ML4T - Assignment 6 - Manual Strategy

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1 Introduction

Technical analysis is a technique employed "to evaluate investments and identify trading opportunities by analyzing statistical trends gathered from trading activity".[1] In this assignment, we will consider three indicators and evaluate their usage in through a manual investment strategy. This strategy will be compared to the theoretically-optimal investment and a benchmark buy-and-hold strategy.

2 Indicators

In this section, we will detail three indicators chosen for the manual investment strategy. These will be described in terms of the normalized *adjusted closing price* (hereafter referred to simply as *price*) of the stocks we wish to trade. These indicators are all easily calculated using vectorization, and thus only the formulae are shown in lieu of pseudo-code.

2.1 Simple Moving Average

Simple moving average (SMA) is the mean of recent prices over a set time window. It is commonly used to determine if an asset price will continue to follow a trend. Depending on the length of the time window, SMAs can smooth out volatility at the cost of added lag between the SMA data and the source data. We calculate SMA using the following formula:

$$SMA = \frac{p_1 + p_2 + \cdots + p_n}{n}$$

[1] *Technical Analysis.* Investopedia. https://www.investopedia.com/terms/t/technicalanalysis.asp

where p_i is the price of an asset at period i, and n is the number of total periods. For our simulations, we'll pick a period length of 1 day and a time window n of 10 days.

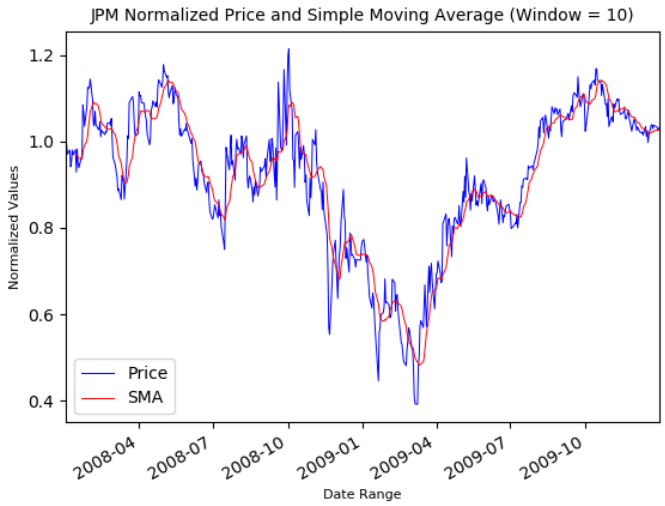

Figure 1: SMA and Price data for the in-sample period between January 1, 2008 and December 31, 2009.

In addition to calculating SMA, we can also compute the Price-to-SMA ratio. This new indicator provides better trading signals. Any ratio above 1 will indicate that the price is above the average, and thus indicates a signal to sell. Likewise, a signal below 1 will indicate that the price is below the average, and thus indicates a signal to buy. However, this should be constrained to within tolerances. This is shown in Figure 2: The red lines indicate top, middle, and bottom of the threshold, centered around a ratio of 1.

