CS 7646 ML4T
Project 8: Strategy Evaluation

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1 INTRODUCTION:

This project studies 5 stock indicators and use them to create a manual trading strategy and a strategy learner. The manual strategy is tweaked and optimized over an in-sample trading period and applied to an out-of-sample period. The strategy learner is trained over the in-sample period, and compared with the manual strategy and a benchmark trade. The project also discussed the effect of changing impact on learner strategy performance over the in-sample period. The overall results shows the strategy learner can consistently out perform the manually rule-based strategy, and the increasing of impact can significantly declines the performance of the learner strategy.

2 INDICATOR OVERVIEW:

The stock indicators that used in this project are the Bias Ratio ($BIAS$), Bollinger Bands® value ($BOLL$), Momentum Index (MTM), the moving average convergence/divergence (the MACD line DIF, and the signal line DEA).

The N-day Bias Ratio is defined as:

$$BIAS(N) = \frac{price[t] - SMA(N)}{SMA(N)} \times 100\% \tag{1}$$

where the parameter N is used to calculate the N-day simple moving average of the closing price, $SMA(N)$. In this project, N is set to 12.

The Bollinger Band value is defined as:

$$BOLL(N, M) = \frac{price[t] - SMA(N)}{M \times \sigma(N)[t]} \tag{2}$$

Here, the Bollinger Band is calculated based on N-day simple moving average of the closing price $SMA(N)$, and M defines the bandwidth, $\sigma(N)$ is the standard deviation of last N-day closing price. In this project, the parameters are set to $N = 20$, and $M = 2$.

The N-day Momentum rate is defined as N-day closing price difference rate:

$$MTM(N) = \frac{price[t] - price[t-N]}{price[t-N]} \tag{3}$$

where $price[t-N]$ is the closing price of N-days before. In this project, the 12-day Momentum rate is chosen as an indicator, $N = 12$.

The moving average convergence/divergence (MACD) indicator is used to analyze the market trend and consist of three components: the MACD line (DIF), the signal line (DEA), and the histogram ($DIF - DEA$). Here, only the MACD line (DIF) and the signal line (DEA) are used as the indicators to create the trading signals.

The MACD line is defined as:

$$DIF[t] = EMA(N)[t] - EMA(M)[t] \tag{4}$$

where $EMA(N)$ represents the exponential moving average of the last N-day closing price. In this project, the classical parameter settings are used, which are $N = 12$, and $M = 26$.

The signal line is the L-day exponential moving average of DIF, defined as:

$$DEA[t] = DIF.EMA(L)[t] \tag{5}$$

In this project, the classical parameter setting is used as $L = 9$.

3 MANUAL STRATEGY:

Based on the features of indicators that are described in the previous part, simple trading signals are first created for each indicator, then combined together to create an overall trading signal and build the manual strategy. The simple signals for each indicators are set as below:

1. For 12-day Bias Ratio, $BIAS(12)$, when it's above 5, the stock price is 5% higher than the 12-day moving average price. The stock price is highly possible to go down in the next period. It creates a short signal when $BIAS(12) > 5$. In contrast, a long signal is created when $BIAS(12) < -5$.
2. When Bollinger Bands® value ($BOLL(20, 2)$) is higher than 1 or lower than -1, the price deviates more than 2 standard deviation of the simple moving average and is out of the band. It's a good signal to trade when the price goes into the band. Here, a short signal is created when $BOLL(20, 2)$ goes from

above 1 to below 1, and a long signal is created when $BOLL(20, 2)$ goes from below -1 to above -1.

3. The 12-day momentum indicates the price difference ratio between present price and the price on 12 days before. It represents the price trend in a short period. When the $MTM(12)$ goes from positive to negative, the current price is at a low region, then a long signal is created. When it goes from negative to positive, the price is at a high region, a short signal is created.
4. The DIF indicator is measures the divergence between the fast exponential moving average $EMA(12)$ and the slow moving average $EMA(26)$. Therefore, in the continuing rally, the 12-day EMA is above the 26-day EMA. The positive deviation DIF during this period will become larger. Conversely, in a downtrend, the deviation value may become negative DIF and smaller. As for the market start to turn, the positive or negative deviation must be reduced to a certain extent before it is the real signal of the market reversal. The MACD reversal signal DEA is defined as the 9-day moving average (9-day DIF) of the "divergence value". When DIF and DEA are both greater than 0 and move upward, it is generally expressed as the market is in a long market, and a long position is created. When DIF and DEA are both less than 0 and move down, it is generally indicated that the market is in a short market, and a short position is created. When DIF and DEA are both greater than 0 but both move downward, it is generally indicated that the market is in a downward phase, and a short position is created. When both DIF and DEA are less than 0 but move upward, it generally means that the market is about to rise, and the stock will rise. A long position is created.

