Trend Following System for Stock Index Trading

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Abstract—There have been wide applications of trend following based trading system in real world. The traditional methods include 5 days moving average,20 days moving average, 200 days moving average and so on. If the midterm market trend is the biggest concern, 20 days and 50 days moving averages can provide efficient forecast information about stock trend. However, the solo stock price moving average cant give information about the current market healthy condition in a timely manner.

This paper discusses the mathematical formulation of stock trend decision and the related prediction delay problem. We provide an efficient method which utilize the 5 days moving average of Market Sentiment Index to forecast the stock price local and global top and bottom position information. This new method leads to specific trading rules on two major indexes SPY and QQQQ. The experimental results show very accurate position estimation and support that our system implements much more reliable trading rules than the bench mark buy and hold strategy in terms of market exposure and account balance

Key Words: *Trend*, *MovingAverage*, *MarketSentimentIndex*, *prediction*, *tradingrules*.

I. Introduction

The standard operation style for investors is to invest their capital into stocks or mutual fund by using buy and hold method, a strategy that focus on the long term performance and ignore the fluctuation of stocks in short term. However, the capital gain for such a method has a high correlation with the market trend or stock trend. To reduce the capital loss due to the trend transition of a stock or stock market, a trend following investing method was proposed and had been used by many mutual fund managers. But the general trend decision based on moving average also suffers the weak performance at period of trend transition. We proposed the usage of simple moving average of Market Sentiment Index (MSI), an average put/call ratio on equity at Chicago Board Options Exchange to reduce the risk exposure that investment account has during the trend transition period. The trend estimation and MSI are incorporated into a rule-based system for investment.

Our goal is to investigate the effectiveness of the new rule-based system for trading of major stock and bond indices such as SP500 (symbol SPY), NASDAQ 100 (symbol QQQQ). Notice that The trading decision for opening a position (BUY long or SELL short or do nothing) are made once a day, typically at the market opening. All positions are usually closed at the end of each trading day.

In this paper, we present a case-study of using our new rule-based system for trading to evaluate the performance over three distinctly major market trend which includes downtrend, uptrend, and neutral circumstance. We start from a general purpose of trend estimation algorithm and introduce the discovery based on MSI to estimate the stock top and bottom position,. We then take the advantage of this critical information of market top and bottom positions and implement a trading rule on incorporation both the outputs from trend estimation and Top/bottom estimation module. Our results show that the new trading rules are very effective in downtrend market or neutral market with relatively low market exposure which are 50

The rest of the paper is organized as follows: Section 2 presents an overview of trend following for trading methodology. Section 3 explains the details of our trading system which includes the trend estimation, MSI processing and new trading rules. Section 4 compares system performance for two stocks in three categories of market trend condition in terms of account balance, error rate and market exposure. Section 5 presents the lesson learned in this work.

II. Overview of rules based system for trading in stock trend

A trend rule-based system for trading is composed of a stock trend estimation module. The module has an implementation of trend estimation algorithm to predict the stock moving trend which can be used to assist in trading decision.

It is assumed that a tradable index (i.e., QQQQ) follows a well-defined medium-term trend, i.e. UP, DOWN or FLAT. See Figure 1 below. This trend can last from a couple of weeks to a few months. This trend is can be fairly accurately estimated using past historical data. The trend is estimated daily based on the last 30 trading days closing prices. For example the daily adjusted close price changed for Index (QQQQ) as shown in Figure 1.

In Figure 1, it is clear to see that market have a mixed down trend between end of 2004 and May 2005, an up trend after then. This information provides us the opportunity to trade the stock following its moving trend in a mid term investment.

III. Trading system

In this section, a introduction on the trend estimation module and our novel method on finding the stock price top/bottom positions is presented, and then a trading rule is designed and refined using our information from stock top/bottom tracing algorithm.

Fig. 1. Daily Closing Price of QQQQ

A. Trend estimation

This system estimates medium-term trend for a stock index based on past (historical) data. The trend predictions are calculated (updated) in the end of each trading day, and used for the next days trading decision. The set of rules is shown below: - *Calculate c* = the most recent 5 days moving average price of an index. - *calculate mid* = the 5 days (from 14 days to 10 days ago) moving average price. - *Calculate e* = the 5 days (from 30 days to 26 days ago) moving average price. Then if *c* is greater than both *mid* and *e*, todays trend is *UP*. if *c* is smaller than both *mid* and *e*, todays trend is *DOWN*. If neither of the above two conditions holds, we estimate that the trend is *FLAT*. This can be represented in Figure 2. To classify the output value of trend estimation system, we are going to use '1' to represent '*Up*', '−1' as '*Down*' and '0' as '*Flat*'.
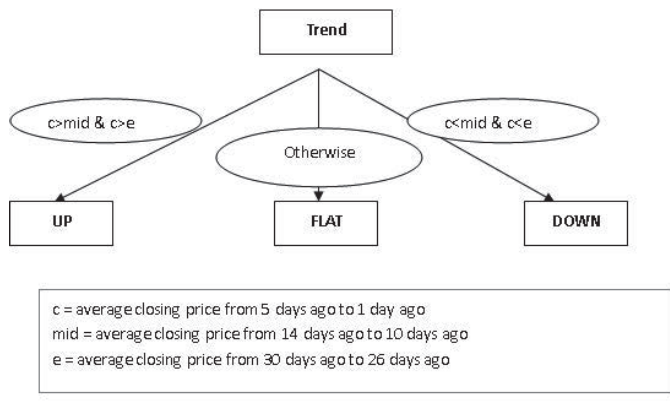

Fig. 2. The algorithm for trend estimation

B. Top and bottom position estimation

The trend estimation is simply based on information from 5 days simple moving average of stock price or market index. However, at the transition period (i.e. from a up trend to a downtrend at market local top position), the trend information generated will see a delay due to its moving average nature. To reduce the risk of error, a more sensitive market metric- Market Sentiment Index is introduced into our system to compensate the lack of sensitivity to market sharp change originally from trend estimation system.

