Fast Fourier Transform or FFT can filter out the noise and it does this by moving time series from time domain to frequency domain, and after applying the inverse Fourier transform, we get a filtered time series. FFT filters the noise at different levels of n_components, the higher this value is, more frequencies are removed. As with most techniques it is very important to find the right parameters, in this case a parameter which keeps the trend but removes the noise. The disadvantage of the FFT is that we do not know when the frequencies happen in our time, so this method is not the best for non-stationary time series. In our research we used 2400 for n_components and although it seems filtering the data improved our final return but also because we rather over fitted the data.

Therefore, we decided to go with Kalman filter and implement it in our trading strategy. Of course, it is also important to select the right parameters for this technique, so we tune the algorithm to bring out the underlying signal. Kalman filter can correctly estimate hidden states using its observable variables.

In order to implement our Kalman filtered modelling technique we use the pykalman.py library. As parameters are key for this model, we use variance 1 and an initial guess for the mean is 0. One of the advantages of the Kalman filter is that it realizes our initial guess and adjusts these quickly. Furthermore, window length does not needed to be selected, thus there is less chance for overfitting.

In order to test the Fast Fourier Transform, we calculate the Hurst values using the filtered prices by the FFT on hourly and daily SPY data, as well as on the original price data for the same periods and the results are plotted on the same chart for comparison.

On Figure 1, using Daily chart prices, eventually FFT does a good job filtering out noise from our SPY series, the filtered prices are much smoother compared to the original data as there are no big swings in the filtered data. On the other hand, the Hurst values calculated from the filtered prices are do not provide useful information whether our time series are trending or mean-reverting compared to the Hurst values calculated based on the original SPY data. As it can be seen on Figure 1, there are several trending periods in the series, however the FFT data Hurst values are never go beyond 0.5, and most of the time these values are below 0.4 and even approaching 0 when the market crashed during the first Covid lockdown in early 2020.While the Hurst values from the original SPY data are correctly showing when the market is trending (H > 0.5) or mean-reverting (H < 0.5).

Figure 1. Comparison between Daily SPY and FFT filtered SPY prices and their Hurst values
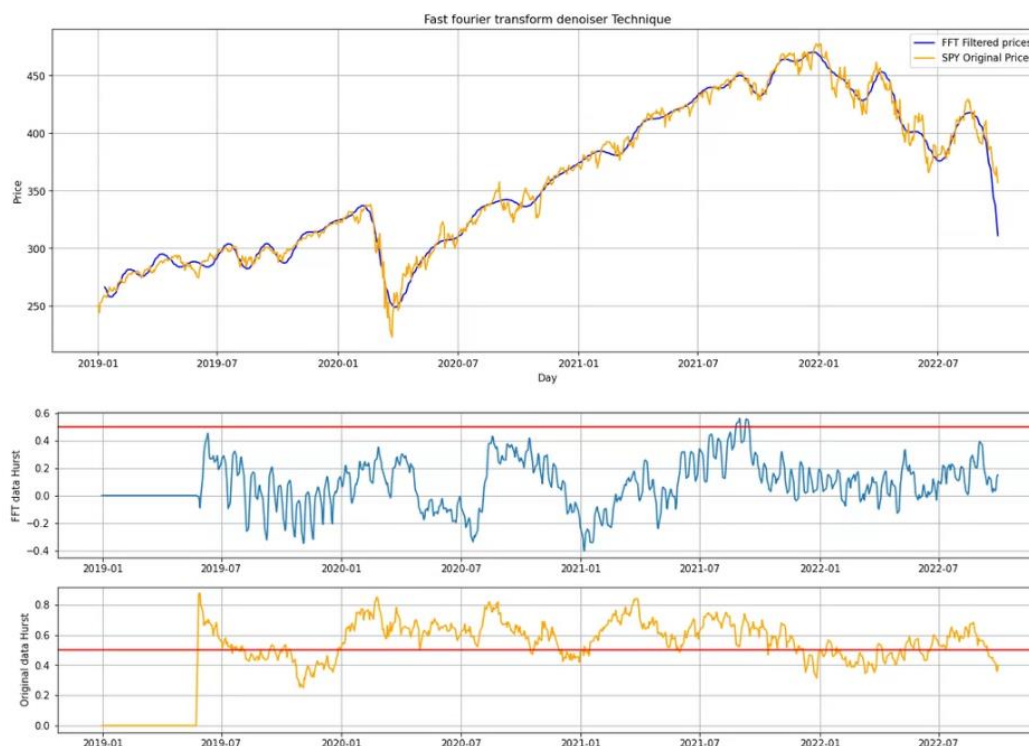
As it can be seen on Figure 2. below, on shorter time frames, on Hourly data, the Hurst values from FFT filtered prices are incorrect as they go below 0 into minus territory, thus these values do no provide useful readings, while again the Hurst values calculated from the original SPY price are showing when the market is trending or not.

As mentioned earlier, the Fast Fourier Transform denoiser is not a reliable technique to minimize the white noise in time series as our research shows that it can be over fitted easily and not useful for trending or non-stationary time series. Therefore, we decided to use Kalman filter technique and implement it in our strategies. For testing the effectiveness of this technique, the Hurst values are calculated on daily and hourly chart data, on both the Kalman filtered and original prices and plotted on the same graphs for comparison, which we will illustrate below Figure 3.