Since the 4 conditions are relatively independent, any one of these conditions can trigger a position change independently. Thus, combining the $BIAS(12)$, $BOLL(20, 2)$, $MTM(12)$, DIF, and DEA, the overall manual strategy is created as:

$$(1.)or(2.)or(3.)or(4.) \tag{6}$$

Figure 1 shows the in-sample comparison of Benchmark portfolio value and the Manual Strategy portfolio value on trading JPM stock. Here, both of the two values are start with $100,000 cash and normalized to 1.0 at the start. The Benchmark marked as green line invests 1000 shares of JPM and holding the position to the end of the trading period. The Manual Strategy marked as red line has a position limitation. The allowable positions are: 1000 shares long, 1000

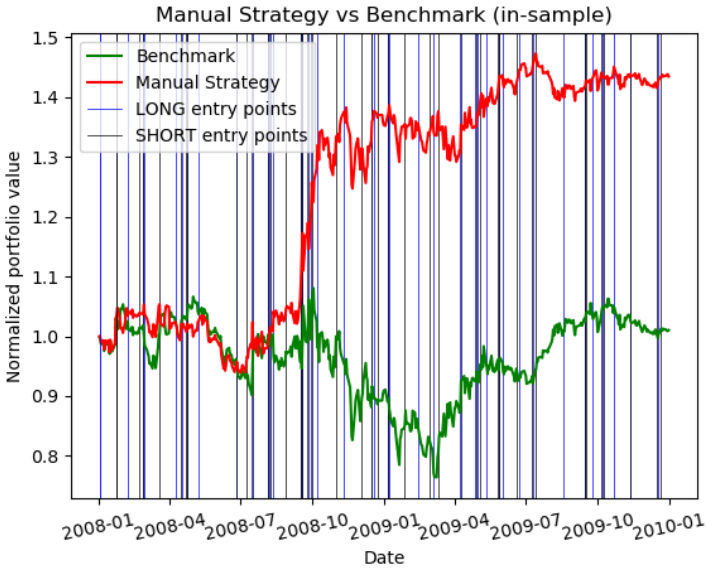

Figure 1—Value of manual strategy portfolio vs benchmark for in-sample period.

shares short, and 0 shares. The in-sample trading period is from January 1st, 2008 to December 31st, 2009. The commission is $9.95, and the impact is 0.005. In Figure 1, the vertical blue lines indicate the long entry points, and the vertical black lines indicate the short entry points.

As it shows, the Manual Strategy obtained a cumulative return of 43.4% during the in-sample period and beats the Benchmark with the cumulative return of 12.3%. The rule-based strategy outperforms the benchmark over the in-sample period.

Figure 2 compares the performance of the Manual Strategy versus the Benchmark for the in-sample and out-of-sample time periods. The out-of-sample period is from January 1st, 2010 to December 31st, 2011.

As it shows, the cumulative return of Manual Strategy does not beat the Benchmark during the out-of-sample period. The manual strategy which tweaked rules over the in-sample period does not work well over the out-of-sample period.

