

A TRADING STRATEGY BASED ON MYCIN'S CERTAINTY FACTOR MODEL

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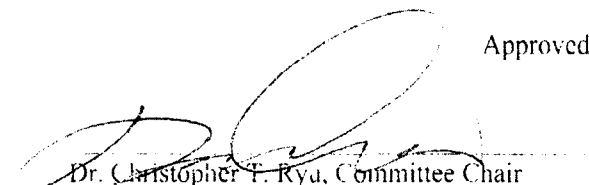
in

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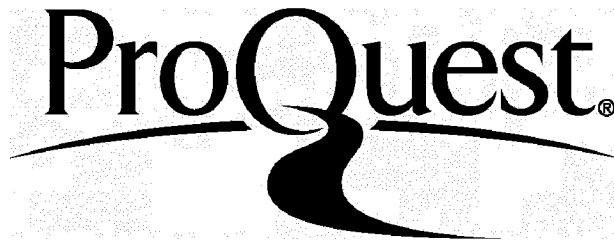
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## ABSTRACT

The key issues for decision making in stock market are what the best stock to trade and when the best time for trading. Many approaches have been used by investors to predict in stock market. One of the most affective approaches is using technical indicators. Although using technical indicators is useful to help the traders in predicting to buy or sell, sometimes wrong interpretation of the technical indicators can cause real loss. In this work, comprehensive results of a study on various technical indicators, which have been effective on selling and buying decisions in stock markets, are provided. Understanding how to compute those technical indicators and the purpose of each indicator also are presented in this work.

This work is divided into two main sections. The first one includes calculating ten technical indicators for the 30 companies of Dow Jones historical data (2013-2014) that obtained from Google finance to find buy and sell signals. For each technical indicator monthly return regardless of buy signal and monthly return upon buy signal are calculated and used as evidences to help making decisions for trading. Then four technical indicators that have high certainty factor value are combined. In the second section, annual return, volatility, excess return, maximum drawdown, and sharpe ratio metrics are computed for backtesting to verify the trading results. These backtesting metrics are calculated for the all 30 companies of Dow Jones when the combined technical indicators show a trade signal. Finally and according to the backtesting results,

the presented approach that uses the MYCIN's certainty factor model can be used as an effective trading strategy.

## TABLE OF CONTENTS

ABSTRACT.....	i
LIST OF TABLES.....	vi
LIST OF FIGURES .....	vii
ACKNOWLEDGMENTS .....	viii
 Chapter	
1. TECHNICAL INDICATORS .....	1
Introduction.....	1
Momentum Indicators.....	2
Trend Indicators.....	2
Volatility Indicators .....	2
Volume Indicators.....	3
Lagging Indicators.....	3
Leading Indicators .....	3
Bollinger Bands .....	4
Commodity Channel Index.....	6
Chande Momentum Oscillator.....	7
Force Index .....	7
Moving Average Convergence and Divergence MACD.....	9
Money Flow Index MFI.....	10
Momentum.....	11
Price Rate of Change ROC .....	11
Relative Strength Index RSI .....	12
Stochastic Oscillator .....	13
2. MYCIN CERTAINTY FACTOR MODEL .....	14
Background.....	14
Certainty Factor Calculations .....	16

3. A TRADING STRATEGY BASED ON MYCIN'S CERTAINTY FACTOR MODEL .....	19
Introduction.....	19
Simulation and Results .....	20
4. BACKTESTING .....	25
Introduction.....	25
Annual Return.....	26
Excess Return .....	26
Volatility... ..	27
Portfolio Drawdown .....	28
Sharpe Ratio .....	29
5. CONCLUSION AND FUTURE WORKS .....	32
Conclusion .....	32
Future Works .....	33
REFERENCES .....	34

## LIST OF TABLES

<u>Table</u>	<u>Page</u>
1. Calculation Values of Each technical Indicator.....	22
2. Backtesting Results.....	30
3. Annual Return for the 30 Companies of Dow Jones .....	31

## LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
1. Structure of Expert System .....	15



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## CHAPTER 1

### TECHNICAL INDICATORS

#### Introduction

The key issue for decision making in the stock market is the selection of the best stock and the best time to invest. To solve this issue many approaches and strategies have been used by investors. One of the most effective approaches is using technical indicators. A technical indicator uses calculations of past prices to show future behavior of the stock. That's because technical analysis presupposes that any stock or market in general repeats its behavior [Gandevani, 2010]. It is helpful for investors to consider using technical indicators to reduce the level of risks once they make an investment. According to [Larson, 2012] the key technical indicators are relevant strength index, money flow index, stochastic oscillator, moving average convergence divergence, and bollinger bands.