Figure 2. Comparison between Hourly SPY and FFT filtered SPY prices and their Hurst values
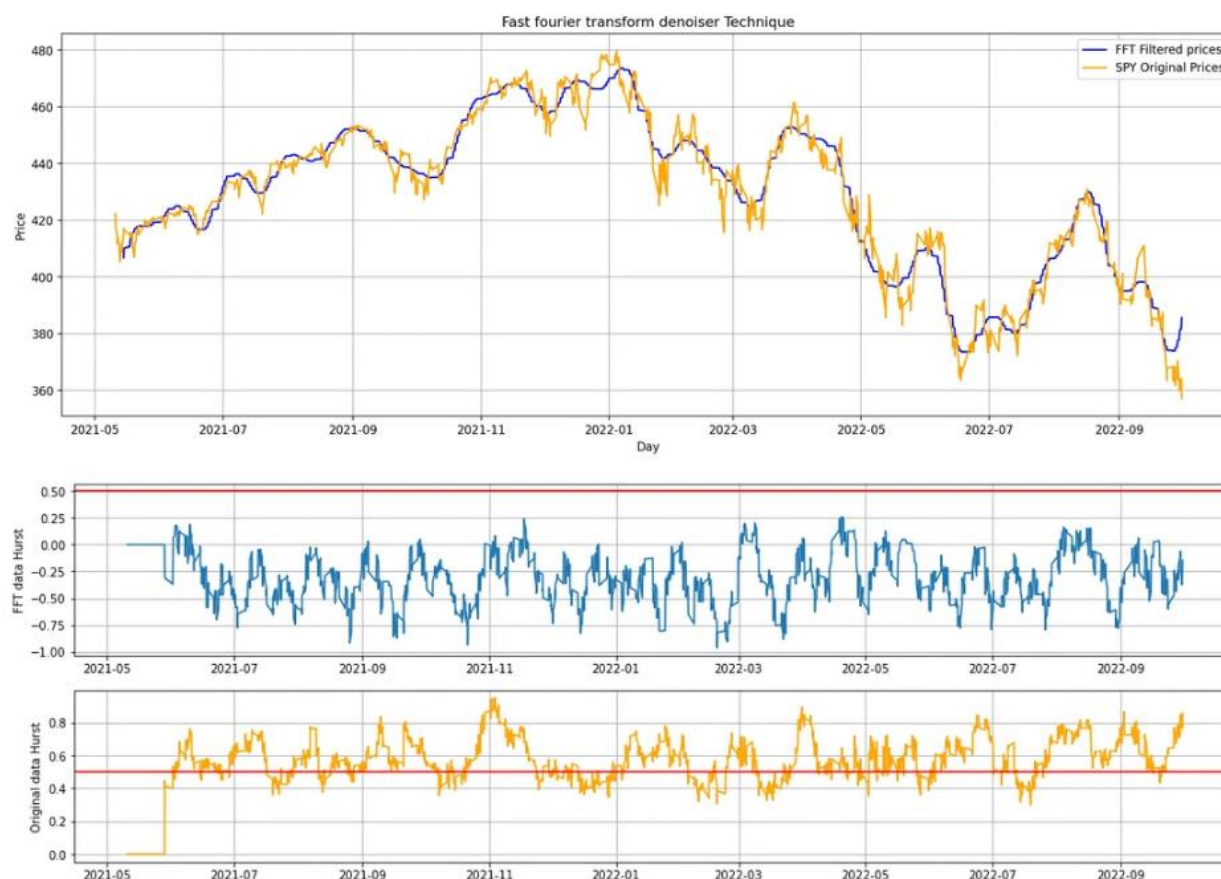

As, we can see it on the below on the Daily chart Kalman filter does a better job on filtering out the noise from our SPY series compared to the FFT technique. First of all, there are much less swings in the Kalman filtered prices compared to the original SPY prices, which means less noise, and if we compare Figure 1 and Figure 3, there are bigger swings in the FFT filtered prices compared to the Kalman filtered prices. Eventually, being able to filter out the noise from time series can utilize the Supertrend indicator to provide more accurate and reliable signals as one of the backbones of this indicator is the Average True Range volatility indicator. Furthermore, on the Hurst values, the Kalman filer provides real values compared to the FFT technique, and as we can see on Figure 3 the Kalam filtered Hurst values react to the prices changes more rapidly compared to the Hurst values calculated on the original prices. On the other, the Kalman filtered Hurst values do not always provide correct reading whether the SPY series trending or not. For example, when the market crashed during the first Covid lockdown early 2020, the Kalman filtered Hurst values are showing that our series is mean-reverting when H < 0.5, while the price was clearly trending lower. Also, when the market turned in early May of 2020, the Hurst values calculated from the original SPY data are showing us a trending market H > 0.5, however the Kalman filtered Hurst values only go above 0.5 in mid-August of 2020 and showing us that the market is trending, so basically despite Kalman filtered Hurst values react rapidly to the price changes, which would be useful to know earlier when a time series start or stop trending, yet it seems lagging behind the Hurst values calculated from the original prices. As our research is focusing on short term trading, we will examine if the same observation is true on hourly chart prices on Figure 4.

Figure 3. Comparison between Daily SPY and Kalman filtered SPY prices and their Hurst values

Figure 4. Comparison between Hourly SPY and Kalman filtered SPY prices and their Hurst values
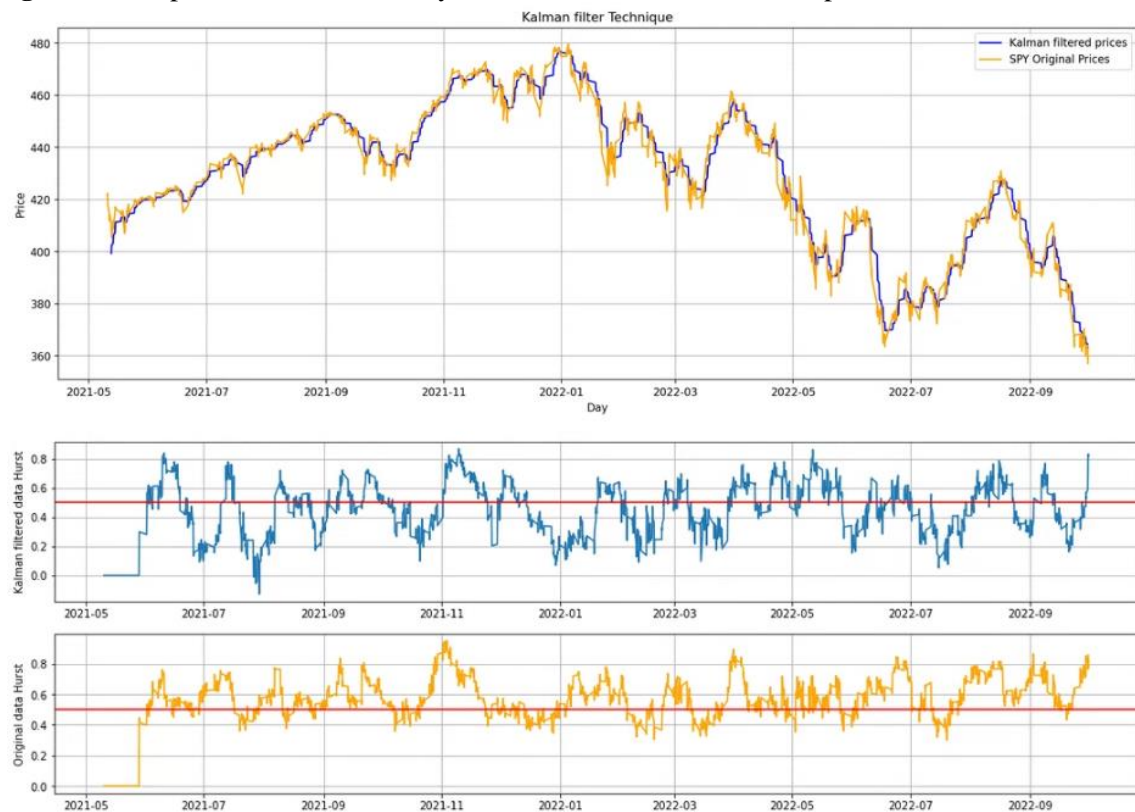
As Figure 4 shows Hourly SPY prices above, the Kalman filtered prices are smoother compared to the original SPY prices, and Kalman filtered prices showing less swings in the price, however even though this technique does a good job reducing the noise in our series, again the Kalman filtered Hurst values are lagging behind the Hurst values calculated from the original prices, just like on the Daily chart. For example, we can see that Hurst values calculated from the original prices are already showing trending series H > 0.5 from early October of 2021, while the Kalman filtered Hurst values only start showing from early November of 2021 that our series is in trend H > 0.

