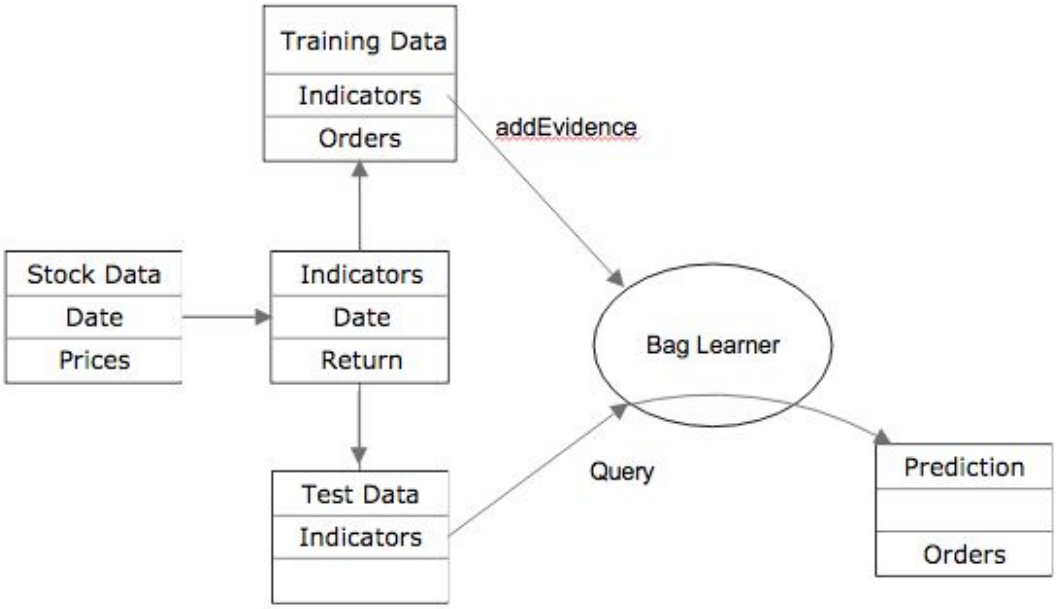
Assignment: Strategy Learner

Part 1: Strategy Learner Design

The design is based on a Bag Learner of Decision Trees, both of which were developed and implemented in the assignment 'assess learners'. The design of the Strategy Learner class is illustrated below:



1. **process()** method: This method take stock data as input and processed data as output, which includes **Indicators** (Momentrum, SMAP,BBP) based on the backward window, **Orders**[-1, 1] based on a Order_threshold cutting off the **Returns**, which is calculated based on the forward window. Order_threshold, Backward window and forward window can be adjusted so that we can optimize the input data quality.
2. **addEvidence()** method: This method implements the machine learning process. In this method, a Bag Learner of 20 Decision Tree learners was adopted as the machine learning component. To fulfill the assignment requirement, the leaf size of the Decision Trees are set to 5. The learning process take the **Indicators** as the features and the **Orders** as the target. This method take the stock price data as input, by calling the **process()** method to generate training data, then train the Bag Learner with this training data. After these steps, the model training is completed.
3. **testPolicy()** method: This method implements the prediction process. In this method, the trained Bag Learner takes the Indicators as the features and generate the predicted **Orders** [-1, 1]. The method generates the test data by calling the **process()** method.

Then it predict the **Orders**[-1,1] with the Bag Learner model. At last it calls the **order_generate()** method to generate order in required format and range[-2000, 2000].

4. **order_generate()** method: This method take the **Order**[-1,1] from the prediction process as input data. This method is the data adjustation process in the assignment. Because the predicted data, Order[-1,1] is a continuous number between -1 to 1, this method discretize the number into three integers -1, 0, 1 by comparing them with parameters, which indicate sell, hold and buy. It uses two parameters, buy_trigger and sell_trigger, to generate buy and sell orders, so we can generate optimized output by adjusting these parameters. It generate the order data as output in required format and range[-2000, 2000], which is the return output of the **testPolicy()** method.