Even though using technical indicators holds the capacity of facilitating decision making on whether to invest on a particular stock or not, technical indicators have also problems since their interpretation is sometimes misleading. The interpretation of the technical indicators requires distinct understanding on how they are computed and used. The lack of the accurate interpretation of technical indicators has made the investors make wrong buying and selling decisions of stocks thereby exposing them to acute loss.

According to [Folger, n.d.] there are four main types of technical indicators:

### Momentum Indicators

Momentum indicators help buyer and seller identify the speed of price movement by comparing prices over time. These technical indicators appear as a line below a price chart that fluctuates as momentum changes. When there is a divergence between price and a momentum indicator, it can indicate a change in future prices. Examples of momentum indicators include momentum, relative strength index, and stochastic.

### Trend Indicators

Trend indicators are used to measure the direction and strength of a trend using some form of price averaging to establish a baseline. As prices exceed the average, it can be thought of as a bullish uptrend, and when prices descend below the average it indicates a bearish downtrend. The most popular trend indicators include moving averages, moving average convergence divergence, and average directional index.

### Volatility Indicators

Volatility indicators are used to measure the rate of price movement, regardless of the direction. This is generally based on a change in the highest and lowest historical prices in a security, commodity, currency pair or other trading instrument. These indicators help by providing useful information about the range of buying and selling that happens in a specific market. This information can help traders to determine the possible points where the market may change the trade direction. Popular volatility indicators are bollinger bands and average true range

## Volume Indicators

Independent of the price, volume represents the amount of buying and selling activities that occur during a specific interval. Most volume indicators are based on some form of averaging or smoothing of raw volume. They can indicate a strengthening of a trend or a confirmation of a trading direction when volume levels move above their average. The strongest trends often occur while volume increases. In fact, increasing in trading volume can lead to large movements in price. Popular volume indicators include on balance volume, money flow index, and chaikin money.

On the other hand, [Achelis, 2000] classifies the technical indicators into two main classes:

1. *Lagging Indicators.* These indicators are excellent when prices move in relatively long trends. They don't warn the traders for upcoming changes in prices but they simply inform them what prices are doing so they can invest accordingly. That means they can reduce the risk by keeping the traders on the right side of the market.
2. *Leading Indicators.* These indicators help the traders to gain by predicting what the prices will be next. They typically measure how "overbought" or "oversold" a security is. This is done with the assumption that a security that is "oversold" will rebound back.

It is important to understand not only how the indicators work, but in which markets they may be most effective and how they can be interpreted. Technical indicators must be applied correctly to the markets in order to provide the most

profitable results. Also, traders should be selective and avoid using every possible indicator. More technical indicators do not necessarily lead to more accurate trading.

In trading, timing is everything and waiting for too many indicators could cause traders to miss out on significant trading opportunities, therefore, traders should apply the indicators which provide matchless signals and work best in combination with their trading styles.

The ten technical indicators that are used, computed, and demonstrated in this work are bollinger bands, commodity channel index, chande momentum oscillator, moving average convergence divergence, force, money flow index, momentum, rate of change, relative strength index, and stochastic oscillator. Following is the explanation of each one of these technical indicators.

#### Bollinger Bands

This indicator, which is developed by John Bollinger, operates on the belief that a market's value can go up or down depending on the volatility bands. Volatility bands are placed up and down a moving average. Volatility is based on the standard deviation which can be changed when volatility increases and decreases. The bands automatically expand when volatility increases and contract when volatility decreases. With this dynamic nature of bollinger bands, they can be used on different securities with the standard settings. Basically, bollinger bands are used to gauge whether a price is considered high or low based on the price history. For signals, bollinger bands can be used to identify M-Tops and W-Bottoms or to determine the strength of the trend [Bollinger Bands, n.d.].