1) Market sentiment index: CBOE(Chicago Board Option Exchange) Market Sentiment index is designed to show how investors view stock prices. The CBOE only measures opening long customer transactions on CBOE. Transactions made by market makers and firms are not included because they are not considered representative of market sentiment due to the often specialized nature of those transactions. Customer transactions, meanwhile, are often thought to best represent market sentiment because customers, which include individual investors, often buy call and put options to express their sentiment toward a particular stock. The MSI can be computed by dividing opening long call options bought by customers by opening long put options bought by customers.

$$MSI = \frac{LongPuts(OpeningPosition)}{LongCalls(OpeningPosition)} * 100 \qquad (1)$$

(1) MSI ¡ 100 More customers have opened long call options than put options. Call options increase in value when the underlying stock price increases. (2) MSI ¿ 100 More customers have opened long put options than call options. Put options increase in value when the underlying stock price decreases. Calls and puts may provide a relatively candid view of how investors feel about a stock, or even the stock market. Those views may often appear in the options market before the stock market. Sentiment indicators can be a valuable part of investment research because they provide a snapshot into the psychology of the options market. And according to our experiments and test, the incorporation of MSI does provide a signal about market change so that the trading decision can be adjusted faster than that solely on trend estimation. The Market Put/Call ratio data can be downloaded from Equation 1 on a daily basis. The original market sentiment index data are processed to match the 5 day moving average format used in our system via the procedure if Figure 3. The outputs from MSI processing module and trend estimation module will be jointly exploited to make the trading decision which will be described later.
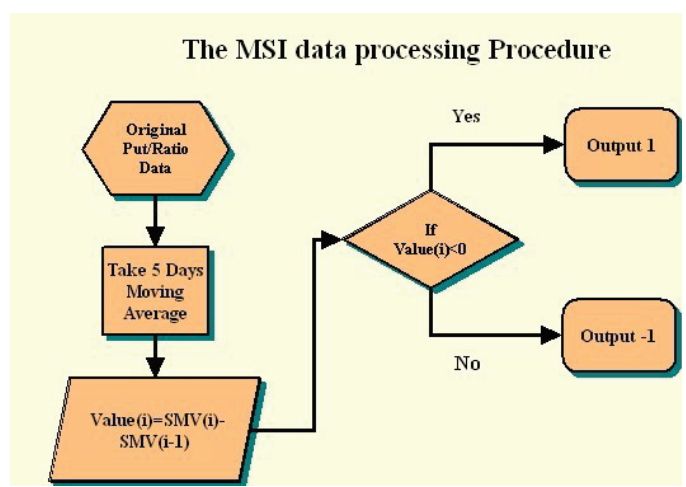

Fig. 3. The processing procedure of market sentiment index module

2) Market bottom and top tracing algorithm: Most of the time, it is very difficult to mark the market bottom and top positions accurately. In technical analysis, people try to use the cross points of 5 days moving average and 10 days moving average to forecast the market top or bottom position. For instance, if 5 days moving average line crosses downward 10 days moving average, a downtrend of market will be forecasted. However this method suffers the time delay ranging from 2 to several days, a critical drawback that may induce the trading loss frequently. After trial and fails, a new market top and bottom algorithm is developed to indicate those desired positions in a timely manner. The top position tracing algorithm is shown in Algorithm 1 and Algorithm 2

Algorithm 1 Top position tracing algorithm

1: **if** $data_i$s trend estimation is *up* and $data_{i-1}$s trend estimation is *up* **then**
2:    **if** $date_i$s MSI processing module output is '-1' and $date_{i-1}$s MSI processing module output is '1') **then**
3:       **if** $data_i$s closed price is lower than $date_{i-1}$s closed price **then**
4:          $Top\_index \leftarrow true$;
5:       **else**
6:          $Top\_index \leftarrow false$;
7:       **end if**
8:    **else**
9:       $Top\_index \leftarrow false$;
10:    **end if**
11: **end if**

Algorithm 2 Bottom position tracing algorithm

1: **if** $data_i$s trend estimation is *down* and $data_{i-1}$s trend estimation is *down* **then**
2:    **if** $date_i$s MSI processing module output is '-1' and $data_{i-1}$s MSI processing module output is '1') **then**
3:       **if** $data_i$s closed price is higher than $date_{i-1}$s closed price **then**
4:          $Bottom\_Index \leftarrow true$;
5:       **else**
6:          $Bottom\_Index \leftarrow false$;
7:       **end if**
8:    **else**
9:       $Bottom\_Index \leftarrow false$;
10:    **end if**
11: **end if**

To be more clearly, the algorithm is depicted in Figure 4. The tracing algorithm is executed on a daily basis, thus provides a quick analysis of current market situation. Those indexes that record yields from the tracing algorithm Trading Rules therefore can be incorporated into trend estimation system for more complicated analysis.

