CHAPTER V

DESIGN OF COMBINATIONAL QUANTITATIVE TECHNICAL ALGORITHMS

5.1 Introduction

This chapter deals with the core of this research work written around a family of quantitative technical algorithms to predict financial time series data. Three innovative combinational analytics are designed to overcome most of the limitations specified in the study and analysis to enhance the predictability.

A brief recap: Under the design of combinational quantitative technical algorithms, the following open problems identified during the study and analysis of various stock market prediction techniques were taken up and solved.

- In crucial situations, most of the trading rules are generating trading signals. But all the trading rules are not generating correct trading signals in all the situations. In some situations, some trading rules are disoriented. Therefore, there is a need to build alert expert systems that combine a number of efficient trading rules which are properly oriented [76] for the generation of more profitable trading signals during most of the crucial situations.

- Some of the technical indicators are leading ones and some are lagging ones. An indicator that lags too much should not be used for taking buy or sell decision. However these indicators could be used for confirming the already taken decision.
Some of the technical indicators need some modification in its basic structure to generate trade signals. Hence variations of existing indicators are to be designed and devised.

All the financial time series forecasting algorithms reported till date use “Generation of Correct Trade Signal – GCTS” metric reflecting the Market Trend to prove the effectiveness of the respective algorithms. The effectiveness of any financial time series forecasting algorithm cannot be measured simply by means of the number of trade signal generated which reflects the stock market trend correctly, because all the correct trade signals do not yield net profit which results in making good Returns On the Investment (ROI) of money. A correct signal which does not result in any net profit is of very poor use to the stock traders. Hence a trade signal is said to be profitable if and only if it signals a closed trade matching the market trend which yields good ROI of money. Therefore, this thesis introduces “Correct Profit Trade Signal – CPTS” metric to evaluate the combinational quantitative technical algorithms. CPTS is armed with suitable evaluation metrics indicating profit which is very important to justify the usefulness and profitability of the trade signals generated by the analytics.

When a stock price goes down, progressively the price reduction diminishes. As the price reduction diminishes, the volume also diminishes. Then all of a sudden, in Candlestick chart, the candle color changes from red to green (or black to white) with small positive price change and the
volume percentage remains below 90%. The Candlestick bodies are colored black or red if the closing price was lower than the previous period's closing price. The Candlestick bodies are colored white or green if the closing price was higher than the previous period's closing price. This might happen for a few days. This really indicates that the stock is available only when buyers pay a higher price and there is only limited buying interest as indicated by less than 100% volume index. It is observed that the Bollinger bands are the well suited indicator to reflect this situation. The expansion and contraction of Bollinger bands are related to up or down price move. Another important thing studied is that Bollinger Bands do not generate buy and sell signals. They should always be used with another indicator for the generation of profitable buy / sell signals. The Bollinger bands become quite powerful, when combined with a suitable indicator and is used in this thesis to assist the trade signal generation process.

- Bollinger Bands [47] are trading bands plotted around the price. This indicator is plotted as a grouping of 3 lines. The upper and lower lines are plotted according to market volatility. The middle line is the simple moving average between the two outer lines (bands). Market reversals occur near the upper and lower bands. The middle band acts as a support line. The widths of the Bollinger bands narrow at this point in time.
The novel class of combinational quantitative algorithms for the analysis of inter-day stock market time series data proposed in this thesis is equipped with the capability to generate higher percentage of profitable buy / sell signals resulting in higher returns.

The innovative combinational quantitative techniques of stock market prediction resulted in this research are given below:

1. Time Series Quantitative Analytics 3 – TSQA3
2. Time Series Quantitative Analytics 4 – TSQA4
3. Time Series Quantitative Analytics 5 – TSQA5

All these algorithms are designed and devised based on the technical indicators presented below. The variations of the existing indicators are also formulated exclusively for enhancing the generation of profitable trade signals.

5.2 Prices

The Prices are central quantities. Four types of prices are distinguished in the inter-day stock market data namely Open, High, Low and Close.

The Price at time “t” is defined by

$$P_t = \frac{w_1 O_t + w_2 H_t + w_3 L_t + w_4 C_t}{w_1 + w_2 + w_3 + w_4},$$ (5.1)

where the default values for the non-negative weights are

$w_1 = w_2 = w_3 = w_4 = 1$
• The open price \("O_t\) indicates the price of an asset at the start of trading day \("t\)\.