Based on, these data and chart we cannot conclude that reducing white noise in a time series helps improving the values of the Hurst Exponent.

Trading Strategies

The initial idea to utilize the Hurst Exponent and its effectiveness in trading was to combine with a trend following indicator we choose SuperTrend as trough our observations it seemed to provide profitable trading signals in trending market environment, however it also provides a lot of false signals when the market is moving in a thigh range otherwise time series showing mean-reverting behavior. Obviously as the Hurst Exponent can identify which market we are in at the time, it seemed logical to combine the two and possibly limit the false signals of the SuperTrend indicator.

So, the buy and signals is defined by SuperTrend level:

- If price is crossing over SuperTrend level, it is a buy signal.
- If price is crossing down SuperTrend level, it is a sell signal.

However, the general idea is that only enter the market if the Hurst Exponent is above 0.5. Moreover, we have implemented optional and configurable Hurst Exponent logic and white noise reduction logic. Those optional logics give us an opportunity to apply backtesting different combination of strategies easily.

We have two parameters as *apply_hurst_exponent* and *apply_noise_reduction* to identify if we apply HE or white noise reduction.

Applying HE

If we apply HE, we are extending SuperTrend signal by checking if HE is smaller than 0.5 which means that the data is not trend following. So, we are not executing any buy/sell signal while the data is not trend following.

Applying White Noise Reduction

We are feeding SuperTrend strategy with two different data sources as filtered ETF price data (filtered by Kalman Filtering) and original ETF price data. If we apply noise reduction, we are using filtered data to build our HE and SuperTrend Indicator. Then, we are defining buy and sell signal as following:

- If filtered data price is crossing over SuperTrend level, it is a buy signal.

- If filtered price is crossing down SuperTrend level, it is a sell signal.

On the other hand, we are executing trade transaction by using original data.

Backtesting

Backtest logic was implemented as following.

1. We defined different combination of strategies for example SuperTred with Hurst Exponent, SuperTrend with white noise reduction.
2. For each ETF and strategy, backtest engine was executed. Backtest engine was run for 2 ETFs and 4 different combinations.
3. All backtest results were saved to Excel File (Table Name: StrategyResult)

Static Stop Loss and Volatility Adjusted Stop Loss

To implement *static percentage stop loss*, we are checking if current close price is smaller than certain amount ($Stop\ Loss\ Amount$), then I am closing the position.

$$Stop\ Loss\ Amount = Price\ of\ buy\ \times (1 - Stop\ Loss\ Percentage)$$

To implement *volatility adjusted stop loss*, first I used Bollinger band to measure volatility (σ).

$$Volatility(\sigma) = (BB_{top} - BB_{mid})/BB_{dev\_factor}$$

where

- BB_{top} is the top line value of Bollinger band at current bar.
- BB_{mid} is the midline value of Bollinger band at current bar.
- BB_{dev_factor} is the dev factor of Bollinger band.

Then, we calculated stop loss percentage based on volatility as following.

$$Volatilty\ Adjusted(VA)\ Stop\ Loss\ Percentage = Stop\ Loss\ Percentage * (1 + \sigma)$$

Finally, we checked if current close price is smaller than certain amount ($Volatility\ Adjusted(VA)\ Stop\ Loss\ Amount$), then we are closing the position.

$$VA\ Stop\ Loss\ Amount = Price\ of\ buy\ \times (1 - VA\ Stop\ Loss\ Percentage)$$

After running several combinations of backtesing, we have selected the four best performing strategies

- Strategy 1 – Backtested QQQ on Hourly chart data combining SuperTrend and Hurst Exponent with no Noise Reduction nor Stop Loss. Data period: 1st of June of 2021 till 10th of October 2022.
- Strategy 2 – Backtested SPY on Hourly chart data using only SuperTrend with no Noise Reduction nor Stop Loss. Data period: 1st of June of 2021 till 10th of October 2022.
- Strategy 3 – Backtested QQQ on Daily chart data using only SuperTrend indicator with no Noise Reduction no Stop Loss. Data period: 2019 till 2022 10th of October 2022.
- Strategy 4 – Backtested SPY on Daily chart data combining SuperTrend and Hurst Exponent with Noise Reduction and Volatility Adjusted Stop Loss at 4%. Data period: 2019 till 2022 10th of October 2022.

For all the strategies, in terms of the indicators, following parameters are used:
- SuperTrend indicator takes two parameters:
  - Period: 10.
  - Multiplier: 3.
- Hurst Exponent only has period set to 20 as parameter.

Strategies Result

Backtrader`s celebro plot function plots out and clearly illustrates, how the four strategies performed on the selected data sets. Each graph, show the realized PnL on the top and under that the dates the strategy executed a traded. The first price chart shows the original data along with the signals of the SuperTrend indicator as well as the values of the Hurst Exponent. The second price chart shows the Kalman filtered prices.

Below metrics helped us to analyze backtest results:

- Strike Rate or Win/Loss ratio: measures rate of successful trade in all trades.
- Profit Rate or Return: The percentage return on our investment.
- PnL: show total amount of profit for all trades.
- Max Drawdown: refers to how much an investment or trading account is down from the peak before it recovers back to the peak. [9]
- Sharpe Ratio: measures excess return adhering to risk of an asset and compares this return with risk-free rate of return.

Strategy 1 – Backtest result of QQQ on Hourly chart data combining SuperTrend and Hurst Exponent with no Noise Reduction nor Stop Loss:

Overall, Strategy 1, made 14% on QQQ over 16 months period, which is much better than QQQ`s performance which lost 18% over the same period.