For Your Reference:

Momentum: *The ratio of equity price between a fixed time interval. It can be calculated as Pt/Pt-n,where Pt is the price of the equity at time t, Pt-n is the price of the equity at n days before time t.*
SMAP: *The percentage of the equity price outperform(underperform) the Simple Moving Average(SMA). It can be calculated as (Pt/SMA)-1, where Pt is the price of the equity at time t, SMA is the simple moving average price of the equity at time t. SMA is the moving average of the equity price in previous n days. It can be calculated as (i=t-ntPi)/n, Piis the equity price at time t, n is the time interval in days.*
BBP: *The ratio of the equity performance over the Bollinger Band. It can be calculated as Pt-Lower BandUpper Band-Lower Band . Moving standard deviation is calculated as (i=t-nt(Pi-SMA)2)/n, Lower Band is calculated as SMA+2, Upper Band is calculated as SMA-2.*

Part 2: Experiment 1

The experiment is implemented in the script experiment1.py.
When experiment1.py runs:

ms_testStrategy(symbol='JPM', sd=dt.datetime(2008, 1, 1), ed=dt.datetime(2009, 12, 31), sv=100000)

experiment with the Manual Strategy.

testStrategy(symbol='JPM', sd=dt.datetime(2008, 1, 1), ed=dt.datetime(2009, 12, 31), sv=100000)

experiment with the Strategy Learner strategy.

1.Manual Rule-Based Trader

The idea behind the manual strategy is a combination of three indicators described above: Momentum, SMAP, BBP.

The reasoning behind the Manual Rule is that:
If the momentum is less than zero, or SMAP is less than -0.05 and the BBP is less than 0, it means the stock is reaching outside the Bollinger lower band and it is very likely to bounce back and there is a chance to make profit by longing the stock;
If the momentum is great than zero, or SMAP is larger than 0.05 and the BBP is larger than 1, it means the stock is reaching outside the Bollinger upper band and it is very likely to bounce back and there is a chance to make profit by shorting the stock.
The Manual Rule is implemented as follows:

```
If Momentum < 0 or SMAP < -0.05 and BBP < 0 Then:
    Buy stocks till the position is long 1000
Else If Momentum > 0 and SMAP > 0.05 and BBP > 1 Then:
    Sell stocks till the position is short 1000
Else
    Do nothing
```

Experiment: Develop the strategy with the manual rule for the ‘JPM’ stock during the period from 2008-Jan-01 to 2009-Dec-31 with initial cash of 100,000. Compare the portfolio value of the trading strategy and the value of holding 1000 shares of the stock ‘JPM’.

Output:
Strategy:

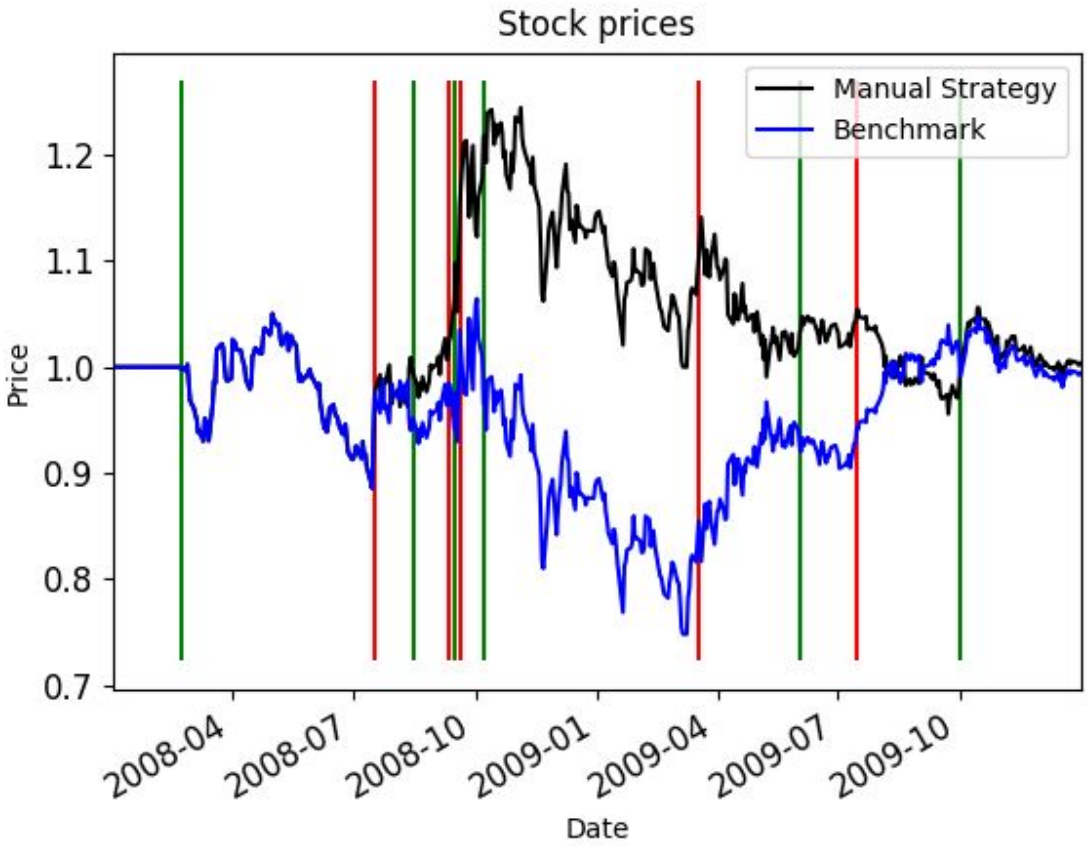
	Date	Symbol	Order	Shares
0	2008-02-22	JPM	BUY	1000
1	2008-07-17	JPM	SELL	2000
2	2008-08-15	JPM	BUY	2000
3	2008-09-11	JPM	SELL	2000
4	2008-09-15	JPM	BUY	2000
5	2008-09-19	JPM	SELL	2000
6	2008-10-07	JPM	BUY	2000
7	2009-03-18	JPM	SELL	2000
8	2009-06-03	JPM	BUY	2000
9	2009-07-15	JPM	SELL	2000
10	2009-10-01	JPM	BUY	2000