[Achelis, 2000] explains the following characteristic of the bollinger bands

indicators:

1. Sudden changes in prices tend to happen after the band has contracted because of the decrease of the volatility.
2. Continuation of the current trend is to be expected when prices break through the upper band.
3. If the pikes and hollows outside the band are followed by pikes and hollows inside the band, a reverse of trend may occur.
4. The price movement that has started from one of the band's lines usually reaches the opposite one. The last observation is useful for forecasting price guideposts.

One common strategy that has been used in the market is to sell when the price touches the upper bollinger band and buy when it hits the lower bollinger band [Bollinger Bands, n.d.]. Also, bollinger bands indicator helps the traders to watch out for overbought and oversold conditions. Basically, if the price moves closer to the upper band, it indicates an overbought condition. If the price moves closer to the lower band, it indicates an oversold condition.

Bollinger bands are calculated by using the following formula as explained by [Bollinger Bands, n.d.]

Middle Band = 20-day simple moving average (SMA)

$$\text{SMA} = \text{sum}(\text{close}, 20) / 20$$

Upper Band = 20-day SMA + (20-day standard deviation of price \* 2)

$$= \text{Middle Band} + \text{STDEVPA}(\text{close}, 20) * 2$$

STDEVPA: this function in excel calculates the standard deviation of the price.

Lower Band = 20-day SMA - (20-day standard deviation of price \* 2)

= Middle Band - STDEVPA (close, 20) \* 2

### Commodity Channel Index

The commodity channel index ("CCI"), which is developed by Donald Lambert, measures the variation of a security's price from its statistical mean. High values show that prices are unusually high compared to average prices while low values indicate that prices are unusually low. CCI can be used effectively on any type of security [Kuepper, 2015].

There are two basic methods of interpreting the CCI:

- Looking for divergences. A divergence occurs when the security's prices are going new highs while the CCI is failing to exceed its previous highs. This classic divergence is usually followed by a correction in the security's price.
- As an overbought/oversold indicator. To use the CCI as an overbought/oversold indicator, readings above +100 mean an overbought condition whereas readings below -100 mean an oversold condition [Achelis, 2000].

CCI is calculated by following these steps:

1. Finding the typical price: Typical price = (high + low + close) / 3
2. Calculating the 20-day SMA of typical price: SMA =sum (typical price, 20)/20
3. Calculating 20-day Mean Deviation. There are four steps to calculate the Mean Deviation:
  - i. Subtracting the most recent 20-day SMA of the typical price (step2) from each period's typical price (step 1).
  - ii. Taking the absolute values of these numbers.
  - iii. Finding the summation of the absolute values.
  - iv. Divide the summation of the absolute values by (20).

4. Finding CCI = (Typical Price - 20-day SMA of typical price) / (.015 x Mean Deviation).

#### Chande Momentum Oscillator

The CMO, a technical momentum indicator invented by the technical analyst Tushar Chande, differs from other momentum oscillators by using both up and down day's data to measure momentum directly [TAI Chande Momentum, n.d.]. The calculations of this indicator are applied to non-smoothed data; so short-term extreme price movements are not hidden. The CMO can also be used to look for trends. The standard method of CMO interpretation is looking for overselling/overbuying. Overselling occurs if value is under -50. Overbuying occurs when the value overcomes +50 point [Chande Momentum, n.d.].

CMO is calculated by using the following formula as explained by [Hill, n.d.]

$$\text{CMO} = [(Su - Sd) / (Su + Sd)] * 100$$

$$Su = \text{sum} ((\text{today's close price} - \text{yesterday's close price}) > 0, 14)$$

$$Sd = \text{Absolute} (\text{sum} ((\text{today's close price} - \text{yesterday's close price}) < 0, 14))$$

#### Force Index

The force index, developed by Alexander Elder, is an indicator that uses price and volume to determine the power behind a move or identify possible turning points. The force index combines all the three essential elements of a stock's price movement, which are direction, extent and volume. The force index can be used to confirm the overall trend and to predict reversals with divergences.