Figure 3 evaluates the out-of-sample performance of the Manual Strategy on trading JPM stock. The Manual Strategy rules used for out-of-sample period are

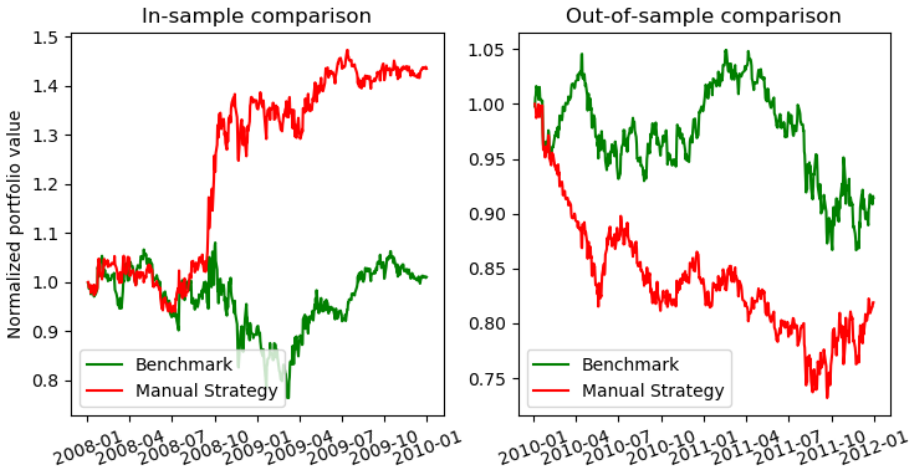

Figure 2—Performance of the Manual Strategy versus the Benchmark for the in-sample and out-of-sample time periods.

same as the in-sample period.

As it shows, the Manual Strategy obtained a cumulative return of -18.1% over the out-of-sample period and the Benchmark obtained -8.4%. The rule-based strategy does not work better than the benchmark over the out-of-sample period.

Tabel 1 summarizes the performance of the stock and the Manual Strategy for both in-sample and out-of-sample periods.

Table 1—Performance of the stock, and the Manual Strategy for both in-sample and out-of-sample periods

	Benchmark (in-sample)	**Manual Strategy (in-sample)**	**Benchmark (out-of-sample)**	**Manual Strategy (out-of-sample)**
Cumulative return	0.0123249	0.4344425	-0.0835791	-0.180998
STDEV of daily returns	0.0170246	0.0129327	0.00849217	0.00953103
Mean of daily returns	0.000164419	0.000797914	-0.000141408	-0.000350749
Sharpe ratio	0.153311	0.979416	-0.264336	-0.584194

As it shows for Manual Strategy, the in-sample period has higher cumulative returns, mean of daily returns and Sharpe ratio than the out-of-sample period. This is mainly because the trading rules are tweaked to have higher returns over the in-sample period, and do not optimize for out-of-sample period. Another reason is because the stock itself performs better over the in-sample period as

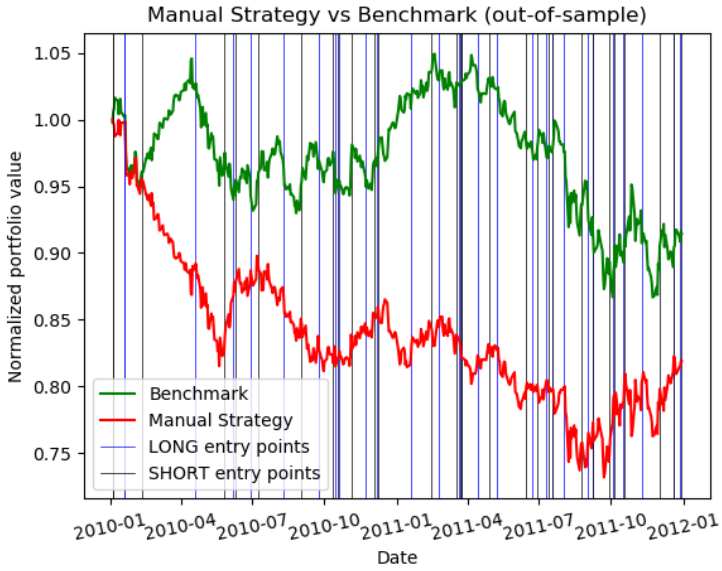

Figure 3—Value of manual strategy portfolio vs benchmark for out-of-sample period.

shown with the Benchmark performance. The standard deviation of daily returns of the in-sample and out-of-sample period for Manual Strategy are close. This is because the stand deviation are not considered when tweaking rules for better in-sample performance.