Performance Criteria:
Cumulative return of the benchmark is -0.005803
Cumulative return of the portfolio is 0.003507

Stdev of the daily return of the benchmark is 0.016988
Stdev of the daily return of the portfolio is 0.014568

Mean of the daily return of the benchmark is 0.000132
Mean of the daily return of the portfolio is 0.000112

Performance Chart:



The chart above reports the Benchmark value normalized to 1.0 with Blue line and the best possible portfolio value normalized to 1.0 with black line. The green vertical line indicates the enter point and the red vertical line indicates the exit point.

2.Strategy Learner Trader

The idea behind the Strategy Learner is that, by learning the relationship of the indicators described above: Momentum, SMAP, BBP and the Orders based on futures return on historical data, the Strategy Learner can predict future Orders based on current Indicators.

The Strategy Learner trading experiment is implemented exactly the same with the Manual Strategy trading experiment except the Orders are generated based on model prediction with the Indicators.

Experiment: Develop the strategy with the Strategy Learner for the ‘JPM’ stock during the period from 2008-Jan-01 to 2009-Dec-31 with initial cash of 100,000. Compare the portfolio value of the trading strategy and the value of holding 1000 shares of the stock ‘JPM’.

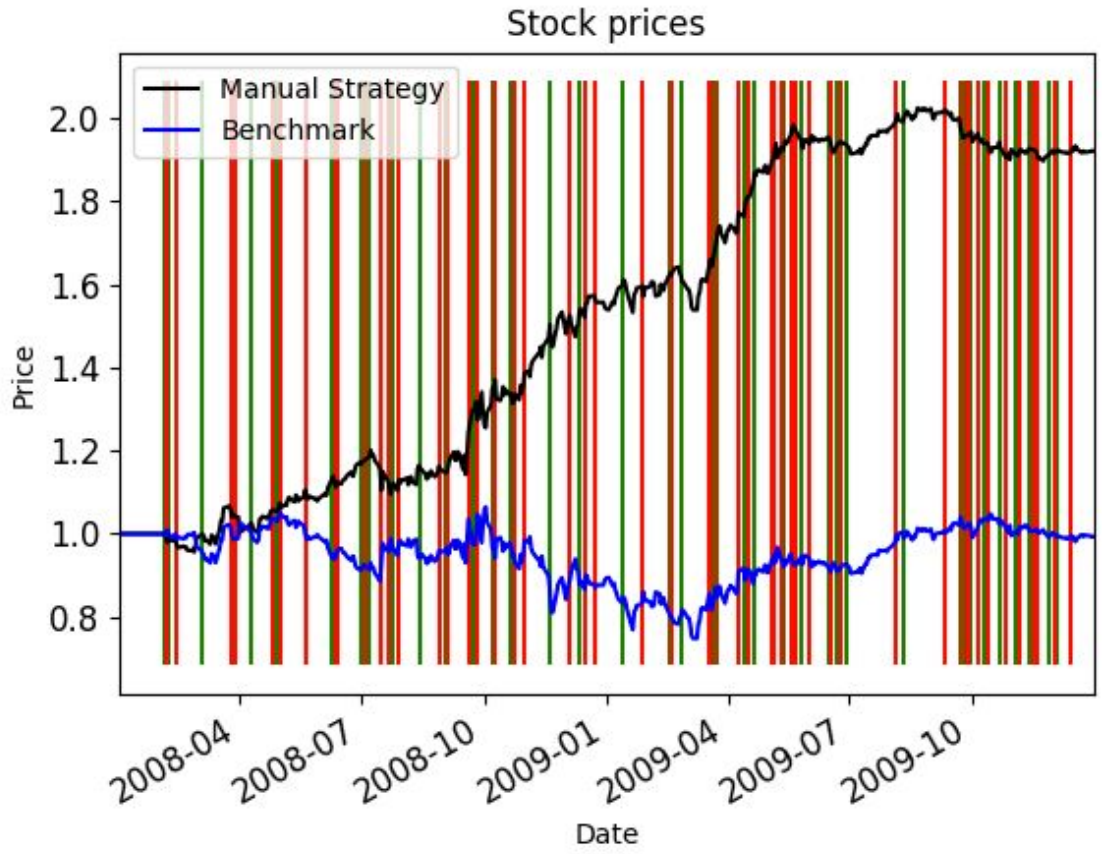
In this experiment, the Strategy Learner is trained with ‘JPM’ data from 2008-Jan-01 to 2009-Dec-31 and tested with the same data. The back window is set to 21 for the Indicators and the forward window is set to 10 for the Return and Orders. The buy_trigger is set to 0.05, the sell_trigger is set to -0.05 and the order_threshold is set to 0.05. These setting makes the model very sensitive to Indicators, as a result, frequent Orders are generated.