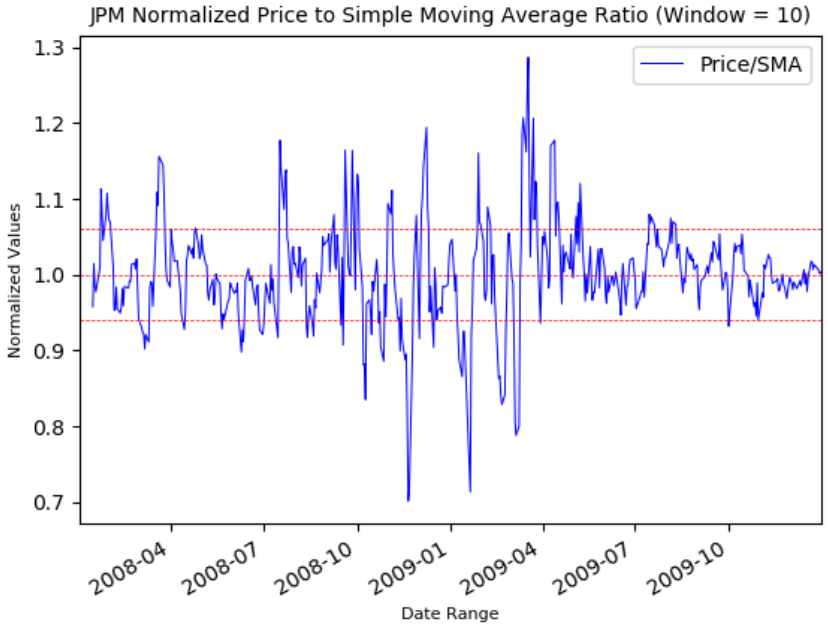

Figure 2: Price-to-SMA ratio for the in-sample period. $SMA_{threshold} = 0.06$

Finding the threshold is a bit more difficult, and will be discussed once we construct a manual strategy for trading.

2.2 Bollinger Bands®

Bollinger Bands® are a type of indicator that characterize the prices and volatility over time of an asset using an envelope of the maximum and minimum of the moving average. In general, the upper band and the lower band are a set number of standard deviations away from the moving average (typically 2). Therefore, we can determine the Bollinger Bands® using the following formulae:

- $BB_{upper} = SMA + k\sigma$
- $BB_{lower} = SMA - k\sigma$

where BB_{upper} and BB_{lower} represent the upper and lower bands, respectively, and $k\sigma$ represents a constant number of standard deviations. Furthermore, for each day's price, we can calculate its deviation from the SMA

as a fraction of the Bollinger Band®:

$$BB_{ratio} = \frac{price - SMA}{k\sigma}$$

Thus, a ratio of 1 indicates that the price has reached the upper bound of the Bollinger Band®, or that the asset has been overbought. Likewise, a ratio of -1 indicates that the price has reached the lower bound of the Bollinger Band®, and indicates that the asset has been oversold.

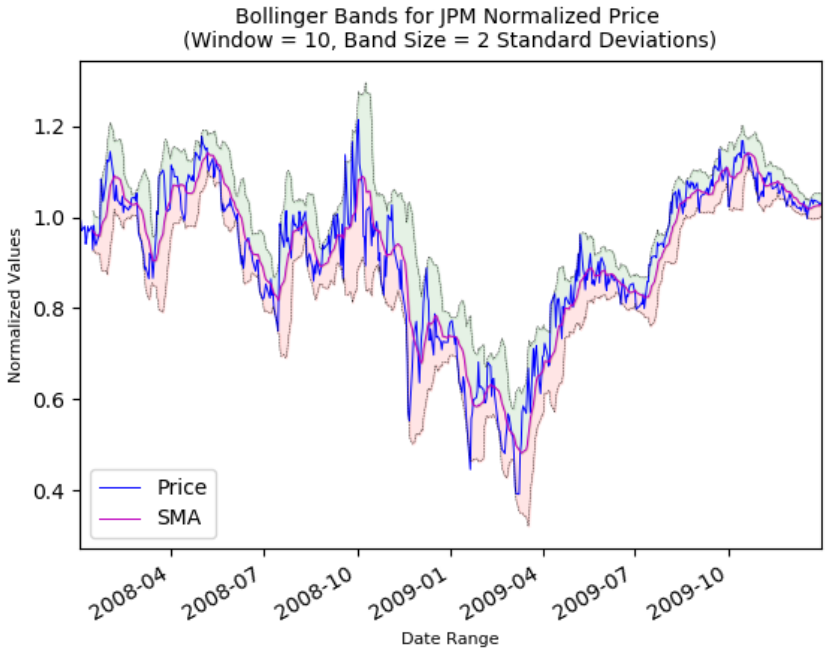

Figure 3: Bollinger Band® for the in-sample period. Green band indicates from SMA to upper-bound, and red band indicates from SMA to lower-bound.