In the force index, there is either a positive or negative price change. A positive price change indicates that buyers are stronger than sellers, while a negative price change



indicates that sellers are stronger than buyers. Furthermore, there is the extent of the price change, which is simply the current close less the prior close. This “extent” shows how far prices are moving. A big advance elucidates strong buying pressure, where as a big decline elucidates strong selling pressure. The third and final element is volume that measures commitment and shows how committed are the buyers and sellers. A big advance on heavy volume indicates a strong commitment from buyers. Likewise, a big decline on heavy volume indicates a strong commitment from sellers. The Force Index gags these three elements into one indicator that measures buying and selling pressure [Force Index, n.d.].

Force index is calculated using this formula as explained by [Bergen, n.d.]

Force index = (today's close price - yesterday's close price) \* today's volume

13-period EMA of Force index = sum (Force index, 13) /13

Force index is one of the best indicators that combine both price and volume into a single readable figure. The difference between yesterday and today's close gives more information about the bullish and bearish signals. Also, volume is added into the calculation to give a greater sense of the degree of buying and selling signals.

One of the strategies that the traders follow with the force index is to buy when the 13-period EMA of Force index turns negative during the uptrend and to sell when the 13-period EMA of Force index turns positive during the downtrend. Another strategy is to plot the Force index value as histogram with zero center line. Then buy signal is indicated when the Force index value is below the centerline and sell signal is indicated when the Force index value is above the centerline [Bergen, n.d.].

### Moving Average Convergence and Divergence MACD

MACD, developed by Gerald Appel in the late seventies, shows the relationship between two moving averages of prices. MACD is one of the most popular oscillators because it can be used as both as an oscillator and a momentum indicator. As an oscillator, the MACD can be used to identify overbought and oversold conditions for a stock. As a momentum indicator, it can be used to follow a trend.

MACD is calculated as:

$$12\text{-EMA} = \text{sum (close price, 12)} / 12$$

$$26\text{-EMA} = \text{sum (close price, 26)} / 26$$

$$\text{MACD Line} = (12\text{-EMA}) - (26\text{-EMA})$$

$$\text{Signal Line} = \text{sum (MACD Line, 9)} / 9$$

$$\text{MACD Histogram} = \text{MACD Line} - \text{Signal Line}$$

There are three common methods that help to identify buy and sell signals using the MACD [Moving Average, 2015]:

1. *Crossovers*. In this method, sell signal is indicated when the MACD falls below the signal line. Conversely, when the MACD rises above the signal line, the buy signal is indicated.
2. *Divergence*. It indicates the end of the current trend when the security price diverges from the MACD.
3. *Dramatic rise*. Overbought is indicated when the shorter moving average pulls away from the longer-term moving average.

Traders also watch for a moving above or below the zero line because this signals the position of the short-term average relative to the long-term average. A buy signal is

generated when the MACD crosses above the zero line. Conversely, when the MACD crosses below the zero line a sell signal is generated [Moving Average, 2015].

### Money Flow Index MFI

The money flow index (MFI). Created by Gene Quong and Avrum Soudack, is an oscillator that uses both price and volume to measure buying and selling pressure. MFI is also known as volume-weighted RSI because it is related to the relative strength index, but where the RSI only uses prices, the money flow index considers volume too [Achelis, 2000].

Money flow index is calculated by following these steps:

1. Finding the typical price: Typical price=(high price +low price +close price)/3
2. Finding the row money flow RMF: RMF = typical price \* volume
3. Finding 14-period positive money flow PMF: PMF = sum ((typical price of today > typical price of yesterday), 14)
4. Finding 14-period negative money flow NMF: NMF =sum ((typical price of today < typical price of yesterday), 14)
5. Finding money flow ratio MFR: MFR = 14-period positive money flow / 14-period negative money flow
6. Finding the money flow index MFI: MFI =100 - [100/(1 + money flow ratio)]

The money flow index can generate several signals like overbought and oversold conditions, divergences, and failure swings. MFI is considered helpful in confirming trends in prices and warning of potential reversals in prices. The most common strategy that has been used by the traders is to buy when the MFI value is below 20 (oversold) and to sell when the MFI value above 80 (overbought) [Money Flow, 2013].