4 STRATEGY LEARNER:

In this project, a bag learner containing 20 random tree learners is utilized to construct as a strategy leaner to train and test a learning trading algorithm. The learning trading algorithm first assigns 20 random decision trees, then train the trees with the same training data set. The input of the training set consists of five indicators $\mathrm{BIAS}(12)$, $\mathrm{BOLL}(20,2)$, $\mathrm{MTM}(12)$, DIF, and DEA of the trading stock over the in-sample period. The target of the training set consists of the trading positions LONG, CASH, and SHORT. The position is separated based on 3-day returns of the stock. After finishing training, the trading positions based on the learner strategy can be obtained by query the trees and returning the mode of results from the 20 trees. Using the queried trading positions, a corresponding order book is created finally.

In order to change random tree regression learner into a classification learner, discretizing the target data is a crucial step for classification. The input values

are simply the values of your indicators for the stock. The target data is based on 3-day returns. The examples are classified as LONG if the 3-day return exceeds a BUY threshold. The examples are classified as SHORT if the 3-day return is below a SELL threshold. Otherwise, the sample should be classified as a CASH. The input values are calculated each day from the current day's and earlier data, and the target value is calculated using data from the future.

The trading algorithm has three hyperparameters: SELL and BUY threshold, leaf size, and the number of bags. The SELL and BUY threshold separates the LONG, CASH, and SHORT positions. Because the target of the training set is based on the 3-day return, the learner can learn a short-term trading strategy. For 3-day return, 1% price change is enough to generate a trading signal and gain a considerable profit, the SELL threshold is set to 1% and the BUY threshold is set to -1%.

The leaf size is set for limit the maximum number of samples that are assigned to a leaf of a decision tree. Reducing the leaf size can significantly increase the cumulative return over in-sample period as the trading decision match more precisely. However, the small leaf size may generate overfit problem. In order to avoid this, the leaf size is required to set larger than 5. After trying from 5 to 20, the leaf size with maximum cumulative return over the out-of-sample period is chosen, which is 10.

The number of bags is another hyperparameter which decides how many trees are contained in the bag learner. Increasing the number of bags can eliminate the bias from each single tree. However, too large number will cost too long to train and is not efficient to make sufficient change. After trying from 10 to 50, the number of bags is chosen to be 20 as an efficient number in this project.

5 EXPERIMENT 1 (MANUAL STRATEGY / STRATEGY LEARNER):

In this experiment, the Manual Strategy, the Learner Strategy and the Benchmark are compared in-sample trading JPM. The in-sample period is January 1, 2008 to December 31, 2009. The starting cash is $100,000. The allowable positions are: 1000 shares long, 1000 shares short, 0 shares. The transaction costs are: Commission: $9.95, Impact: 0.005. The Benchmark portfolio starts with $100,000 cash, invests in 1000 shares of the symbol in use on the first trading day, and holding that position.

Figure 4 compares the portfolio returns of the Manual Strategy with the Strategy Learner. In Figure 4, the Benchmark is marked as green line, the Manual Strategy marked as red line, the Learner Strategy. All the portfolio values are normalized to 1.0 at the start. The Strategy Learner obtained the highest cumulative returns of 109.5% over the period while the Manual Strategy gained 43.4%, and the Benchmark only has 1.0%. For the Strategy Learner, the portfolio value continually rise as a whole. As a comparison, the Manual Strategy has dramatic increases in some short periods while in most of the period is not as well as the Strategy Learner. This is because the Strategy Learner randomly choose the indicators as the features to split the decision tree and return the mode of 20 random trees. The random process eliminates the bias from a single indicator or a single decision tree.