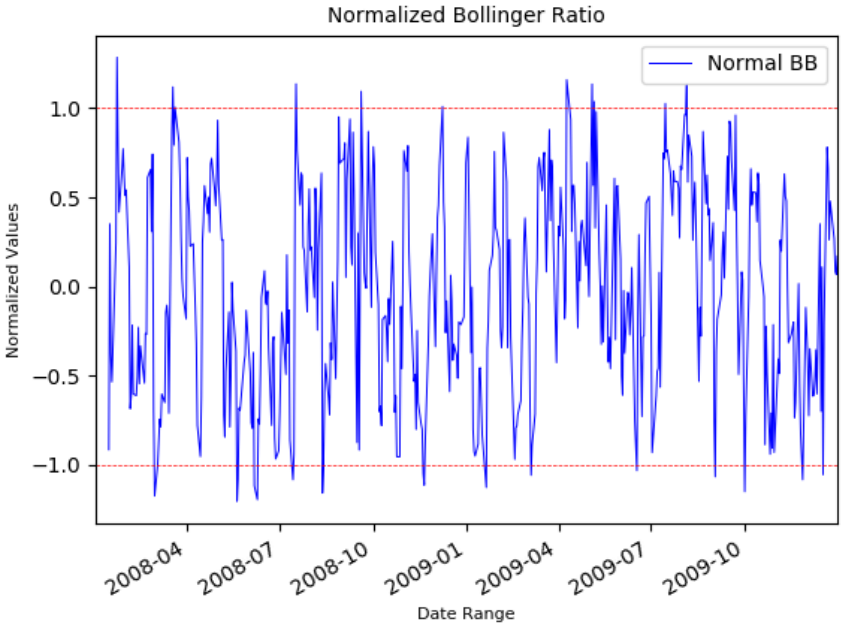

Figure 4: Ratio of price deviation from SMA to band size for in-sample period.

Just like with the Price-to-SMA ratio, the thresholds here can be adjusted to better fit the data. This will be discussed further in the Manual Strategy section.

2.3 Momentum

The final indicator we would like to discuss is *momentum*, or the rate at which prices change over a period of time. Since momentum is a rate of change, it's important to specify a time window:

$$Momentum = V - V_x$$

where V represents the current price, and V_x represents the prior price x days ago.

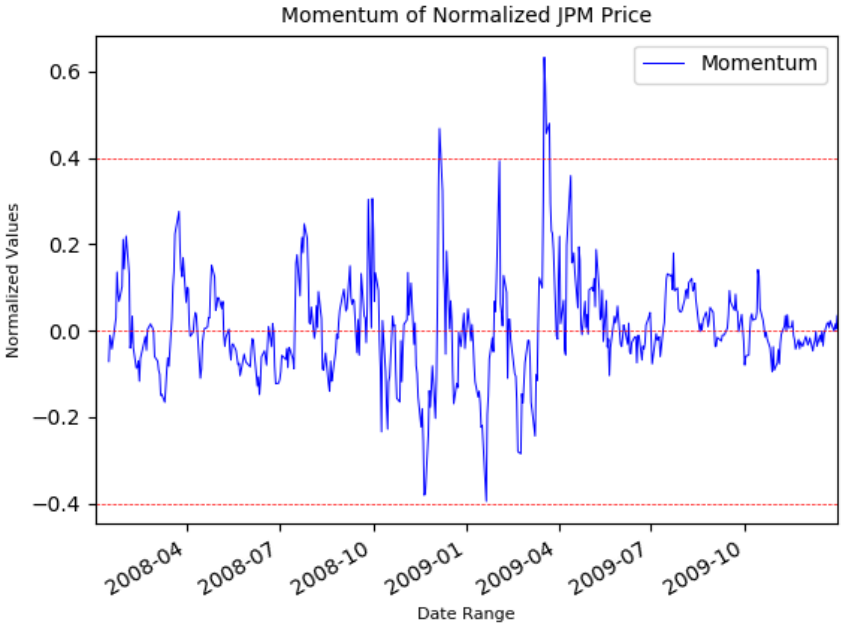

Figure 5: Momentum with window=10 days during in-sample period.