Figure 5. Backtest result of Strategy 1.
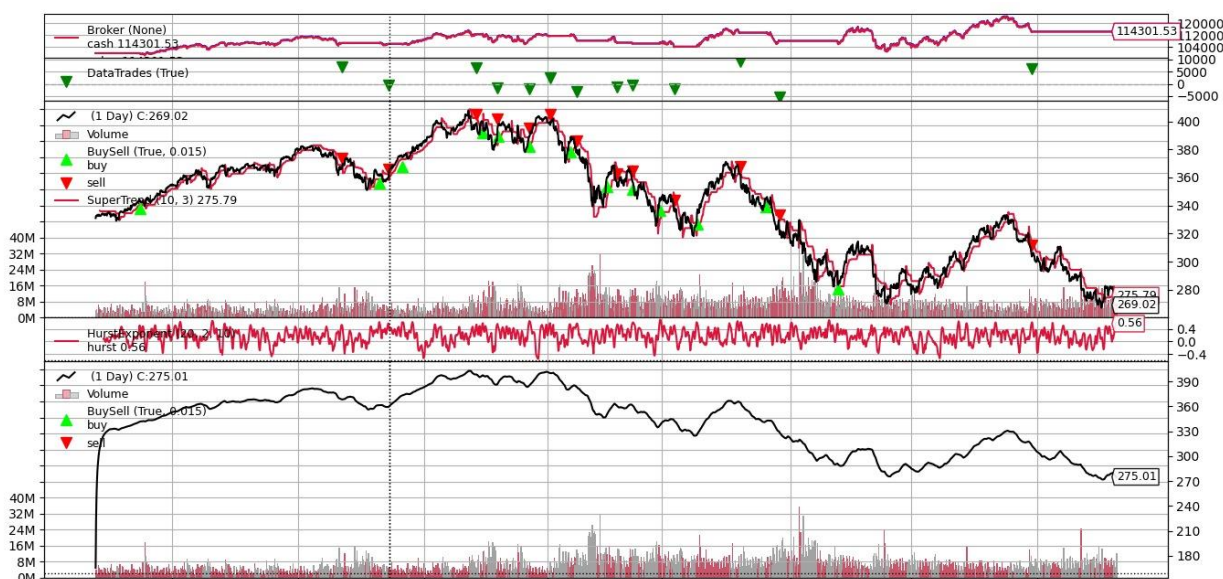
Strategy 2 – Backtest result of SPY on Hourly chart data using only SuperTrend with no Noise Reduction nor Stop Loss:

Strategy 2 on SPY did not perform as well compared to Strategy 1; however, the historical volatility of the S&P 500 is lower compared to the Nasdaq 100. [7] Still this strategy made 10.7% over the period, while SPY is down 12% during the same period.

Figure 6. Backtest result of Strategy 2.

Strategy 3 – Backtest result of QQQ on Daily chart data using only SuperTrend indicator with no Noise Reduction no Stop Loss:

Now, testing on the daily chart shows that despite volatility during and after the Covid crash, clear up and down trends in QQQ during our selected time period, a buy and hold strategy would have made 172% return, while Strategy 3 only made 55% return.

Figure 7. Backtest result of Strategy 3.
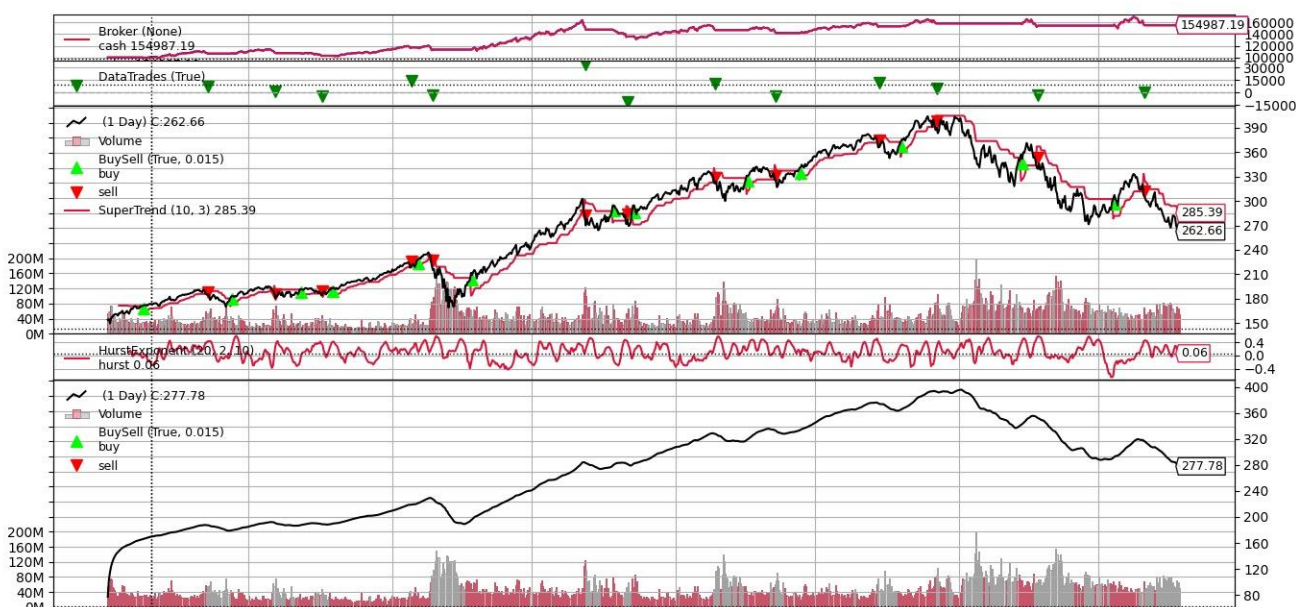
Strategy 4 – Backtest result of SPY on Daily chart data combining SuperTrend and Hurst Exponent with Noise Reduction and Volatility Adjusted Stop Loss at 4%:

On SPY, using daily chart data, our noise reduction technique with volatility stop loss performed better then without these functions. Although with its 21% return in 4 years it underperforms the S&P 500 with its 144% return.

Figure 8. Backtest result of Strategy 4.
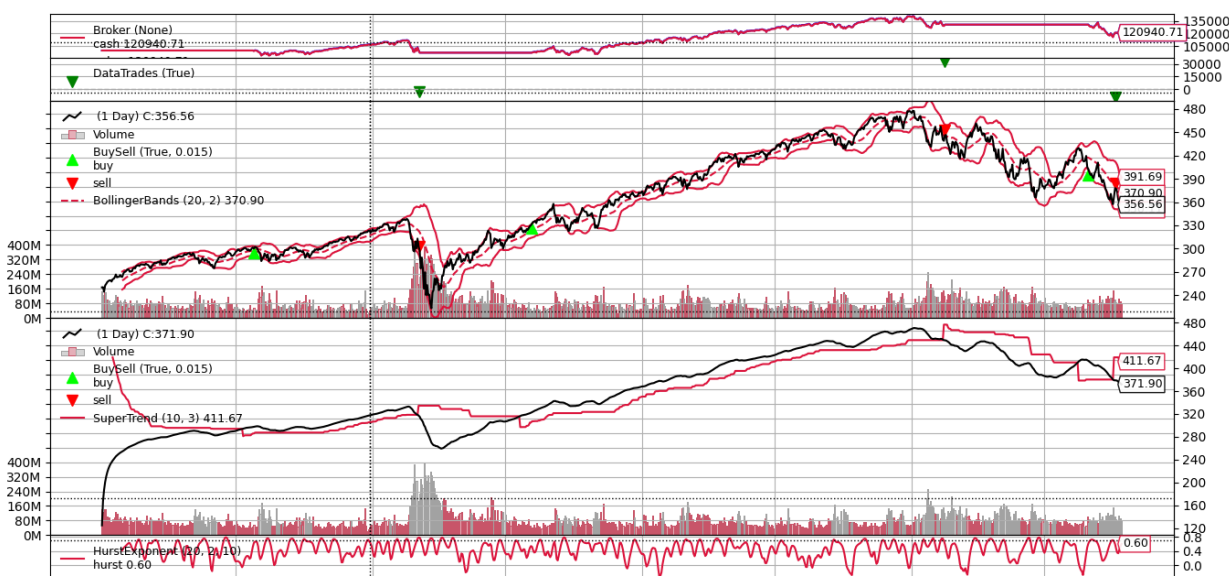
Finally, we put the results into a table for comparison.