• The high price \("H_t\) indicates the highest price at which an asset was traded during trading day \("t\)\.

• The low price \("L_t\) indicates the lowest price at which an asset was traded during trading day \("t\)\.

• The close price \("C_t\) indicates the price of an asset at the end of trading day \("t\)\.

5.3 Bollinger Bands Calculation

Bollinger Bands are trading bands plotted around the price introduced by John Bollinger [47]. This indicator is plotted as a grouping of 3 lines. The upper and lower lines are plotted according to market volatility. The middle line is the simple moving average between the two outer lines (bands). Market reversals occur near the upper and lower bands. The middle band acts as a support line. Bollinger bands are used to assist the generation of trade signals in the proposed algorithms.

Bollinger Bands indicate the range of expected price action. The middle of this range is characterized by a Simple Moving Average (SMA) of prices explained in section 5.4.1 of this chapter.

The middle band at time \("t\)\, \("MiddleBand_t\)\, is given by a SMA of length \("n\) of the prices \("P\) in equation 5.2,
MiddleBand_t = SMA_t(P, n) \quad (5.2)

The upper and lower band at time t, UpperBand_t and LowerBand_t, are defined by equations 5.3 and 5.4.

\[
UpperBand_t = SMA_t(P, n) + k \sigma_t, \quad (5.3)
\]

\[
LowerBand_t = SMA_t(P, n) - k \sigma_t, \quad (5.4)
\]

where \( \sigma_t = \sqrt{\left(\frac{1}{n} \sum_{i=t-n+1}^{t} (P_{i-1})^2\right) - (SMA_t(P, n))^2} \) is the standard deviation of the n most recent prices. Default value for the averaging period "n" is 20 days. Default value for k is 2; this captures at about 95% of the variation in price action.

The two main applications of Bollinger Bands are

- Overbought and oversold indicator - In an overbought or oversold market prices have risen or fallen too far and are likely to retrace. Prices near the lower band signal an oversold market. Prices near the upper band signal an overbought market.

- Generation of buy and sell signals - A buy-signal (sell-signal) is generated if the Bollinger Band indicate an oversold (overbought) market at the same time another oscillator like the Relative Strength Index (RSI) signals a divergence.
5.3.1 Simple Moving Average

The Simple Moving Average (SMA) [16], [86] is a most widely used indicator. It can be used in many different ways and often used as basic building block of other technical indicators.

The SMA of length “n” of a data set “v” at day “t” is defined by equation 5.5

\[ \text{SMA}_t(v, n) = \frac{1}{n} \sum_{i=0}^{n-1} v_{t-i}, \ t \geq n \]  

(5.5)

Usually, the data set “v” is represented by the prices of an asset. The default value for the averaging period “n” depends on the exact purpose of the SMA.

The two main applications of SMA are:

- Trend identification - Trends can be identified by looking at the slope of a SMA and at the relationship of SMA to the prices. If the SMA is sloping down and the prices are below the SMA, then the prices are in a down-trend. If the SMA is sloping up and the prices are above the SMA, then the prices are in an up-trend. A non-trending market exists if prices move above and below the SMA and also if the SMA is flat.

- Generation of buy and sell signals - There are two methods:

  1. A buy signal is given if the close price is above the SMA and a sell signal is given if the close price is below the SMA.

  2. Use a second SMA with a shorter observation period than the first one. It reacts faster to market movements than the first
SMA. Buy-signals are generated when the shorter SMA crosses the longer SMA from below. Sell-signals are generated when the shorter SMA crosses the longer SMA from above.

Note that SMAs are most effective in trending markets; but in non-trending markets they are likely to give false signals.

5.4 Chaikin Money Flow Indicator

Developed by Marc Chaikin, the Chaikin Money Flow indicator (CMF) [90] is calculated by summing Accumulation / Distribution over the given period and then dividing by the sum of volume over the given period [47] as mentioned in equation 5.6. A period of 21 is recommended and gives better results.

\[
\text{sum}(((C-L)-(H-C))/(H-L)) \times V,21 \bigg) \bigg) / \text{sum}(V,21), \quad (5.6)
\]

where “C” is the closing price, “L” is the lowest price, “H” is the highest price and “V” is the volume of stock traded. The volume is essentially nothing more than volume times change divided by range. A positive CMF value signals accumulation, while a negative CMF value signals distribution. The further the deviation from the zero reference, the stronger the signal.