This curve is centered around 0, which implies that momentum close to 0 indicates that the price likely exhibits no trend. A higher momentum indicates positive trend, and a lower momentum indicates negative trend. However, changes in momentum do not necessarily indicate that a trend is over. Therefore, a threshold value can be set to ameliorate risk. This will be discussed in the Manual Strategy section.

3 Theoretically Optimal Strategy

In order to begin our discussion of investment strategies, we must first discuss the theoretically best possible strategy. For this strategy, we will need to assume that the trader has knowledge of the future, and thus is able to predict when the prices will rise and drop. In addition, we will also assume that trades are free (no commission and impact costs).

In such a glorious world, the optimal strategy would be to *short* if the next day's price drops and buy *long* if the next day's price rises. The trader thus will capture all possible benefit from day-to-day price deviations.

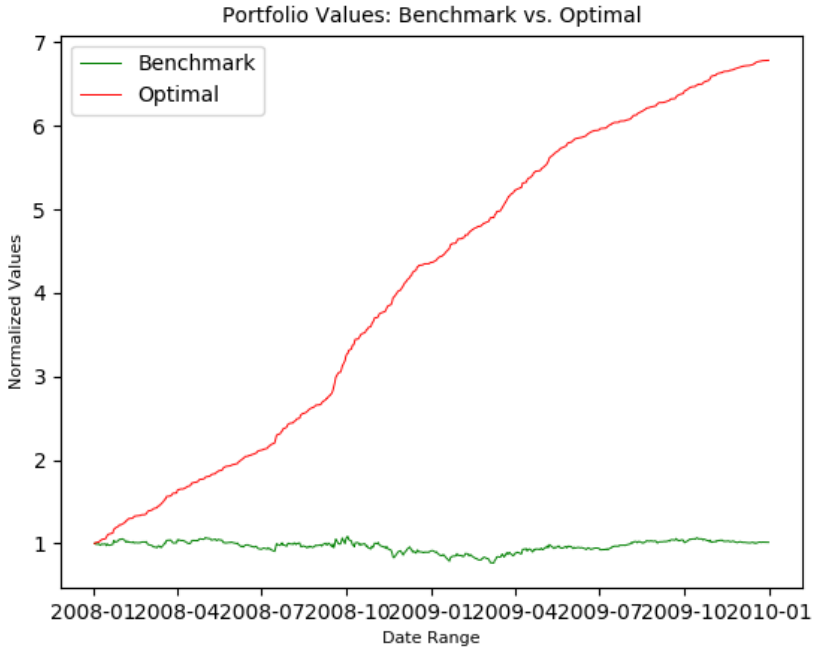

Figure 6: Theoretically optimal portfolio over in-sample period in comparison to a buy-and-hold benchmark.

In comparison to the buy-and-hold benchmark, the optimal strategy demonstrates significant returns. Statistics for this strategy are shown in Table 1:

	Theoretically Optimal	**Benchmark**
Cumulative Return	5.7861	0.0123
Average Daily Return	0.003817	0.000168
Standard Dev. Daily Return	0.004548	0.017004
Sharpe Ratio	13.32	0.16

Table 1: Performance criteria for theoretically optimal strategy vs. benchmark.

Again, this impossibly-high return is due to the ability to peer into the future. While the magnitude of the number is certainly exciting, without prescience, reality is often a bit more drab.