Table 1. Strategy Results

	# Of Trade	Return	Win/Loss ratio	PnL net	Max DrawDown	Sharpe Ratio	Benchmark return
Strategy 1 QQQ Hourly	13	14%	38.46	14,301	13.9%	1.35	-18%
Strategy 2 SPY Hourly	40	10.7%	45	10,721	9.1%	5.91	-12%
Strategy 3 QQQ Daily	13	55%	61.54	54,987	19.9%	0.80	172%
Strategy 4 SPY Daily	3	21%	33.33	20,941	17.4%	0.28	144%

Overall, Strategy 3 has performed the best among the four strategies, however it has the highest drawdown, and it is really behind the benchmark return. The second-best performing is Strategy 4; with its 21% net return, although this is as well on Daily time frame for which we used a longer time period, compared to Strategy 1 & 2. Between the two short term strategies, Strategy 1 performed better in terms of return, however, we like Strategy 2 better as it has very high 5.91 Sharp Ratio and its win/loss ratio is also better compared to Strategy 1. Based on these numbers, we conclude that our base strategy performs better in terms of return on a relatively volatile ETF and eventually filtering signal by the Hurst Exponent increases our return, on the other hand it increases our risk as well. Eventually, trading on a less volatile ETF like SPY provides much higher Sharp Ratio.

Conclusions

This research project explores the effectiveness of the Hurst Exponent by reducing white noise and its profitability combined with a trend following indicator. Based on our research and backtesting several combinations of the parameters, we found that using our Kalman filter technique to reduce white noise in a time series does not necessarily improve the signals and the effectiveness of the HE and SuperTrend indicator, as the backtesting results with applying noise reduction did not provide superior returns.

On the other hand, using HE and SuperTrend indicators, we managed to create a profitable alpha generating trading short term trading strategy, which seems works better on hourly time frame, compared to 1 or 5 minute and daily time frames as we have also backtested our base strategy on minute time frames, however the results were not profitable. Of course, we must mention that the research was limited due to the lack of free availably of historical data.

Our developed Kalman filter modeling technique to minimize effect of white noise indeed reduces the noise in a time series; however, it did not improve the signals of the Hurst Exponent. With that we believe our base strategy combining the Hurst Exponent and SuperTrend indicators can generate alpha during volatile market conditions.

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Appendix A - The outputs from Backtrader for the four Strategies

- Strategy 1 QQQ on Hourly chart data combining SuperTrend and Hurst Exponent

```
**************QQQ***************
Start Date:     2021-06-01 00:00:00
End Date:       2022-10-10 00:00:00
Frequency:      Hourly
==========================================================================
Hurst Exponent: True
Stop Loss:      False
Noise Reduction: False
VA Stop Loss:   False
2021-06-15T14:00:00, BUY COMPLETE, 343.89
2021-06-15T14:00:00, TRADE OPENED, SIZE 290
2021-09-21T19:00:00, SELL COMPLETE, 367.22
2021-09-21T19:00:00, TRADE PROFIT, GROSS 6765.70, NET 6765.12
2021-10-08T18:00:00, BUY COMPLETE, 361.49
2021-10-08T18:00:00, TRADE OPENED, SIZE 295
2021-10-13T18:00:00, SELL COMPLETE, 359.60
2021-10-13T18:00:00, TRADE PROFIT, GROSS -556.07, NET -556.66
2021-10-20T17:00:00, BUY COMPLETE, 375.24
2021-10-20T17:00:00, TRADE OPENED, SIZE 283
2021-11-24T20:00:00, SELL COMPLETE, 397.97
2021-11-24T20:00:00, TRADE PROFIT, GROSS 6432.59, NET 6432.02
2021-11-30T14:00:00, BUY COMPLETE, 398.70
2021-11-30T14:00:00, TRADE OPENED, SIZE 281
2021-12-07T14:00:00, SELL COMPLETE, 393.00
2021-12-07T14:00:00, TRADE PROFIT, GROSS -1601.70, NET -1602.26
2021-12-07T15:00:00, BUY COMPLETE, 395.66
2021-12-07T15:00:00, TRADE OPENED, SIZE 280
2021-12-21T19:00:00, SELL COMPLETE, 387.79
2021-12-21T19:00:00, TRADE PROFIT, GROSS -2203.60, NET -2204.16
2021-12-21T20:00:00, BUY COMPLETE, 389.21
2021-12-21T20:00:00, TRADE OPENED, SIZE 279
2021-12-31T20:00:00, SELL COMPLETE, 398.60
2021-12-31T20:00:00, TRADE PROFIT, GROSS 2619.81, NET 2619.25
2022-01-11T19:00:00, BUY COMPLETE, 385.13
2022-01-11T19:00:00, TRADE OPENED, SIZE 289
2022-01-14T14:00:00, SELL COMPLETE, 374.24
2022-01-14T14:00:00, TRADE PROFIT, GROSS -3147.21, NET -3147.79
2022-01-31T17:00:00, BUY COMPLETE, 360.17
2022-01-31T17:00:00, TRADE OPENED, SIZE 300
2022-02-03T20:00:00, SELL COMPLETE, 355.77
2022-02-03T20:00:00, TRADE PROFIT, GROSS -1320.00, NET -1320.60
2022-02-11T14:00:00, BUY COMPLETE, 358.95
2022-02-11T14:00:00, TRADE OPENED, SIZE 298
2022-02-11T15:00:00, SELL COMPLETE, 356.95
2022-02-11T15:00:00, TRADE PROFIT, GROSS -596.00, NET -596.60
2022-02-25T16:00:00, BUY COMPLETE, 342.84
2022-02-25T16:00:00, TRADE OPENED, SIZE 310
2022-03-04T17:00:00, SELL COMPLETE, 336.22
2022-03-04T17:00:00, TRADE PROFIT, GROSS -2052.20, NET -2052.82
2022-03-16T13:00:00, BUY COMPLETE, 332.89
2022-03-16T13:00:00, TRADE OPENED, SIZE 317
2022-04-05T19:00:00, SELL COMPLETE, 362.14
2022-04-05T19:00:00, TRADE PROFIT, GROSS 9272.25, NET 9271.62
2022-04-19T17:00:00, BUY COMPLETE, 344.80
2022-04-19T17:00:00, TRADE OPENED, SIZE 329
2022-04-26T13:00:00, SELL COMPLETE, 328.28
2022-04-26T13:00:00, TRADE PROFIT, GROSS -5435.08, NET -5435.74
2022-05-24T13:00:00, BUY COMPLETE, 288.72
2022-05-24T13:00:00, TRADE OPENED, SIZE 368
2022-08-29T14:00:00, SELL COMPLETE, 305.38
2022-08-29T14:00:00, TRADE PROFIT, GROSS 6130.88, NET 6130.14
# of Trade      :13.000
Profit Rate     :0.143
Strike Rate     :38.462
PnL net         :14301.530
Max DrawDown    :13.903 percent
Sharpe Ratio    :1.350
```