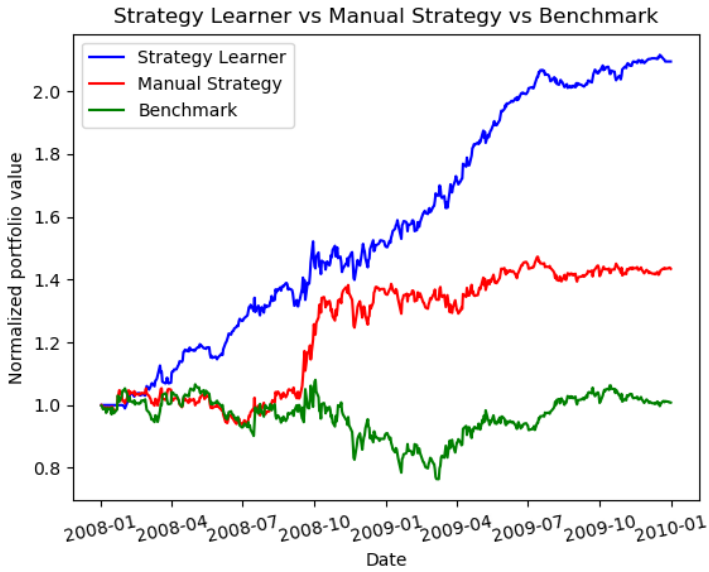

Figure 4—Portfolio value comparison of Strategy Learner, Manual Strategy, and Benchmark over in-sample period.

Table 2 summarizes the overall performance of the experiment. The Strategy Learner consistently has the highest cumulative return, mean of daily return, and Sharpe ratio over the in-sample period.

6 EXPERIMENT 2 (STRATEGY LEARNER):

In this experiment, how changing the value of impact should affect in-sample trading behavior is shown with the Strategy Learner. The stock JPM is trade on

Table 2—Strategy Learner performance with changing impact over in-sample period

Strategy	Cumulative return	STDEV of daily returns	Mean of daily returns	Sharpe ratio
Strategy Learner	1.095278	0.01014929	0.00151712	2.372933
Manual Strategy	0.4344425	0.01293270	0.000797914	0.979416
Benchmark	0.0102362	0.01702459	0.000160328	0.149497

the in-sample period with a commission of $0.00.

The impact increases transaction costs. For each trade, the transaction fee is deducted from the portfolio value at the ratio of impact. Thus, the higher trading frequency will affected more by the impact. The cumulative return will significantly decrease by increasing the impact on the same strategy. Figure 5 shows the normalized portfolio values of the Strategy Learner over the in-sample period under the effect of changing impact. The cumulative return starts at 166.4% with impact of 0, drop down to -54.0% with impact of 0.02.

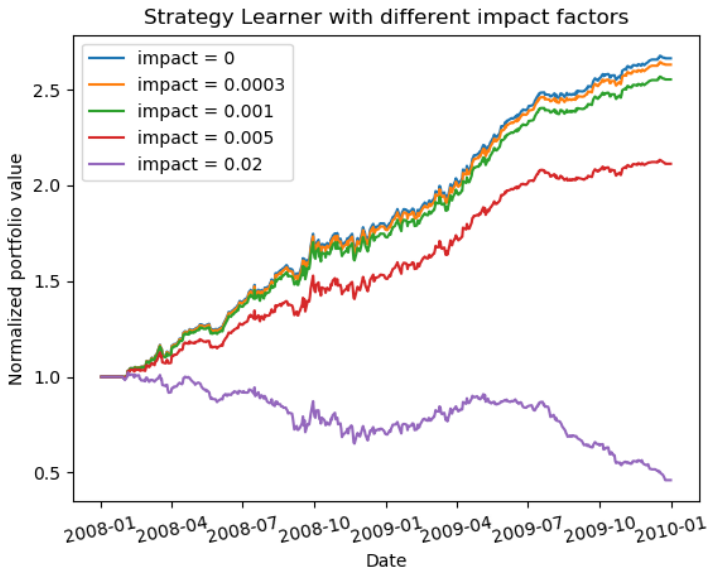

Figure 5—Portfolio value comparison of Strategy Learner with changing impact over in-sample period.

Table 3 shows the cumulative return, the standard deviation of daily returns, the mean of daily returns, and the Sharpe ratio over the in-sample period. As it

shows in the table 3, the cumulative return, the mean of daily returns and the Sharpe ratio decreases with increase of impact, and the standard deviation of daily returns increase with increase of impact.

Table 3—Strategy Learner performance with changing impact over in-sample period

Impact	**Cumulative return**	**STDEV of daily returns**	**Mean of daily returns**	**Sharpe ratio**
0.0	1.66360	0.00921526	0.001984113	3.417899
0.0003	1.63055	0.00925843	0.001959742	3.360175
0.001	1.55344	0.00936391	0.001901698	3.223924
0.005	1.11279	0.01011428	0.001533274	2.406496
0.02	-0.53964	0.01840538	-0.001365612	-1.177831