4 Manual Strategy

A normal trader with no powers of prescience cannot make decisions on future insight, but must use indicators to optimize the return. In addition, a normal trader will be required to pay both commission and impact penalties ($9.95 and $0.005, respectively). Given our indicators describe in Section 2, we need to determine how to use them to make trading decisions. To do so, we use the analysis from that section to construct a simple state machine for our trades:

- Sell to SHORT position (short 1000 shares) when any of the following are true...
  - Price-to-SMA ratio is above a threshold (or, when the asset is over-valued compared to the moving average).
  - Price deviation as a fraction of the Bollinger Band® is above a threshold (or, the asset has been over-bought).
  - Momentum is below a threshold (or, the market is bearish for this asset).
- Buy to LONG position (hold 1000 shares) when any of the following are true..
  - Price-to-SMA ratio is below a threshold (or, when the asset is under-valued compared to the moving average).
  - Price deviation as a fraction of the Bollinger Band® is below a threshold (or, the asset has been over-sold).
  - Momentum is above a threshold (or, the market is bullish for this asset).

Determining the thresholds for these values is more difficult. To do so, optimization can be done for the negative Sharpe ratio. Alternatively, grid search can be employed to determine local maxima. Due to time constraints, we settled on the following thresholds:

- Bollinger Band® fraction: 1.0[2]
- Price-to-SMA threshold: 0.06

[2]To be frank, I did not tune this value, as I do not see the mathematical benefit for lowering the threshold to within the band, nor do I see the benefit for raising the threshold to without.

- Momentum threshold: 0.4

Using these threshold values, the manual strategy demonstrated strong performance in comparison the the benchmark strategy of buy-and-hold.

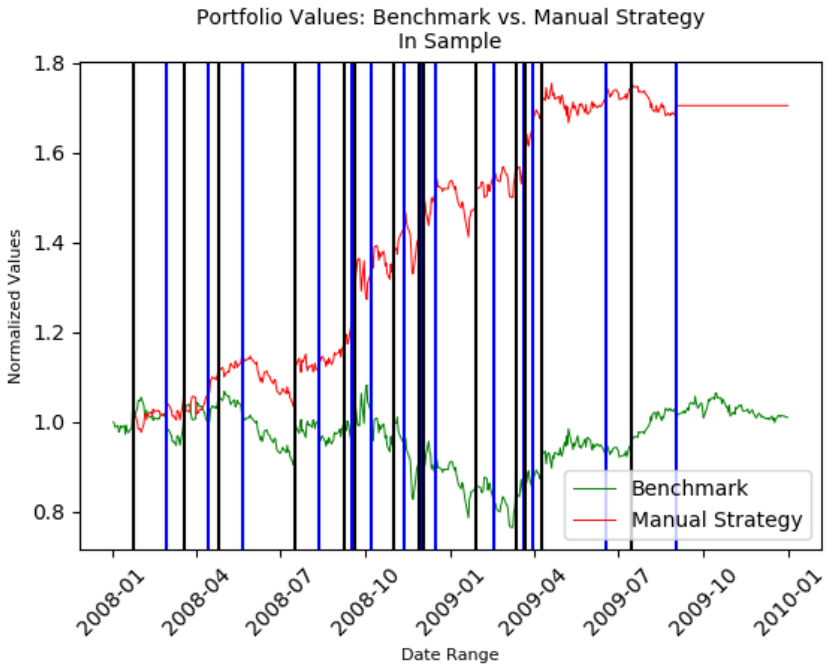

Figure 7: Manual strategy vs. benchmark for in-sample period. Blue vertical lines indicate LONG entry points, and black vertical lines indicate SHORT entry points.

The overall performance of the manual strategy can be characterized with the same metrics as for the optimal strategy. This is shown in Table 2 below.

While clearly not as performant as the optimal strategy, the manual strategy did significantly outperform the benchmark strategy, with over a tenfold increase in average daily return. In addition, the manual strategy had a lower standard deviation of daily return, indicating stronger inoculation against volatility.