- Strategy 2 – Backtested SPY on Hourly chart data using only SuperTrend

```
**************SPY****************
Start Date:    2019-06-01 00:00:00
End Date:      2022-10-10 00:00:00
Frequency:     Hourly
===========================================================================
Hurst Exponent: False
Stop Loss:     False
Noise Reduction: False
VA Stop Loss:  False
2021-06-01T14:00:00, BUY COMPLETE, 421.30
2021-06-01T14:00:00, TRADE OPENED, SIZE 237
2021-06-03T14:00:00, SELL COMPLETE, 417.16
2021-06-03T14:00:00, TRADE PROFIT, GROSS -981.18, NET -981.65
2021-06-04T14:00:00, BUY COMPLETE, 421.25
2021-06-04T14:00:00, TRADE OPENED, SIZE 235
2021-06-16T19:00:00, SELL COMPLETE, 421.67
2021-06-16T19:00:00, TRADE PROFIT, GROSS 98.70, NET 98.23
2021-06-22T13:00:00, BUY COMPLETE, 420.78
2021-06-22T13:00:00, TRADE OPENED, SIZE 235
2021-07-06T15:00:00, SELL COMPLETE, 431.02
2021-07-06T15:00:00, TRADE PROFIT, GROSS 2406.40, NET 2405.93
2021-07-07T14:00:00, BUY COMPLETE, 433.74
2021-07-07T14:00:00, TRADE OPENED, SIZE 234
2021-07-08T14:00:00, SELL COMPLETE, 429.45
2021-07-08T14:00:00, TRADE PROFIT, GROSS -1003.86, NET -1004.33
2021-07-09T14:00:00, BUY COMPLETE, 433.58
2021-07-09T14:00:00, TRADE OPENED, SIZE 231
2021-07-15T15:00:00, SELL COMPLETE, 434.78
2021-07-15T15:00:00, TRADE PROFIT, GROSS 277.20, NET 276.74
2021-07-20T15:00:00, BUY COMPLETE, 430.22
2021-07-20T15:00:00, TRADE OPENED, SIZE 234
2021-07-27T16:00:00, SELL COMPLETE, 437.60
2021-07-27T16:00:00, TRADE PROFIT, GROSS 1726.92, NET 1726.45
2021-07-29T14:00:00, BUY COMPLETE, 440.76
2021-07-29T14:00:00, TRADE OPENED, SIZE 232
2021-08-03T13:00:00, SELL COMPLETE, 438.69
2021-08-03T13:00:00, TRADE PROFIT, GROSS -480.24, NET -480.70
2021-08-06T13:00:00, BUY COMPLETE, 441.86
2021-08-06T13:00:00, TRADE OPENED, SIZE 230
2021-08-16T14:00:00, SELL COMPLETE, 443.39
2021-08-16T14:00:00, TRADE PROFIT, GROSS 351.90, NET 351.44
2021-08-16T19:00:00, BUY COMPLETE, 446.11
2021-08-16T19:00:00, TRADE OPENED, SIZE 229
2021-08-17T14:00:00, SELL COMPLETE, 443.67
2021-08-17T14:00:00, TRADE PROFIT, GROSS -557.62, NET -558.07
2021-08-20T17:00:00, BUY COMPLETE, 443.22
2021-08-20T17:00:00, TRADE OPENED, SIZE 229
2021-08-26T15:00:00, SELL COMPLETE, 446.91
2021-08-26T15:00:00, TRADE PROFIT, GROSS 845.01, NET 844.55
2021-08-27T15:00:00, BUY COMPLETE, 449.64
2021-08-27T15:00:00, TRADE OPENED, SIZE 228
2021-09-08T15:00:00, SELL COMPLETE, 449.43
2021-09-08T15:00:00, TRADE PROFIT, GROSS -47.88, NET -48.34
2021-09-22T15:00:00, BUY COMPLETE, 437.96
2021-09-22T15:00:00, TRADE OPENED, SIZE 234
2021-09-28T14:00:00, SELL COMPLETE, 438.01
2021-09-28T14:00:00, TRADE PROFIT, GROSS 11.70, NET 11.23
2021-10-07T14:00:00, BUY COMPLETE, 440.67
2021-10-07T14:00:00, TRADE OPENED, SIZE 232
2021-10-12T14:00:00, SELL COMPLETE, 434.12
2021-10-12T14:00:00, TRADE PROFIT, GROSS -1519.60, NET -1520.06
2021-10-14T14:00:00, BUY COMPLETE, 439.58
2021-10-14T14:00:00, TRADE OPENED, SIZE 230
2021-10-28T13:00:00, SELL COMPLETE, 455.37
2021-10-28T13:00:00, TRADE PROFIT, GROSS 3631.70, NET 3631.24
2021-11-01T13:00:00, BUY COMPLETE, 460.41
2021-11-01T13:00:00, TRADE OPENED, SIZE 228
2021-11-09T19:00:00, SELL COMPLETE, 466.17
2021-11-09T19:00:00, TRADE PROFIT, GROSS 1312.87, NET 1312.41
2021-11-15T15:00:00, BUY COMPLETE, 468.56
2021-11-15T15:00:00, TRADE OPENED, SIZE 226
2021-11-23T14:00:00, SELL COMPLETE, 467.46
2021-11-23T14:00:00, TRADE PROFIT, GROSS -248.60, NET -249.05
2021-11-29T17:00:00, BUY COMPLETE, 464.49
2021-11-29T17:00:00, TRADE OPENED, SIZE 227
2021-11-30T16:00:00, SELL COMPLETE, 458.03
2021-11-30T16:00:00, TRADE PROFIT, GROSS -1466.42, NET -1466.87
2021-12-06T19:00:00, BUY COMPLETE, 460.36
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2021-12-06T19:00:00, TRADE OPENED, SIZE 226
2021-12-14T16:00:00, SELL COMPLETE, 461.65
2021-12-14T16:00:00, TRADE PROFIT, GROSS 291.54, NET 291.09
2021-12-16T14:00:00, BUY COMPLETE, 473.03
2021-12-16T14:00:00, TRADE OPENED, SIZE 222
2021-12-17T15:00:00, SELL COMPLETE, 460.45
2021-12-17T15:00:00, TRADE PROFIT, GROSS -2792.76, NET -2793.20
2021-12-21T20:00:00, BUY COMPLETE, 462.77
2021-12-21T20:00:00, TRADE OPENED, SIZE 220
2022-01-03T14:00:00, SELL COMPLETE, 476.53