The interpretation of the Chaikin Money Flow indicator is based on the assumption that the market strength is usually accompanied by prices closing in the upper half of the daily range with increasing volume. Likewise, market weakness is usually accompanied by prices closing in the lower half of the daily range with increasing volume.
The Chaikin Money Flow indicator provides excellent confirmation signals of trend line and support / resistance breakouts. For example, if a security's prices have recently penetrated a downward sloping trend (signaling a potential trend reversal), wait for further confirmation by allowing the Chaikin Money Flow indicator to cross above the zero. This may indicate an overall shift from a downtrend to a new uptrend.

5.5 Relative Strength Indicator

The Relative Strength Index (RSI) was developed by J. Welles Wilder and introduced in the book [105] in 1978. This is an extremely useful and popular momentum oscillator. The RSI compares the magnitude of a stock's recent gains to the magnitude of its recent losses and turns that information into a number that ranges from 0 to 100. It takes a single parameter, the number of time periods to use in the calculation. It is calculated for a certain time span usually between 9 and 15 days.

The RSI's full name is actually rather unfortunate as it is easily confused with other forms of Relative Strength analysis such as John Murphy's "Relative Strength" charts and IBD's "Relative Strength" rankings [83]. Most other kinds of "Relative Strength" stuff involve using more than one stock in the calculation. Like most true indicators, the RSI only needs one stock to be computed. In order to avoid confusion, many people avoid using the RSI's full name and just call it "The RSI".

The RSI indicator [83] compares the number of days a stock finishes up with the number of days it finishes down. The standard number of 14 days of time span is used when calculating the RSI which has yielded good results in this case.
It is important to note that the RSI is a “running” calculation and the accuracy of the calculation depends on how long ago the calculations started. The first RSI value is an estimate; subsequent values improve further on that estimate. To start the running calculation, the First Average Gain is calculated as the total of all gains during the past 14 days divided by 14 as given in equation 5.8. Similarly, the First Average Loss is calculated as the total magnitude of all losses during the past 14 days divided by 14 as mentioned in equation 5.10. The next values for the "averages" are calculated by taking the previous value, multiplying it by 13, adding in the next Gain (or Loss), and then dividing by 14 as shown in equations 5.7 and 5.9. This is Wilder's [105] modified "smoothing" technique in action and is given in the equation. The RS value is simply the Average Gain divided by the Average Loss for each period. Finally, the RSI is simply the “RS” converted into an oscillator that oscillates between zero and 100 using the formula given in the equation 5.11.

\[
\text{Average Gain} = \frac{\text{[(previous Average Gain) x 13 + current Gain]}}{14} \quad (5.7)
\]

\[
\text{First Average Gain} = \frac{\text{Total of Gains during past 14 periods}}{14} \quad (5.8)
\]

\[
\text{Average Loss} = \frac{\text{[(previous Average Loss) x 13 + current Loss]}}{14} \quad (5.9)
\]

\[
\text{First Average Loss} = \frac{\text{Total of Losses during past 14 periods}}{14}. \quad (5.10)
\]

\[
\text{RSI} = 100 - \frac{100}{1 + \frac{\text{RS}}{}} \quad (5.11)
\]

where RS = Average Gain / Average Loss.

Note: “Losses” are to be reported as positive values.
To calculate RSI values for a given dataset, first find the magnitude of all gains and losses for the 14 days prior to the time where you wish to start the calculation. When the Average Gain is greater than the Average Loss, the RSI rises because “RS” will be greater than 1. Conversely, when the Average Loss is greater than the Average Gain, the RSI declines because “RS” will be less than 1. The RSI formula ensures that the indicator oscillates between 0 and 100. Note: If the Average Loss ever becomes zero, RSI becomes 100 by definition.

5.6 Stochastic Momentum Index

The Stochastic Momentum Index (SMI) was created by William Blau [107]. The Stochastic Momentum Index (SMI) is based on the Stochastic Oscillator [83]. The difference is that the Stochastic Oscillator calculates where the close is relative to the high / low range, while the SMI calculates where the close is relative to the mid point of the high / low range.