Output:
Strategy:
The trading strategy is

	Date	Symbol	Order	Shares
0	2008-02-05	JPM	BUY	1000.0
1	2008-02-06	JPM	SELL	2000.0
2	2008-02-08	JPM	BUY	2000.0
3	2008-02-14	JPM	SELL	2000.0
4	2008-03-04	JPM	BUY	2000.0
5	2008-03-26	JPM	SELL	2000.0
6	2008-03-27	JPM	BUY	2000.0
7	2008-03-28	JPM	SELL	2000.0
8	2008-04-10	JPM	BUY	2000.0
9	2008-04-25	JPM	SELL	2000.0
10	2008-04-28	JPM	BUY	2000.0
11	2008-05-02	JPM	SELL	2000.0
12	2008-05-20	JPM	BUY	2000.0
13	2008-05-21	JPM	SELL	2000.0
14	2008-06-09	JPM	BUY	2000.0
15	2008-06-11	JPM	SELL	2000.0
16	2008-06-12	JPM	BUY	2000.0
17	2008-06-13	JPM	SELL	2000.0
18	2008-07-01	JPM	BUY	2000.0
19	2008-07-03	JPM	SELL	2000.0
85	2009-10-13	JPM	SELL	2000.0
86	2009-10-22	JPM	BUY	2000.0
87	2009-10-26	JPM	SELL	2000.0
88	2009-11-02	JPM	BUY	2000.0
89	2009-11-05	JPM	SELL	2000.0
90	2009-11-13	JPM	BUY	2000.0
91	2009-11-16	JPM	SELL	2000.0
92	2009-11-18	JPM	BUY	2000.0
93	2009-11-19	JPM	SELL	2000.0
94	2009-11-27	JPM	BUY	2000.0
95	2009-12-01	JPM	SELL	2000.0
96	2009-12-03	JPM	BUY	2000.0
97	2009-12-14	JPM	SELL	2000.0

Performance Criteria:
Cumulative return of the benchmark is
-0.005401
Cumulative return of the portfolio is
0.919703
Stdev of the daily return of the benchmark is
0.01702
Stdev of the daily return of the portfolio is
0.011314
Mean of the daily return of the benchmark is
0.000133
Mean of the daily return of the portfolio is
0.001358

Performance Chart:



The chart above reports the Benchmark value normalized to 1.0 with Blue line and the best possible portfolio value normalized to 1.0 with black line. The green vertical line indicates the enter point and the red vertical line indicates the exit point.