C. Trading rules

These rules implement our strategies, i.e. BUY (low) if the medium-trend is UP, or SELL SHORT (high) if the trend is DOWN. There are different sets of rules, depending on estimated trend (1). These simple rules
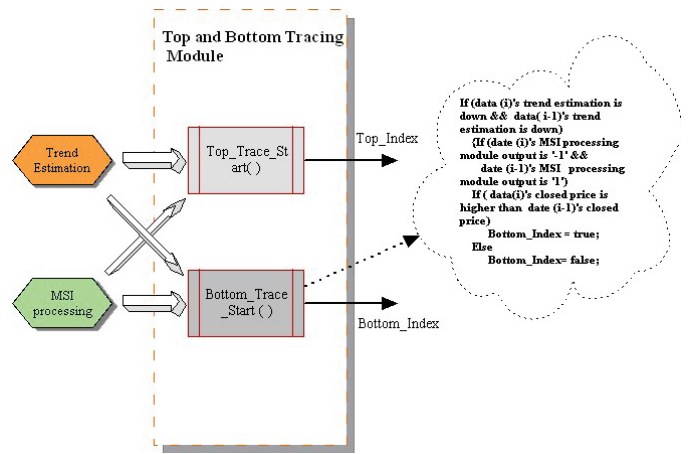

Fig. 4. The operation flow chart for Stock Top/Bottom Tracing Module

are entered as LIMIT orders in the morning (pre-market) of each trading day based on the estimated trend. The following 3 trading strategies are applied for trading stock indices:

(1) IF (the trend is UP) , **IF (Yesterdays TOP INDEX = FALSE)** buy at opening at a price of todays opening price with 100% of our account

Else split into 50% long and 50% short positions at opening at opening price

(2) IF (the trend is DOWN) **IF (Yesterdays BOTTOM INDEX = FALSE)** Sell Short at opening at a price of todays opening price with 100% of our account Else split into 50% long and 50% short positions at opening at a price of todays opening price

(3) IF (the trend is FLAT) enter two limit orders (BUY 50% and SELL SHORT 50%) at opening, where Buy_limit = todays opening price, Sell_short_limit = todays opening price

Note: in addition to above rules, the system will also have default rules for extreme market conditions, such as: - IF (the index is down 5 days in a row) then BUY at opening price - IF (the index is up 5 days in a row) then SELL SHORT at opening price

The trading operation is demonstrated in Figure 5 as well.

IV. Experimental setup and performance analysis

The trend estimation system according to system specification has been implemented and applied onto four stock indexes including SPY, QQQQ. And the overall data have been divided into several regions as shown in Figure 5 according to the big market trend. The purpose is to analyze our trading rules performance under different market circumstance over a long period of time. The first test period is defined from time between point 1 and point 2 shown in the graph. This was a time that market experienced a down trend. The second Period under investigation is period from date point 3 and point 4 in which market experienced uptrend. The
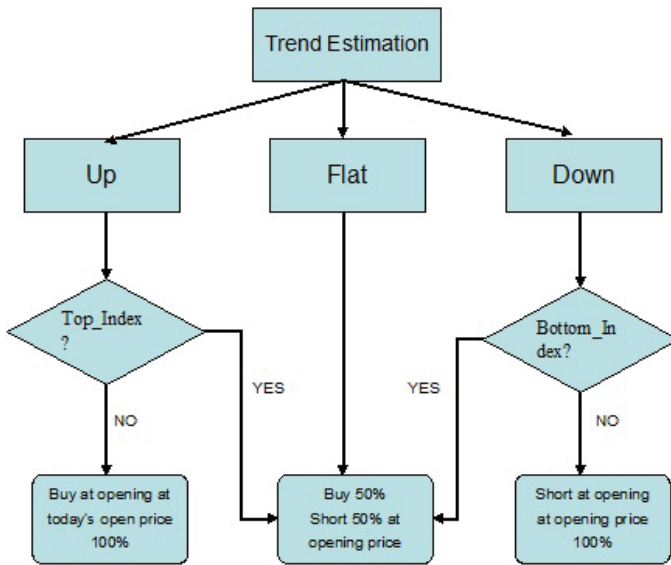
Fig. 5.   The flowchart of trading rules

Fig. 6.   DOWS Index since 2001

last period is time between point 4 to point 5 that market trend is regarded as flat.

Several performance indices are employed as metrics in terms of trading rule performance for different method. These indices include error rate, market exposure and account performance.

Error Rate: please notice the error here is defined as the market movement is reverse to our expectation of trading on that day. (i.e. the close price of a stock is lower than the opening price at a day when the BUY decision is made or the close price of a stock is higher than the opening price at a day when the SELL Short decision is made.) Market exposure: the ratio of a certain period that our account are exposed to the market 100% when only one trading order either buy or sell is set. Account Gain/Loss: the ratio of balance gain/loss in account at the end of investigation period. In our experiment, the initial account balance is $10,000.

A. Performance analysis results

1) Test period 1 (Down Trend Market): The output from trend estimation module will be analyzed on stock index SPY and QQQQ within this period. Their results are demonstrated separately in Figure 7 and Figure 8 (for clarification purpose, only a 6 month segment is shown).

The results are consistent with our expectation as the majority of trend estimation is pointing to down trend. And only a small fraction of results show the uptrend in stock movement. The tracing results of top/bottom module are presented in Figure 9 and 10.