The values of the Stochastic Momentum Index are obtained from the equation 5.13. The SMI is above zero, when the close is greater than the midpoint. The SMI is below zero, when the close is less than the midpoint. The SMI is interpreted the same way as the Stochastic Oscillator. Extreme high / low SMI values indicate overbought / oversold conditions. A buy signal is generated when the SMI rises above, or when it crosses above the signal line. A sell signal is generated when the SMI falls below, or when it crosses below the signal line.

\[
SMI = 100 \times \frac{(MA(MA(C-(5 \times (HHV(H,13) + LLV(L,13))),25,E),2,E))}{(5 \times MA(MA(HHV(H,13)-LLV(L,13),25,E),2,E))}, \tag{5.13}
\]
where

- "MA" is the Moving Average.
- "C", "L" and "H" are the close, low and high price at day "t".
- HHV denotes the maximum high price of the past “n” days or highest high value.
- LLV denotes the minimum of low price of the past “n” days or lowest of low values.

It is an oscillator that shifts between -100 and +100 and can be a bit less inconstant than an equal period Stochastic Oscillator. The oscillator consists of 2 lines - the moving average of the SMI and the SMI. The SMI will be negative if the close is less than the middle point of the range. The SMI will be positive if the close is greater than the middle point of the range.

The SMI interpretation is in fact the same as that of the Stochastic Oscillator. The most ordinary way of using it is to trade from is to sell when the SMI rises above +40 and then returns to the point under that level and to purchase at the moment when the SMI decreases under -40 and then shifts back above it. Another trading sign is to purchase when the SMI shifts above the moving average, and sell when the SMI decreases below the moving average.

5.7 Time Series Quantitative Analytics 3 – TSQA3

Stephen C.W. Chu [90] combined broad range of technical indicators, including Moving Averages, RSI, Stochastic and Bollinger Band. The overall prediction capability
of this algorithm is enhanced by combining the Chaikin Money Flow indicator. The Chaikin Money Flow indicator is calculated from the daily readings of the Accumulation / Distribution Line [90]. The basic premise behind the Accumulation Distribution Line is that the degree of buying or selling pressure can be determined by the location of the Close relative to the High and Low for the corresponding period (Closing Location Value) [47].

Robert. W. Stone [84] demonstrated the technique of producing the greatest single profit using the moving average with the RSI applied on 60 minute trading charts, closely followed by the moving average trading of 1 minute charts. The Bollinger Bands are used as the envelopes which surround the price bars on a chart [47]. The Bollinger Bands adjust themselves to the market conditions. They widen during volatile market periods and contract during less volatile periods. The Bollinger Bands become moving standard deviation bands [46].

The TSQA3 [49] analyzes the stock price using the optimized trading rule, which is evolved by combining the Chaikin Money Flow Indicator (a confirming indicator) with the Relative Strength indicator (RSI), Stochastic Momentum Index, Bollinger Bands Calculation and RSI Signal. All the methods are needed to be in agreement for the algorithm to predict profitable buy / sell.

The RSI signal is a variation of RSI method, devised for the purpose of generating good percentage of profitable trade signals.
5.7.1 RSI signal

The algorithm based on Relative Strength Indicator given in Figure 5.1 generates the RSI Signal, which is used to predict an increase or decrease in next day's closing stock price.

\[
\text{If (RSI} \leq 30) \\
\text{Predict increase in tomorrow's closing price} \\
\text{Else} \\
\text{If (RSI} \geq 70) \\
\text{Predict decrease in tomorrow's closing price} \\
\text{Else} \\
\text{No change in tomorrow's closing price} \\
\text{End if} \\
\text{End if}
\]

Figure 5.1 Algorithm of RSI Signal

A RSI of 70 or above can indicate a stock which is overbought and due for a fall in price. When the RSI falls below 30 the stock may be oversold and is a good time to buy. They can vary depending on whether the market is bullish or bearish. RSI charted over longer periods tend to show less extremes of movement. Looking at historical charts over a period of a year or so can give a good indicator of how a stock price moves in relation to its RSI.
5.8 Time Series Quantitative Algorithm 4 – TSQA4

Piotr Lipinski [76] proposed a new trading rule by combining Stochastic Oscillator with Relative Strength Indicator. The author has not focused on profitable buy / sell signals generation, but proposed a technique of generating warning signals for specific situations relate to the rare circumstances of exceptional raises or drops of share prices. The Stochastic oscillator, a popular and dynamic indicator based on the premise that during an upward trading market, prices tend to close near their high, and during a downward trading market, prices tend to close near their low.