2022-01-03T14:00:00, TRADE PROFIT, GROSS 3027.20, NET 3026.76
2022-01-04T15:00:00, BUY COMPLETE, 479.68
2022-01-04T15:00:00, TRADE OPENED, SIZE 218
2022-01-05T20:00:00, SELL COMPLETE, 471.70
2022-01-05T20:00:00, TRADE PROFIT, GROSS -1739.64, NET -1740.08
2022-01-11T17:00:00, BUY COMPLETE, 467.55
2022-01-11T17:00:00, TRADE OPENED, SIZE 220
2022-01-14T14:00:00, SELL COMPLETE, 460.67
2022-01-14T14:00:00, TRADE PROFIT, GROSS -1513.60, NET -1514.04
2022-01-25T14:00:00, BUY COMPLETE, 433.18
2022-01-25T14:00:00, TRADE OPENED, SIZE 231
2022-02-03T20:00:00, SELL COMPLETE, 448.26
2022-02-03T20:00:00, TRADE PROFIT, GROSS 3484.63, NET 3484.17
2022-02-09T15:00:00, BUY COMPLETE, 455.35
2022-02-09T15:00:00, TRADE OPENED, SIZE 230
2022-02-10T20:00:00, SELL COMPLETE, 449.86
2022-02-10T20:00:00, TRADE PROFIT, GROSS -1262.70, NET -1263.16
2022-02-25T14:00:00, BUY COMPLETE, 430.12
2022-02-25T14:00:00, TRADE OPENED, SIZE 242
2022-03-04T16:00:00, SELL COMPLETE, 428.51
2022-03-04T16:00:00, TRADE PROFIT, GROSS -389.62, NET -390.10
2022-03-09T17:00:00, BUY COMPLETE, 427.38
2022-03-09T17:00:00, TRADE OPENED, SIZE 242
2022-03-14T18:00:00, SELL COMPLETE, 416.71
2022-03-14T18:00:00, TRADE PROFIT, GROSS -2582.14, NET -2582.62
2022-03-16T13:00:00, BUY COMPLETE, 430.10
2022-03-16T13:00:00, TRADE OPENED, SIZE 236
2022-04-01T13:00:00, SELL COMPLETE, 453.20
2022-04-01T13:00:00, TRADE PROFIT, GROSS 5451.60, NET 5451.13
2022-04-05T13:00:00, BUY COMPLETE, 455.44
2022-04-05T13:00:00, TRADE OPENED, SIZE 232
2022-04-06T13:00:00, SELL COMPLETE, 447.01
2022-04-06T13:00:00, TRADE PROFIT, GROSS -1955.76, NET -1956.22
2022-04-19T16:00:00, BUY COMPLETE, 443.72
2022-04-19T16:00:00, TRADE OPENED, SIZE 235
2022-04-21T19:00:00, SELL COMPLETE, 439.23
2022-04-21T19:00:00, TRADE PROFIT, GROSS -1055.15, NET -1055.62
2022-05-04T18:00:00, BUY COMPLETE, 418.16
2022-05-04T18:00:00, TRADE OPENED, SIZE 247
2022-05-05T16:00:00, SELL COMPLETE, 412.33
2022-05-05T16:00:00, TRADE PROFIT, GROSS -1440.01, NET -1440.50
2022-05-13T16:00:00, BUY COMPLETE, 401.58
2022-05-13T16:00:00, TRADE OPENED, SIZE 253
2022-05-18T16:00:00, SELL COMPLETE, 396.51
2022-05-18T16:00:00, TRADE PROFIT, GROSS -1282.71, NET -1283.22
2022-05-23T16:00:00, BUY COMPLETE, 396.45
2022-05-23T16:00:00, TRADE OPENED, SIZE 253
2022-06-09T19:00:00, SELL COMPLETE, 406.61
2022-06-09T19:00:00, TRADE PROFIT, GROSS 2570.48, NET 2569.97
2022-06-22T18:00:00, BUY COMPLETE, 377.11
2022-06-22T18:00:00, TRADE OPENED, SIZE 273
2022-06-28T16:00:00, SELL COMPLETE, 384.10
2022-06-28T16:00:00, TRADE PROFIT, GROSS 1908.27, NET 1907.72
2022-07-06T19:00:00, BUY COMPLETE, 384.56
2022-07-06T19:00:00, TRADE OPENED, SIZE 273
2022-07-12T19:00:00, SELL COMPLETE, 382.51
2022-07-12T19:00:00, TRADE PROFIT, GROSS -559.65, NET -560.20
2022-07-15T14:00:00, BUY COMPLETE, 381.64
2022-07-15T14:00:00, TRADE OPENED, SIZE 273
2022-07-26T16:00:00, SELL COMPLETE, 390.61
2022-07-26T16:00:00, TRADE PROFIT, GROSS 2448.81, NET 2448.26
2022-07-27T16:00:00, BUY COMPLETE, 396.65
2022-07-27T16:00:00, TRADE OPENED, SIZE 269
2022-08-17T15:00:00, SELL COMPLETE, 425.52
2022-08-17T15:00:00, TRADE PROFIT, GROSS 7766.03, NET 7765.49
2022-08-26T13:00:00, BUY COMPLETE, 419.45
2022-08-26T13:00:00, TRADE OPENED, SIZE 273
2022-08-26T15:00:00, SELL COMPLETE, 412.76
2022-08-26T15:00:00, TRADE PROFIT, GROSS -1826.37, NET -1826.92
2022-09-02T15:00:00, BUY COMPLETE, 400.38

2022-09-02T15:00:00, TRADE OPENED, SIZE 281
2022-09-06T13:00:00, SELL COMPLETE, 394.45
2022-09-06T13:00:00, TRADE PROFIT, GROSS -1666.33, NET -1666.89
2022-09-08T15:00:00, BUY COMPLETE, 399.90
2022-09-08T15:00:00, TRADE OPENED, SIZE 278
2022-09-13T14:00:00, SELL COMPLETE, 400.91
2022-09-13T14:00:00, TRADE PROFIT, GROSS 279.39, NET 278.83
2022-10-03T19:00:00, BUY COMPLETE, 368.12
2022-10-03T19:00:00, TRADE OPENED, SIZE 302
2022-10-07T14:00:00, SELL COMPLETE, 365.54
2022-10-07T14:00:00, TRADE PROFIT, GROSS -777.65, NET -778.25
# of Trade   :40.000
Profit Rate   :0.107
Strike Rate   :45.000
PnL net   :10721.550
Max DrawDown   :9.075 percent
Sharpe Ratio   :5.905

- Strategy 3 – Backtested QQQ on Daily chart data using only SuperTrend indicator

==>QQQ