As shown in the graphs, the positions about stock top and bottom are very accurate, though not completely correct for every point. Account performance based on our trading rules in time series are clearly depicted in Figure 11 and 12 in which the buy and hold method
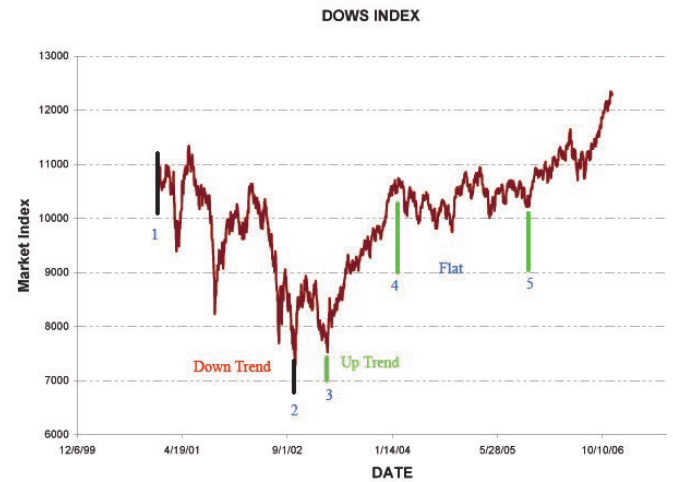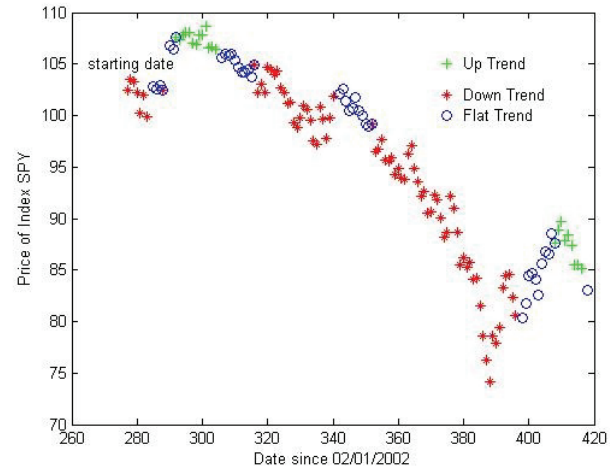

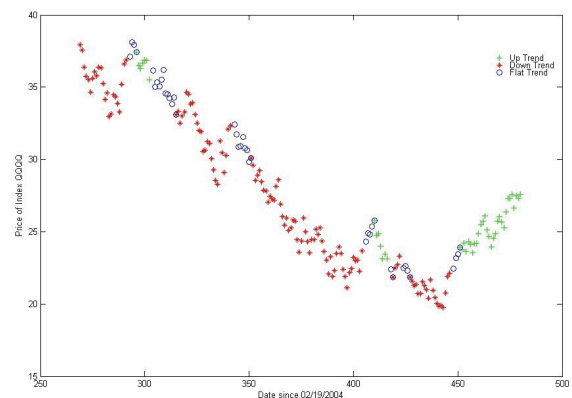Fig. 7.   the trend estimation results for SPY in downtrend period

Fig. 8.   the trend estimation results for QQQQ in downtrend period

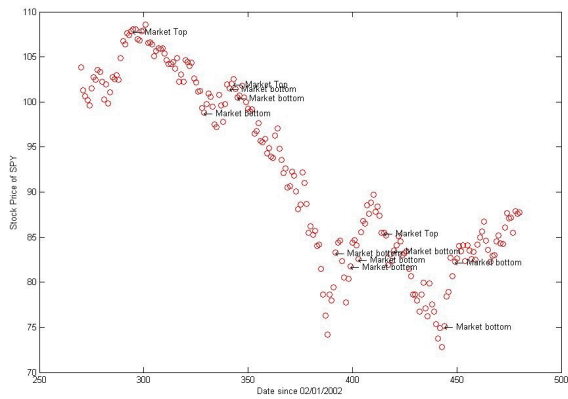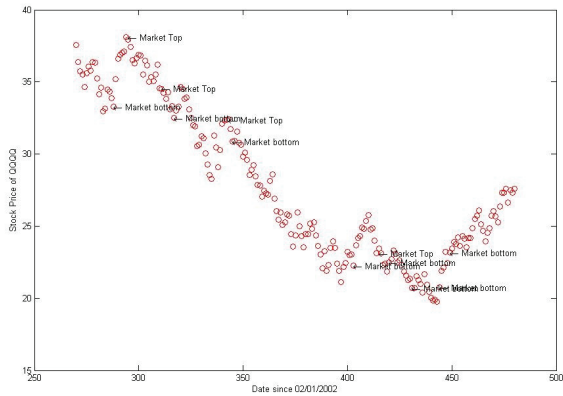Fig. 9. The analysis results of stock top/bottom positions for SPY in downtrend period

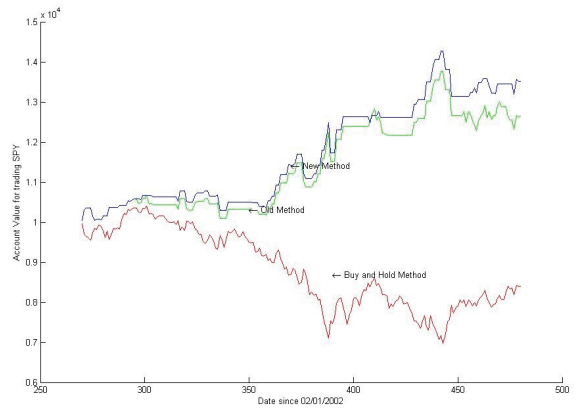Fig. 11. The daily account balance for SPY by three methods during downtrend period
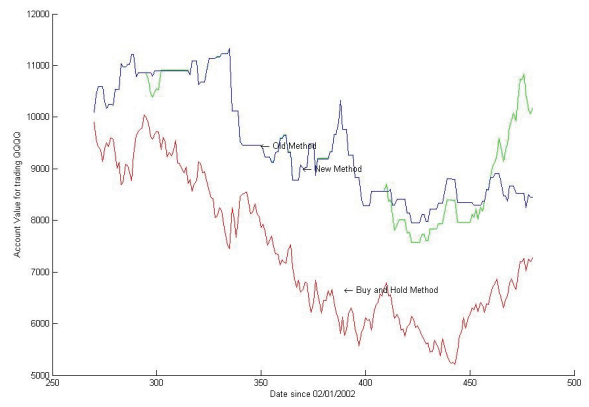

Fig. 10. The analysis results of stock top/bottom positions for SPY in downtrend period

Fig. 12. The daily account balance for QQQQ by three methods during downtrend period

is used as a bench mark.The green line represents the account balance based on trend estimation investment methodology. The blue line represents the account balance based on hybrid methodology. The red line is the account balance from our benchmark-buy and hold method.