	Manual	Benchmark
Cumulative Return	0.7056	0.0102
Average Daily Return	0.001393	0.000165
Standard Dev. Daily Return	0.012748	0.017041
Sharpe Ratio	1.74	0.15

Table 2: Performance criteria for manual strategy vs. benchmark, in-sample period

5 Comparative Analysis

Finally, we need to determine if our manual strategy with threshold parameters tuned to work with our in-sample period, will work with an out-of-sample period (January 1, 2010 to December 31, 2011).

Unfortunately, our manual strategy is not as performant on the out-of-sample period as during the in-sample period. This is shown below in Figure 8.

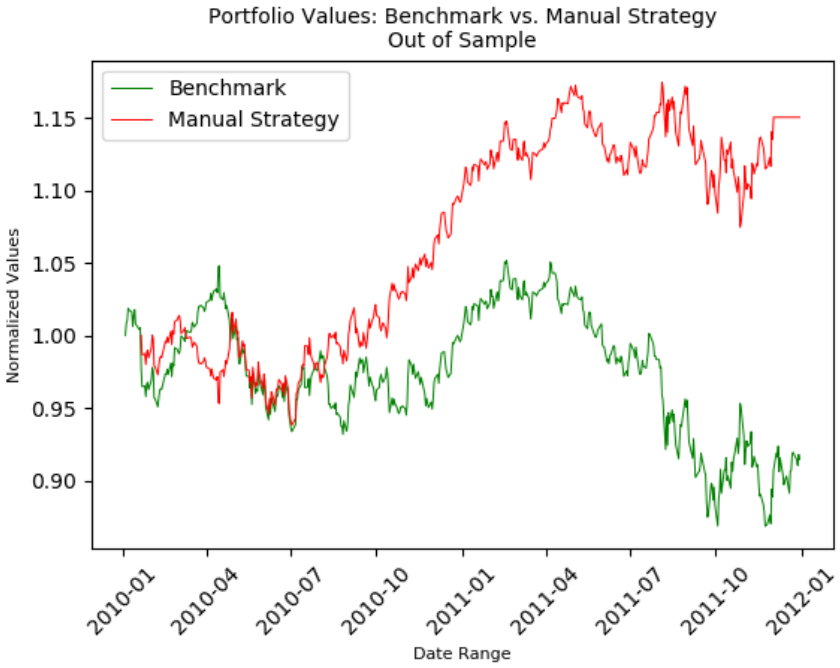

Figure 8: Manual strategy vs. benchmark for out-of-sample period.

Performance metrics are shown in Table 3. These metrics paint a clearer story for our manual strategy. While we tuned the manual strategy to work well with in-sample data, we overfit the strategy and yielded less-performant results for the out-of-sample data. Beyond the drop in cumulative return, of particular is the standard deviation of daily returns: the gap between the manual strategy and benchmark has completely closed, which indicates that our strategy is just as susceptible to volatility as a buy-and-hold strategy.

In-Sample	**Manual**	**Benchmark**
Cumulative Return	0.7056	0.0102
Average Daily Return	0.001393	0.000165
Standard Dev. Daily Return	0.012748	0.017041
Sharpe Ratio	1.74	0.15
Out-of-Sample	**Manual**	**Benchmark**
Cumulative Return	0.1503	-0.0853
Average Daily Return	0.000324	-0.000141
Standard Dev. Daily Return	0.007380	0.008501
Sharpe Ratio	0.70	0.26

Table 3: Performance criteria for manual strategy vs. benchmark, in-sample and out-of-sample periods

Indeed, one might surmise that we were just lucky with picking thresholds that still generated a positive cumulative return on investment. Since the search for optimal thresholds was not particularly rigorous, it is possible that more rigorous fitting of parameters for the in-sample period could lead to even more disastrous out-of-sample results.