====>Supertrend+HE for During Pandemic (01 Jan 2019 - 13 Jul 2022) in on process!
2019-06-14T05:00:00, BUY COMPLETE, 182.44
2019-06-14T05:00:00, TRADE OPENED, SIZE 545
2020-02-28T06:00:00, SELL COMPLETE, 198.92
2020-02-28T06:00:00, TRADE PROFIT, GROSS 8981.60, NET 8980.51
2021-09-20T05:00:00, BUY COMPLETE, 367.46
2021-09-20T05:00:00, TRADE OPENED, SIZE 291
2022-02-09T06:00:00, SELL COMPLETE, 363.76
2022-02-09T06:00:00, TRADE PROFIT, GROSS -1076.70, NET -1077.28
2022-03-25T05:00:00, BUY COMPLETE, 359.59
2022-03-25T05:00:00, TRADE OPENED, SIZE 300
2022-04-12T05:00:00, SELL COMPLETE, 345.76
2022-04-12T05:00:00, TRADE PROFIT, GROSS -4149.00, NET -4149.60
# of Trade   :3.000
Profit Rate   :0.038
Strike Rate   :33.333
PnL net   :3753.630
Max DrawDown   :21.904 percent
Sharpe Ratio   :0.024

- Strategy 4 – Backtested SPY on Daily chart data combining SuperTrend and Hurst Exponent with Noise Reduction and Volatility Adjusted Stop Loss at 4%

==>SPY
====>Supertrend+HE+Noise Reduction+Volatility Adjusted Stop Loss for During Pandemic (01 Jan 2019 - 13 Jul 2022) in on process!
2019-07-25T05:00:00, BUY COMPLETE, 300.94
2019-07-25T05:00:00, TRADE OPENED, SIZE 331
2020-03-06T06:00:00, SELL COMPLETE, 293.15
2020-03-06T06:00:00, TRADE PROFIT, GROSS -2578.49, NET -2579.15
2020-08-05T05:00:00, BUY COMPLETE, 331.47
2020-08-05T05:00:00, TRADE OPENED, SIZE 295
2022-02-15T06:00:00, SELL COMPLETE, 443.73
2022-02-15T06:00:00, TRADE PROFIT, GROSS 33116.70, NET 33116.11
2022-08-29T05:00:00, BUY COMPLETE, 402.20
2022-08-29T05:00:00, TRADE OPENED, SIZE 322
2022-10-04T05:00:00, SELL COMPLETE, 372.40
2022-10-04T05:00:00, TRADE PROFIT, GROSS -9595.60, NET -9596.24
# of Trade   :3.000
Profit Rate   :0.209
Strike Rate   :33.333
PnL net   :20940.710
Max DrawDown   :17.445 percent
Sharpe Ratio   :0.280

Appendix B - The outputs from Backtrader for All the Strategy combinations

Applied Techniques				Results					
Hurst Exponent	Noise Reduction	Stop Loss	VA Stop Loss	#Number of Trade	Profit Rate	Strike Rate	PnL	Max Drawdown (%)	Sharpe Ratio
Time Frame: Hourly									
SPY									
				40	0.11	45.0	10722	9.08	5.91
Yes				10	0.08	60.0	8185	13.06	0.50
		Yes		40	0.11	45.0	10722	9.08	5.91
	Yes			11	-0.08	50.0	-4872	14.79	-1.75
			Yes	40	0.11	45.0	10722	9.08	5.91
Yes		Yes		12	-0.01	50.0	-1270	12.85	-0.10
Yes	Yes			11	-0.09	50.0	-5209	14.86	-1.53
Yes			Yes	10	0.08	60.0	8185	13.06	0.50
	Yes	Yes		12	-0.08	54.5	-4267	14.23	-1.83
	Yes		Yes	11	-0.08	50.0	-4872	14.79	-1.75
Yes	Yes	Yes		11	-0.08	50.0	-4518	14.25	-1.59
Yes	Yes		Yes	11	-0.09	50.0	-5209	14.86	-1.53
QQQ									
				38	0.10	50.0	9574	15.61	0.61
Yes				13	0.14	38.5	14302	13.90	1.35
		Yes		38	0.10	50.0	9574	15.61	0.61
	Yes			8	0.06	62.5	5980	15.94	0.68
			Yes	38	0.10	50.0	9574	15.61	0.61
Yes		Yes		14	0.00	35.7	427	16.11	-0.11
Yes	Yes			8	0.06	50.0	5714	16.97	0.38
Yes			Yes	13	0.14	38.5	14302	13.90	1.35
	Yes	Yes		10	0.06	60.0	5903	16.01	0.65
	Yes		Yes	8	0.06	62.5	5980	15.94	0.68
Yes	Yes	Yes		9	0.06	55.6	6362	16.46	0.47
Yes	Yes		Yes	8	0.06	50.0	5714	16.97	0.38

Applied Techniques				Results					
Hurst Exponent	Noise Reduction	Stop Loss	VA Stop Loss	#Number of Trade	Profit Rate	Strike Rate	PnL	Max Drawdown(%)	Sharpe Ratio
Time Frame: Daily									
SPY									
				20	0.13	50.0	13193	16.01	0.22
Yes				3	0.09	66.7	9257	19.73	0.13
		Yes		20	0.13	50.0	13193	16.01	0.22
	Yes			3	0.17	33.3	16905	21.92	0.22
			Yes	20	0.13	50.0	13193	16.01	0.22
Yes		Yes		4	0.20	50.0	20098	11.24	0.32
Yes	Yes			3	0.21	33.3	20941	17.45	0.28
Yes			Yes	3	0.09	66.7	9257	19.73	0.13
	Yes	Yes		7	0.16	42.9	15657	23.24	0.20
	Yes		Yes	3	0.17	33.3	16905	21.92	0.22
Yes	Yes	Yes		5	0.24	60.0	23946	15.61	0.34
Yes	Yes		Yes	3	0.21	33.3	20941	17.45	0.28
QQQ									
				13	0.55	61.5	54987	19.94	0.80
Yes				3	0.04	33.3	3754	21.90	0.02
		Yes		14	0.55	57.1	54966	19.95	0.80
	Yes			3	0.14	33.3	14077	30.97	0.19
			Yes	13	0.55	61.5	54987	19.94	0.80
Yes		Yes		3	0.01	33.3	954	23.27	-0.06
Yes	Yes			3	0.12	50.0	30095	28.31	0.17
Yes			Yes	3	0.04	33.3	3754	21.90	0.02
	Yes	Yes		8	0.16	25.0	16024	28.00	0.21
	Yes		Yes	3	0.14	33.3	14077	30.97	0.19
Yes	Yes	Yes		5	0.18	20.0	17902	28.58	0.23
Yes	Yes		Yes	3	0.12	50.0	30095	28.31	0.17