As you can see from the account chart, there is a big drop around may 7,2002. It is because at that day the market increased about 10%, however the output from top/bottom analysis module is false, causing the account continued to sell short 100% position at the opening price due to the output from trend estimation module remain to be downtrend.

The results from performance indices are provided in Table I.

	Error Rate(%)		Market Exposure		Cumulative Gain/Loss(%)	
	SPY	QQQQ	SPY	QQQQ	SPY	QQQQ
Trend Only	44.5	46.5	46.9	50.2	26.4	1.5
Trend+MSI	38.1	41.9	36.0	38.4	36.0	-15.5
Buy&Hold			100	100	-15.2	-27.2

TABLE I.   THE EXPERIMENTAL RESULTS OF PERFORMANCE METRICS

The results give a hint about the different performance that the same strategy may create, if the market situation had the similar influence, toward different market index stocks. The account balance in SPY is the highest during the same period provided by the new method which incorporated the market sentiment index. The risk is reduced which follows since market exposure of the new method is lower than trend based method.

B. Test period 2 (Up Trend)

The output from trend estimation module will be analyzed on stock index SPY and QQQQ within this period. Their results are demonstrated separately in Figure **??** and **??** (for clarification purpose, only a 6 month segment is shown).

1) Trend Estimation and desired position results: The partial trend estimation of 6 months period for both SPY and QQQQ are demonstrated in Figure **??** and **??**.As expected, the majority of trend output values indicate a bull market that green stars have the highest frequency. And only a small fraction of results show the weakness of up trend movement. The tracing results of top/bottom
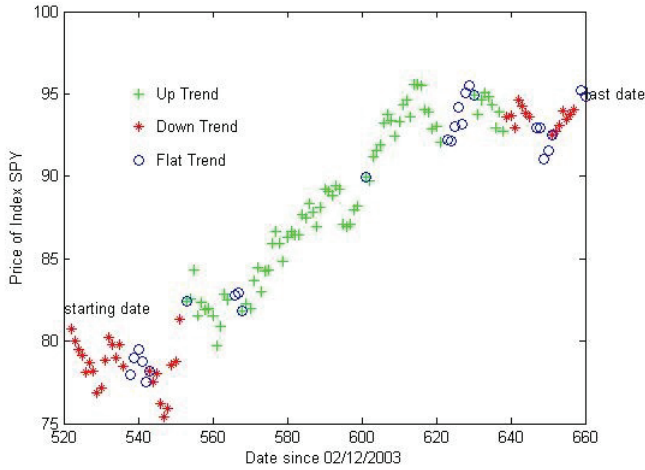
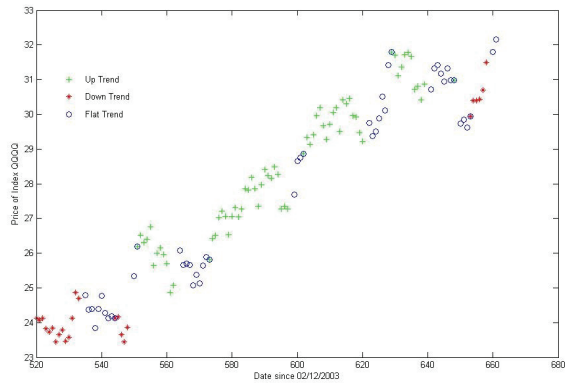Fig. 13. The trend estimation results for SPY in uptrend period

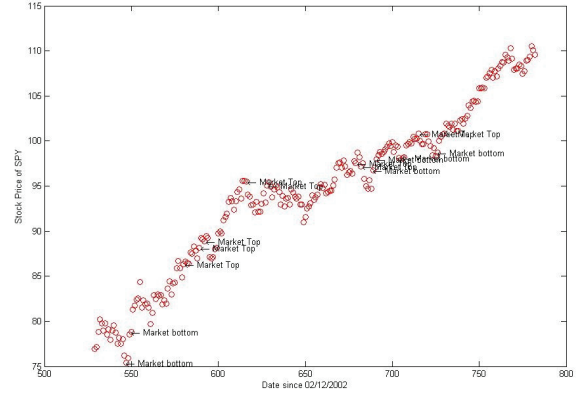Fig. 14. The trend estimation results for QQQQ in uptrend period

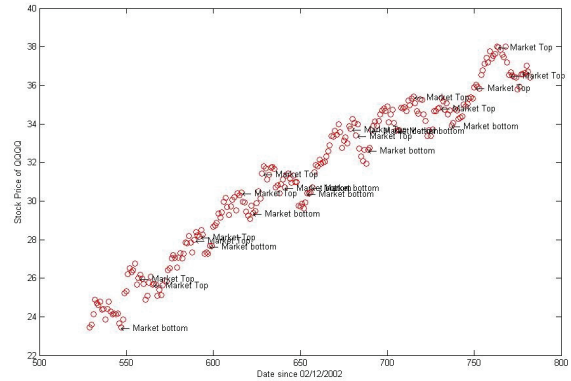Fig. 15. The analysis results of stock top/bottom positions for SPY in uptrend period

Fig. 16. The analysis results of stock top/bottom positions for QQQQ in uptrend period

module are presented in Figure **??** and **??**. This is a typical transition period from a bear market to a bull market. The frequency of stock price top and bottom index signal increased much more than the yield in period 1. This is easily to tell from Figure **??** and **??**.