TSQA4 is formed with a variation of this oscillator called Stochastic Momentum index combined with the confirming indicator, Chaikin Money flow Indicator, Bollinger Bands Calculation, Relative Strength indicator and Stochastic Momentum Index Signal for achieving an average percentage of profitable trade signals generation above 60% level. All the methods are needed to be in agreement for the algorithm to predict profitable buy / sell.

5.8.1 SMI Signal

The algorithm based on the Stochastic Momentum Index generates the SMI Signal. This algorithm is used to predict an increase or decrease in next days closing stock price and is given in Figure 5.2.
If (SMI > 20)

Predict decrease in tomorrow’s closing price

Else

If (SMI < -40)

Predict increase in tomorrow’s closing price

Else

No change in tomorrow’s closing price

End if

End if

Figure 5.2 SMI Signal Algorithm

5.9 Time Series Quantitative Algorithm 5 – TSQA5

The financial indicators, On Balance Volume (OBV), Price Momentum Oscillator (PMO), Relative Strength Index (RSI), Stochastic (%K) and Moving Average (MA) were combined by Garth Garner [29] to obtain 50% of correct prediction. TSQA5 is formed by combining True Strength Index (TSI) with other financial indicators mentioned below to improve the percentage of profitable signals generated. The TSI is a variation of the Relative Strength Indicator. The TSI uses a double smoothed exponential moving average of price momentum to eliminate choppy price changes and spot trend changes. The TSI combines the leading characteristics of momentum calculation with the lagging characteristic of a moving average to create an indicator that reflects price direction and is in synchronization with market turns.
True Strength Index Signal is combined with Stochastic Momentum Index, Bollinger Bands Calculation, Relative Strength indicator, and Chaikin Money Flow indicator yielding TSQA5. All the methods are needed to be in agreement for the algorithm to predict profitable buy / sell.

5.9.1 True Strength Index

The True Strength Index (TSI), introduced by William Blau [107], calculates a running total of price changes. The True Strength Index (TSI) is calculated as detailed in equation 5.14.

Let “A” be the Exponential Moving Average (EMA) of Momentum for term1 periods.

Let “B” be the Exponential MA of (A) for term2 periods.

Let “C” be the Exponential MA of Absolute Momentum for term1 periods

Let “D” be the Exponential MA of (C) for term2 periods.

\[ TSI = \frac{B}{D} \quad (5.14) \]

The three main applications of the TSI are

1. Overbought and oversold indicator - In an overbought or oversold market prices have risen or fallen too far and are likely to retrace. Similar to the RSI it is also possible to define buy- and sell-zones. The market is considered to be overbought (oversold) if the TSI is above 30 (below -30)
In real bull or bear markets, the levels 40 and -40 might be a better choice. Theses signals are more reliable in non-trending markets.

2. Generation of buy- and sell-signals - A falling of the TSI below 30 can be used as sell-signal. Analogously, a rising of the TSI above -30 can be used as buy-signal.

3. Bullish and bearish divergence - A bullish divergence occurs when the TSI is making higher lows while the prices show the opposite tendency. This indicates a weakening down-trend. Analogously, a bearish divergence occurs when the TSI is making lower highs while prices show the opposite tendency. This indicates that the up-trend is weakening. Note that although divergences indicate a weakening trend, they do not indicate that the trend has reversed already.

5.9.2 Momentum

The Momentum (MOM) is an oscillator that measures the amount a stock price has changed over the observation period. It is a trend-follower.

The Momentum measures the price change over a time period of length “n” as given in equation 5.15.

\[
\text{MOM}_t = P_t - P_{t-n}, \quad (5.15)
\]

where \( P_t \) is given in equation 5.1. The MOM oscillates around the zero-line. Default value for “n” is 14 day.
The two most popular applications of Momentum are

- Overbought and oversold indication - In an overbought or oversold market prices have risen or fallen too far and are likely to retrace. This is indicated by a MOM very high above or below the zero-line. These signals are most reliable in non-trending markets.