Conclusion:
Because the cumulative return of the portfolio of the Manual Strategy is 0.003507 compared to the cumulative return of the benchmark of -0.005803. The manual rule strategy outperformed the benchmark over the in sample period.
Because the cumulative return of the portfolio of the Strategy Learner strategy is 0.919703 compared to the cumulative return of the benchmark of -0.005401. The Strategy Learner strategy outperformed the benchmark over the in sample period.

However, because the Strategy Learner used the past data as input for Indicators and future data as input for Orders in training process. So we have different time frame when comparing the Manual Strategy and the Strategy Learner Strategy. But the Strategy Learner strategy is 0.919703 in the cumulative return compared to 0.003507 of the cumulative return of Manual Strategy, which is highly more profitable even take into account the little time frame difference.

Would I expect this relative result every time with in-sample data?

The answer is I will get different result every time. Because I wrapped up the training and prediction process in one test scripts. Every time the experiment1.py script is run. The Strategy Learner will be trained with the same data. However, the implementation of the Bag Learner adopted the Bootstrap aggregating methods, which means the training instances are sampled with replacement and the model will be different each time when it is trained.
As a result, the output and the final portfolio value will be different each time.

Part 3: Experiment 2

The experiment is implemented in the script experiment2.py.
When experiment2.py runs:

```
ms_testStrategy(symbol='JPM', sd=dt.datetime(2008, 1, 1), ed=dt.datetime(2009, 12, 31), sv=100000)
```

experiment with the Manual Strategy.

```
sl_testStrategy(symbol='JPM', sd=dt.datetime(2008, 1, 1), ed=dt.datetime(2009, 12, 31), sv=100000)
```

experiment with the Strategy Learner strategy.

Hypothesis: The increase of the value of *impact* will be disadvantageous to trading activity. The *impact* metrics is the prices inverse change caused by the trading activity. So the increase of the value of *impact* will reduce the trading strategy's cumulative return.

1.Manual Rule-Based Trader

Experiment: Use the same strategy from experiment but increase the value of *impact* by 10 times, which becomes 0.05 compared to 0.005 in experiment 1. Develop the strategy with the manual rule for the 'JPM' stock during the period from 2008-Jan-01 to 2009-Dec-31 with initial cash of 100,000. Compare the portfolio value of the trading strategy and the value of holding 1000 shares of the stock 'JPM'.

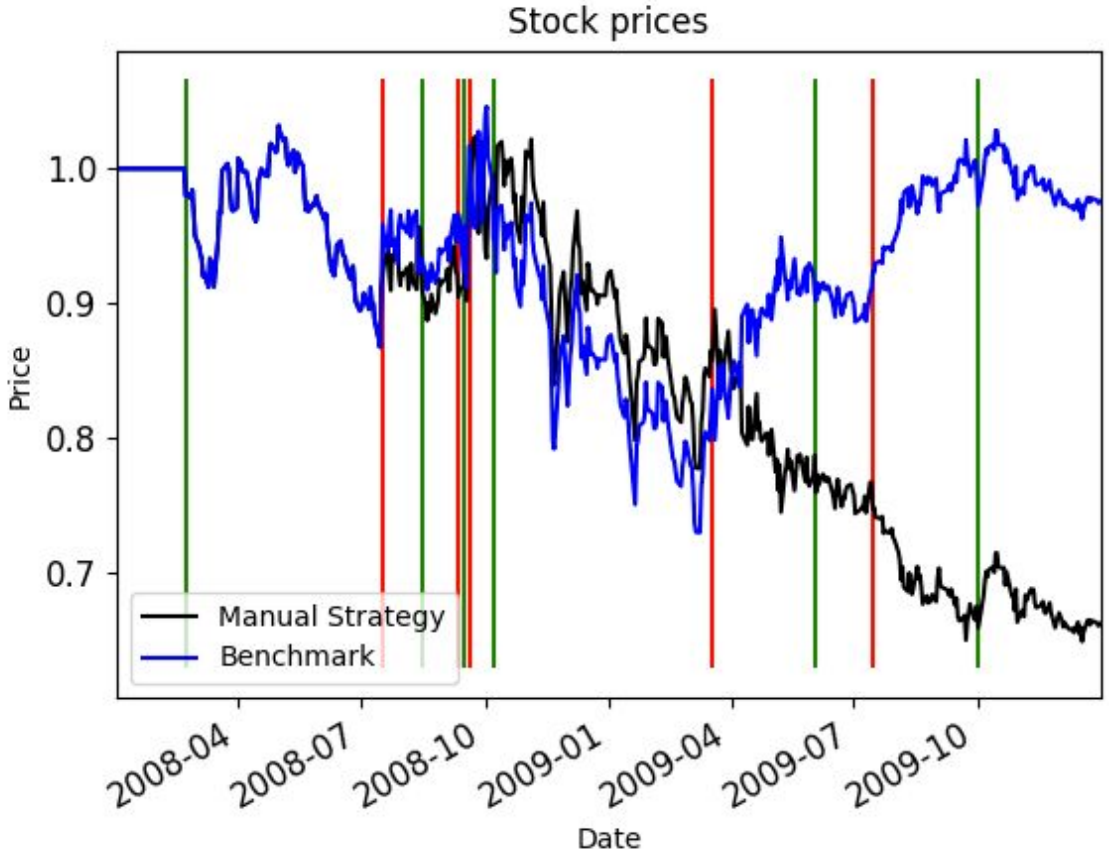
Output:
Strategy:

	Date	Symbol	Order	Shares
0	2008-02-22	JPM	BUY	1000
1	2008-07-17	JPM	SELL	2000
2	2008-08-15	JPM	BUY	2000
3	2008-09-11	JPM	SELL	2000
4	2008-09-15	JPM	BUY	2000
5	2008-09-19	JPM	SELL	2000
6	2008-10-07	JPM	BUY	2000
7	2009-03-18	JPM	SELL	2000
8	2009-06-03	JPM	BUY	2000
9	2009-07-15	JPM	SELL	2000
10	2009-10-01	JPM	BUY	2000

Performance Criteria:

Cumulative return of the benchmark is -0.023834
Cumulative return of the portfolio is -0.337579
Stdev of the daily return of the benchmark is 0.017353
Stdev of the daily return of the portfolio is 0.0174
Mean of the daily return of the benchmark is 0.000102
Mean of the daily return of the portfolio is -0.000666

Performance Chart:



The chart above reports the Benchmark value normalized to 1.0 with Blue line and the best possible portfolio value normalized to 1.0 with black line. The green vertical line indicates the enter point and the red vertical line indicates the exit point.

2.Strategy Learner Trader

Experiment: Use the same strategy from experiment but increase the value of *impact* by 10 times, which becomes 0.05 compared to 0.005 in experiment 1.

Output:

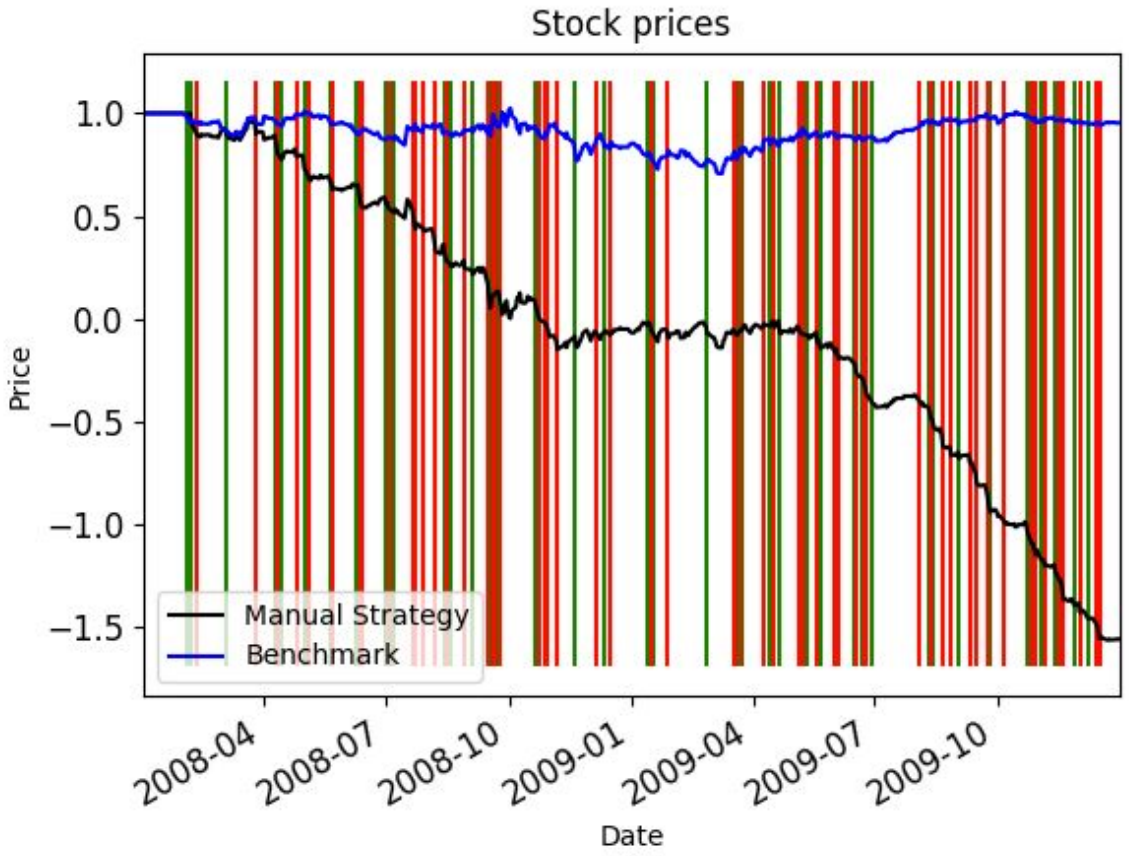
Strategy:

Date Symbol Order Shares

0	2008-02-05	JPM	BUY	1000.0
1	2008-02-06	JPM	SELL	2000.0
2	2008-02-08	JPM	BUY	2000.0
3	2008-02-14	JPM	SELL	2000.0
4	2008-03-04	JPM	BUY	2000.0
5	2008-03-26	JPM	SELL	2000.0
6	2008-03-27	JPM	BUY	2000.0
7	2008-03-28	JPM	SELL	2000.0
8	2008-04-10	JPM	BUY	2000.0
9	2008-04-25	JPM	SELL	2000.0
10	2008-04-28	JPM	BUY	2000.0
11	2008-05-02	JPM	SELL	2000.0
12	2008-05-20	JPM	BUY	2000.0
13	2008-05-21	JPM	SELL	2000.0
14	2008-06-09	JPM	BUY	2000.0
15	2008-06-11	JPM	SELL	2000.0
16	2008-06-12	JPM	BUY	2000.0
17	2008-06-13	JPM	SELL	2000.0
18	2008-07-01	JPM	BUY	2000.0
19	2008-07-03	JPM	SELL	2000.0
85	2009-10-13	JPM	SELL	2000.0
86	2009-10-22	JPM	BUY	2000.0
87	2009-10-26	JPM	SELL	2000.0
88	2009-11-02	JPM	BUY	2000.0
89	2009-11-05	JPM	SELL	2000.0
90	2009-11-13	JPM	BUY	2000.0
91	2009-11-16	JPM	SELL	2000.0
92	2009-11-18	JPM	BUY	2000.0
93	2009-11-19	JPM	SELL	2000.0
94	2009-11-27	JPM	BUY	2000.0
95	2009-12-01	JPM	SELL	2000.0
96	2009-12-03	JPM	BUY	2000.0
97	2009-12-14	JPM	SELL	2000.0

Performance Chart:

Cumulative return of the benchmark is
-0.045779
Cumulative return of the portfolio is
-2.556675
Stdev of the daily return of the benchmark is
0.017858
Stdev of the daily return of the portfolio is
0.657878
Mean of the daily return of the benchmark is
0.000066
Mean of the daily return of the portfolio is
0.062297



The chart above reports the Benchmark value normalized to 1.0 with Blue line and the best possible portfolio value normalized to 1.0 with black line. The green vertical line indicates the enter point and the red vertical line indicates the exit point.

Conclusion:
Because the cumulative return of the portfolio of the Manual Strategy is -0.337579 compared to the cumulative return of the benchmark of -0.023834. The manual rule strategy underperformed the benchmark over the in sample period.
Because the cumulative return of the portfolio of the Strategy Learner strategy is -2.556675 compared to the cumulative return of the benchmark of -0.045779. The Strategy Learner strategy underperformed the benchmark over the in sample period.

However, because the Strategy Learner used the past data as input for Indicators and future data as input for Orders in training process. So we have different time frame when comparing the Manual Strategy and the Strategy Learner Strategy. But the Strategy Learner strategy is -2.556675 in the cumulative return compared to -0.337579 of the cumulative return of Manual Strategy, which loss much more even take into account the little time frame difference.

We can prove that the increase of the value of the impact metrics, frequent trading activity from strategies will be much less profitable and even turn to huge loss.