2) Account Performance in time series: The account balances of both stocks in time series are demonstrated in Figure **??** and Figure **??**. The results from performance indices are provided in Table II.

	Error Rate(%)		Market Exposure		Cumulative Gain/Loss(%)	
	SPY	QQQQ	SPY	QQQQ	SPY	QQQQ
Trend Only	48.7	52.3	72.7	61.2	11.85	4.62
Trend+MSI	43.1	51.1	37.9	31.6	10.0	27.4
Buy&Hold			100	100	40.1	53.0

TABLE II.   THE EXPERIMENTAL RESULTS OF PERFORMANCE METRICS

The gains for Trend with MSI method in both stocks are lower than that from buy and hold method in this up trend period. A reason is that the volatility became very high when market pulled back from a bear market. The risk averse nature of new trading system hereby tried to limit its market exposure to high volatile market situation, a general defense strategy that can be exploited
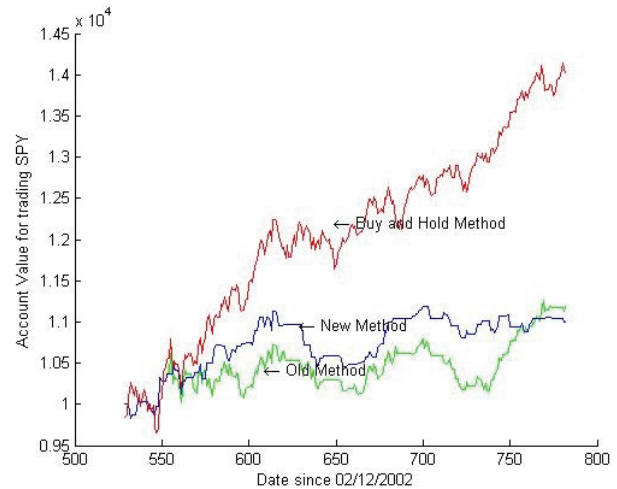

Fig. 17. The daily account balance for SPY by three methods during uptrend period
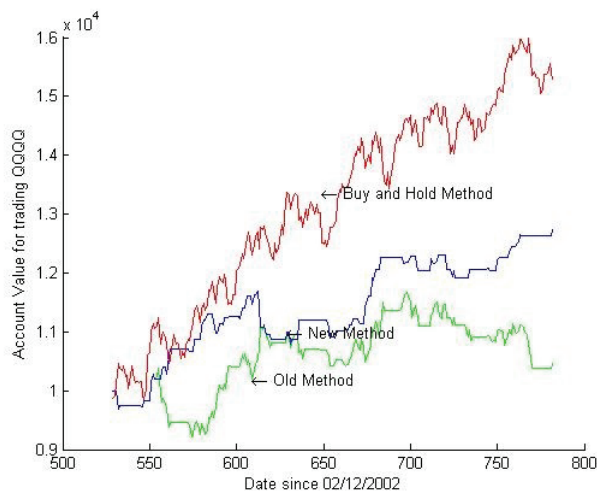
Fig. 18. the account performance for QQQQ in uptrend period

Fig. 20. The trend estimation results for SPY in uptrend period

if a stable return is a prefer. The market exposure of Trend plus MSI method for SPY and QQQQ are about 50% smaller than the trend only method. But the account gain of SPY is much lower than the yield from buy and hold method, pointing a worse investment under bull market situation.

C. Test Period 3 (Flat Trend)

This period is regarded as a market neutral period because there is no apparent market trend found. The trend estimation results and performance metrics are studied as well to discover the effectiveness of our trading system under such an environment.

1) Trend estimation: The output from trend estimation module will be analyzed on stock index SPY and QQQQ within this period. Their results are demonstrated separately in Figure **??** and **??** (for clarification purpose, only a 6 month segment is shown).
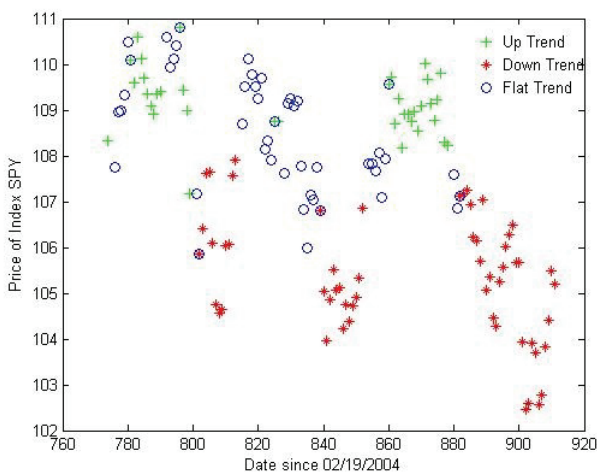

Fig. 21. The analysis results of stock top/bottom positions for SPY in flat trend period
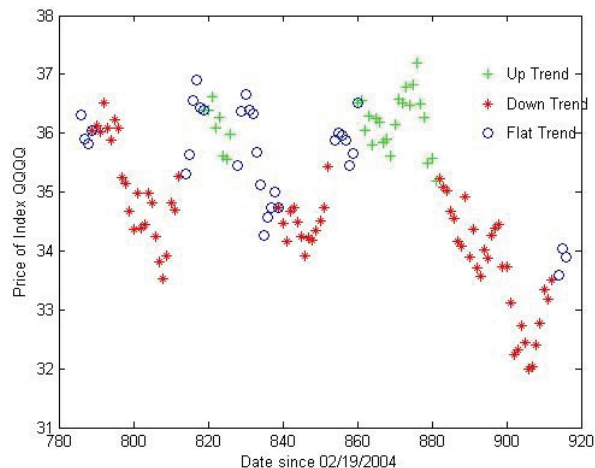