- Bullish and bearish divergence - A bullish divergence occurs when the MOM is making higher lows while the prices show the opposite tendency. This indicates a weakening down-trend. Analogously, a bearish divergence occurs when the MOM is making lower highs while prices show the opposite tendency. This indicates that the up-trend is weakening. Note that although divergences indicate a weakening trend, they do not indicate that the trend has reversed already.

5.9.3 Exponential Moving Average

Exponential Moving Averages (EMA) are similar to Weighted Moving Averages (WMA). As opposed to Simple Moving Averages (SMA), they both put more weight on the most recent data. However, the EMA never drops the oldest data.

The EMA with parameter \( \mu \) of a data set \( v \) at day \( t \) is recursively defined by equation 5.16.

\[
EMA_t(v, \mu) = \begin{cases} 
V_0 & \text{if } t = 0 \\
\mu EMA_{t-1}(v, \mu) + (1 - \mu)v_t & \text{if } t > 0 
\end{cases}
\]

(5.16)
where $\mu = \exp(-1/\tau)$ and "\(\tau\)" characterizes the speed of decay of the weights of past values of "\(v\)". Usually, "\(v\)" is represented by the prices of an asset. Default value for the decay speed $\mu$ is 7.

The two main applications of EMA are:

- **Trend identification** - Trends can be identified by looking at the slope of a EMA and at the relationship of the EMA to the prices. If the EMA is sloping down (up) and the prices are below (above) the EMA, then the prices are in a down-trend (up-trend). A non-trending market exists if prices move above and below the EMA and the EMA is flat.

- **Generation of buy- and sell-signals** - There are two methods:
  
  1. A buy-signal (sell-signal) is given if the close price is above (below) the EMA.

  2. Use a second EMA with a shorter observation period than the first one. It reacts faster to market movements than the first EMA. Buy-signals (sell-signals) are generated when the shorter EMA crosses the longer EMA from below (above).

Note that EMA are most effective in trending markets, in non-trending markets they are likely to give false signals.

The alternate method of calculating TSI is given in equation 5.10. Let $P_t$ denote the price at time $t$. The price change is given in equation 5.17.

$$\text{PriceChange}_t = P_t - P_{t-1} \quad (5.17)$$
and the absolute price change in equation 5.18.

\[ \text{AbsPriceChange}_t = |P_t - P_{t-1}| \]  

(5.18)

A short term Exponential Moving Average (EMA) with parameter “s” and a long term EMA with parameter “l” are introduced. The TSI at time “t” is defined by equation 5.19

\[
\text{TSI}_t = \begin{cases} 
0 & \text{if } \text{EMA}_s(\text{EMA}_l(\text{AbsPriceChange}_t)),s) = 0 \\
100 & \sqrt{\frac{\text{EMA}_s(\text{EMA}_l(\text{PriceChange}_t)),s)}{\text{EMA}_s(\text{EMA}_l(\text{AbsPriceChange}_t)),s)}} \text{ if } \text{EMA}_s(\text{EMA}_l(\text{AbsPriceChange}_t)),s) \neq 0 
\end{cases}
\]  

(5.19)

The TSI oscillates between -100 and 100. Default values are \( s = 7 \) and \( l = 14 \).

5.9.4 TSI Signal

The algorithm for the TSI signal based on the True Strength Index devised for enhancing the predictive power of TSI is given in Figure 5.3.

```
IF ((tsioutput[i] > -30) && (tsioutput[i-1] <= -30) && (tsioutput[i-2] <= -30))
    Generate a buy signal
ELSE
    IF ((tsioutput[i] < 30) && (tsioutput[i-1] >= 30) && (tsioutput[i-2] >= 30))
        Generate a Sell signal
ENDIF
ENDIF
```

Figure 5.3 TSI Signal Algorithm
The Technical indicators and trading rules from financial data analysis techniques are combined together and the power of each technical tool is integrated into a single decision system [32]. The results of the back test performed on the historic data shows that all the above three algorithms outperforms most of the other prominent algorithms in the field.