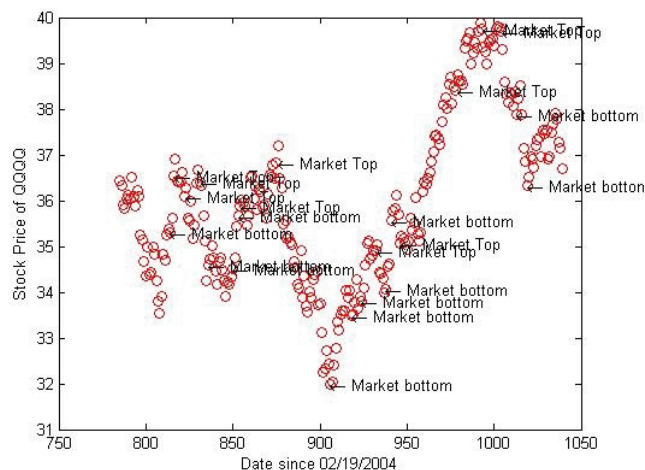Fig. 19. The trend estimation results for SPY in uptrend period

Fig. 22. The analysis results of stock top/bottom positions for QQQQ in flat trend period

In a flat trend market, the fluctuation of stock price appears to be more obvious than both down trend market situation and up trend market situation. According to the outputs seen from both SPY and QQQQ in this period, as shown in Figure **??** and **??**, we can tell clearly when the real long term stock price bottom position is. But it provided a simple trading strategy that buy at the low point and sell at the high point of stock trading band.

2) Account Performance in time series: The account balances of both stocks are demonstrated in Figure **??** and **??**. The investigated results for performance indices are
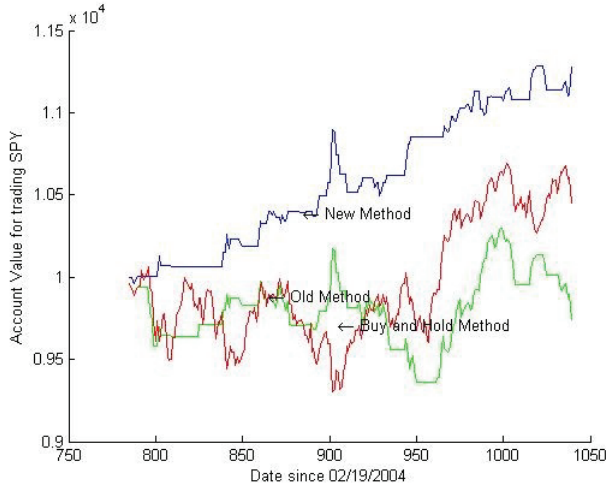

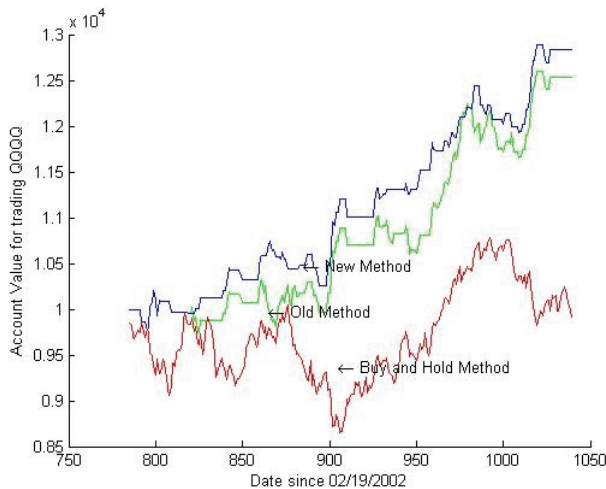Fig. 23.   The account performance for SPY in neutral trend period

Fig. 24.   The account performance for QQQQ in neutral trend period

provided in Table III.

	Error Rate(%)		Market Exposure		Cumulative Gain/Loss(%)	
	SPY	QQQQ	SPY	QQQQ	SPY	QQQQ
Trend Only	51.5	47.0	54.3	55.1	-2.2	25.3
Trend+MSI	51.8	48.9	33.6	36.2	12.8	28.3
Buy&Hold			100	100	4.5	-1.0

TABLE III.   THE EXPERIMENTAL RESULTS OF PERFORMANCE METRICS

D. Experiments Summary

According to the results from our experiment setup, several important claimed can be made as below: (1) Our experimental results show that our trading system have error rate less than 40%, a pretty good indication for practical application. More interestingly, the maximum error rate was found between Test period 2 (point3 C point4), which suggests our trading system may not be as effective as it is in Up market trend or Down market trend. This consideration will be further investigated in our future work. (2) The best system performance in terms of account balance vs exposure rate is achieved for trading SPY at downtrend period in which the gain is 36 percent while the market exposure rate is 36% too. And the average rate of return for SPY is slightly higher than that from QQQQ. 3) Our implemented trading rules-based system is very effective in reducing the risk exposure at market transition period.

V. LESSON LEARNED

This section describes the key optimizations that can be applied to the existing design and some insights obtained in the course of this work.

A. Trading rules optimization

Our trading rules mainly consider the joint value from trend estimation and top/bottom module. Currently we only consider the buy or sell short at the opening price either 50% or 100% of our account. This method promoted the quick evaluation of our trading system without considering the optimized trading price. For instance, the limited order of buy a stock at a price of minimum between yesterdays close prices has the potential to generate more profit in one day trading. However, we didnt consider this part in our current work because it will involve another problem that whether this limited order can be triggered after opening. To make our trading system more practical, we need to incorporate a more flexible trading rule so that we can find an optimized method in trading. One solution for doing this is to analyze the possibility that todays opening price is higher than the yesterdays close price under different market situation and use the information to adjust trading limited price for Buy and Sell Short. The further investigation can also help us to find an optimal portfolio ratio.

B. Using Neural Network or Support Vector Machine Algorithm in prediction

Currently in our trend estimation module, we use historical data to predict todays stock trend. To be more specific, we use the past 5 days to 30 days moving average value to predict todays stock trend. As what we have discussed in section 3, this method suffers the time delay problem which sometime may cause a big loss in our investment. One example can be seen in the big drop of our account in SPY by one mistake of trading operation within one day. It becomes quite important for us to have prediction over 3 to 4 days in advance instead

of only one day prediction. It is wise to implement a 4-day prediction model in assisting us to make trading decision with more time available. One possible way to do this is to use NN or SVM method to train the model by using daily close price $X(i, i-1, i-2, i-3)$ as input values to estimate $Y(i+3)$,the output value of stock close price in 3 days.

C. Risk control

Even though our system has reduced the risk in investment by successfully decreasing the market exposure to those volatile periods, the decision error rates remain at an uncomfortable domain about 40%. Hence it is critical for us to establish a risk control floor plan into our system. An error rate control specification could be added to trading system, which means if the system continuously makes 2 mistakes in prediction in a row, the next prediction result will not be executed by the system. In another sense, stop trading for one day. This constraint could increase the complexity of our system and reduce the investment return. We have to find a tradeoff in such kind of practice.

VI. Conclusion

A trend trading system has been implemented by incorporating the trend estimation and stock price top/bottom position information. The system performance is evaluated and tested for 2 stock indexes (SPY and QQQQ) under three typical market trend situations. Results show a less than 40% prediction error rate, balanced investment gains for both stocks are achieved in most of the situation while the market exposure are reduced significantly compared to the bench market- Buy and Hold method. These results have substantial meaning for mutual fund investors or manager in helping them making trading decision. Trading rules optimization, 3 days prediction methodologies are proposed for future investigation.

VII. Reference

1.   http://www.cboe.com/data/mktstat.aspx
APPENDIX A: THE RESULTS OF TREND ESTIMATIONS FOR SPY, QQQQ, IWM AND MDY.
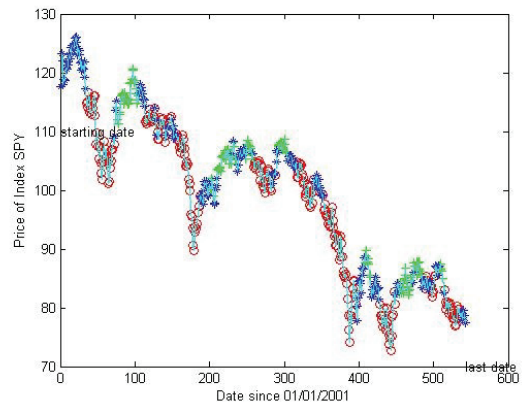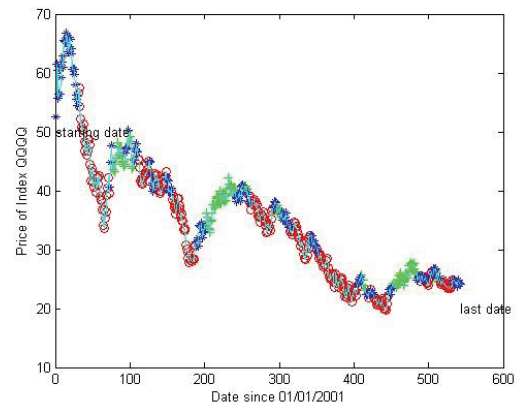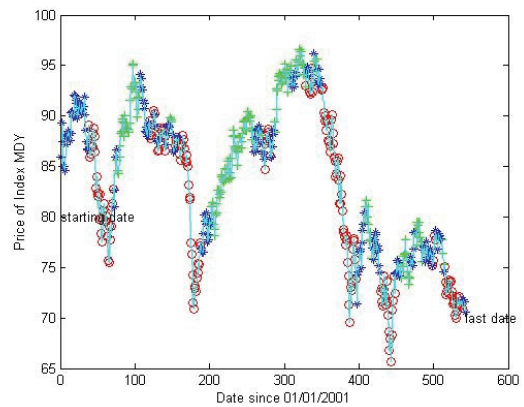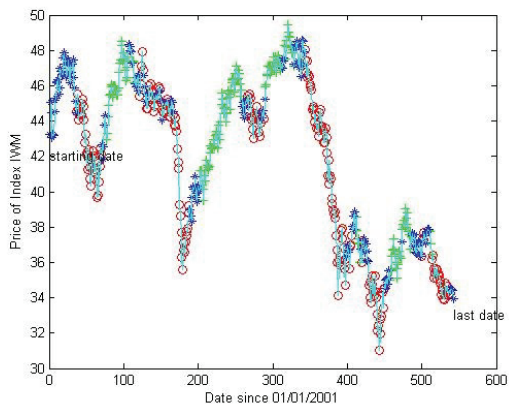
APPENDIX B: The daily account balance for QQQQ and SPY in Neutral trend This is to provide samples data for our account balance in Neutral trend.

Date SPY QQQQ 2/19/04 9962.8 10000
2/20/04 9931.9 10000
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