### Momentum

The momentum indicator measures the rate of the rise or fall in stock prices. When the indicator bottoms out and begins to raise the buy signal is generated. Conversely, it can be considered a sell signal when the indicator peaks and begins to descend [Online Trading, 2007]. Furthermore, buy signal is generated when the momentum indicator crosses above the zero line and the sell signal is generated when the momentum indicator crosses below the zero line [Momentum, 2000].

Momentum indicator is simply calculated by subtracting the close price of (N) days ago from today's close price:

Momentum = today's close price - close price of 9 days ago.

### Price Rate of Change ROC

The rate of change (ROC) indicator measures the percentage change of the current price as compared to the price a certain number of periods ago. The ROC displays the wave-like motion in an oscillator format by measuring the prices changing over a given time period. In general, prices are rising as long as the rate-of-change remains positive. Conversely, prices are falling when the rate-of-change is negative. The greater the change in prices, the greater the change in the ROC. ROC signals include centerline crossovers, divergences and overbought-oversold readings [Rate of Change, 2012]. The time period used to calculate the ROC ranges from 1-day to 200-days (or longer). The most popular time periods are the 12-days for short-term trading and 25-days for intermediate-term trading. For the overbought and oversold signals, when the ROC is high, the stock is considered overbought and when the ROC is low the stock is considered oversold. The 12-day ROC tends to be very cyclical, oscillating back and forth in a fairly regular cycle.

Often, price changes can be expected by studying the previous cycles of the ROC and connecting the previous cycles to the current market [Achelis, 2000]. Many traders use a value greater than zero to indicate an increase in buying pressure and a value less than zero to indicate an increase in selling pressure.

ROC is simply calculated as [Rate of Change, 2012] explains:

$$\text{ROC} = \{(\text{today's close price} - 12 \text{ days ago close price}) / 12 \text{ days ago close price}\} * 100$$

### Relative Strength Index RSI

The relative strength index ("RSI"), a technical momentum indicator that compares the magnitude of recent gains to recent losses in an attempt to determine overbought and oversold conditions of an asset, is created by J. Welles Wilder Jr [Achelis, 2000]. RSI is a price-following oscillator that ranges between 0 and 100. Buy signal is generated when RSI value is less than 30 (oversold) and sell signal is generated when the RSI value is more than 70 (overbought). Signals can also be generated by looking for divergences, failure swings and centerline crossovers. RSI can also be used to identify the general trend [Blystone, 2015].

RSI is calculated using the following steps:

1. Finding the change price: Change price = today's close price - yesterday's close price
2. Finding the average gain: Average gain =  $\text{sum}(\text{change price} > 0, 14) / 14$
3. Finding the average loss: Average loss =  $\text{sum}(\text{change price} < 0, 14) / 14$
4. Calculating the RS:  $\text{RS} = \text{average gain} / \text{average loss}$
5. Calculating the RSI:  $\text{RSI} = 100 - (100 / (1 + \text{RS}))$

### Stochastic Oscillator

The stochastic oscillator, developed by George C. Lane in the late 1950s, compares where a security's price closed relative to its price range over a given time period. The stochastic oscillator includes two lines. The main line is called "%K." The second line is called "%D," which is a moving average of %K [Achelis, 2000]. There are several ways to interpret a stochastic oscillator but the most common methods are:

- Buying signal is generated when the oscillator (either %K or %D) falls below (20) and then rises above that level. Conversely, selling signal is generated when the oscillator rises above a (80) and then falls below that level.
- Buying signal is generated when the %K line rises above the %D line and selling signal is generated when the %K line falls below the %D line. [Stochastic Oscillator, 2001]. Stochastic oscillator is calculated by following these steps:
  - 1) Finding the highest high: Highest high = max (high price, 14)
  - 2) Finding the lowest low: Lowest low = min (low price, 14)
  - 3) Calculating %K:  $\%K = (\text{close price} - \text{lowest low}) / (\text{highest high} - \text{lowest low}) * 100$
  - 4) Calculating the %D:  $\%D = \text{sum} (\%K, 3) / 3$

## CHAPTER 2

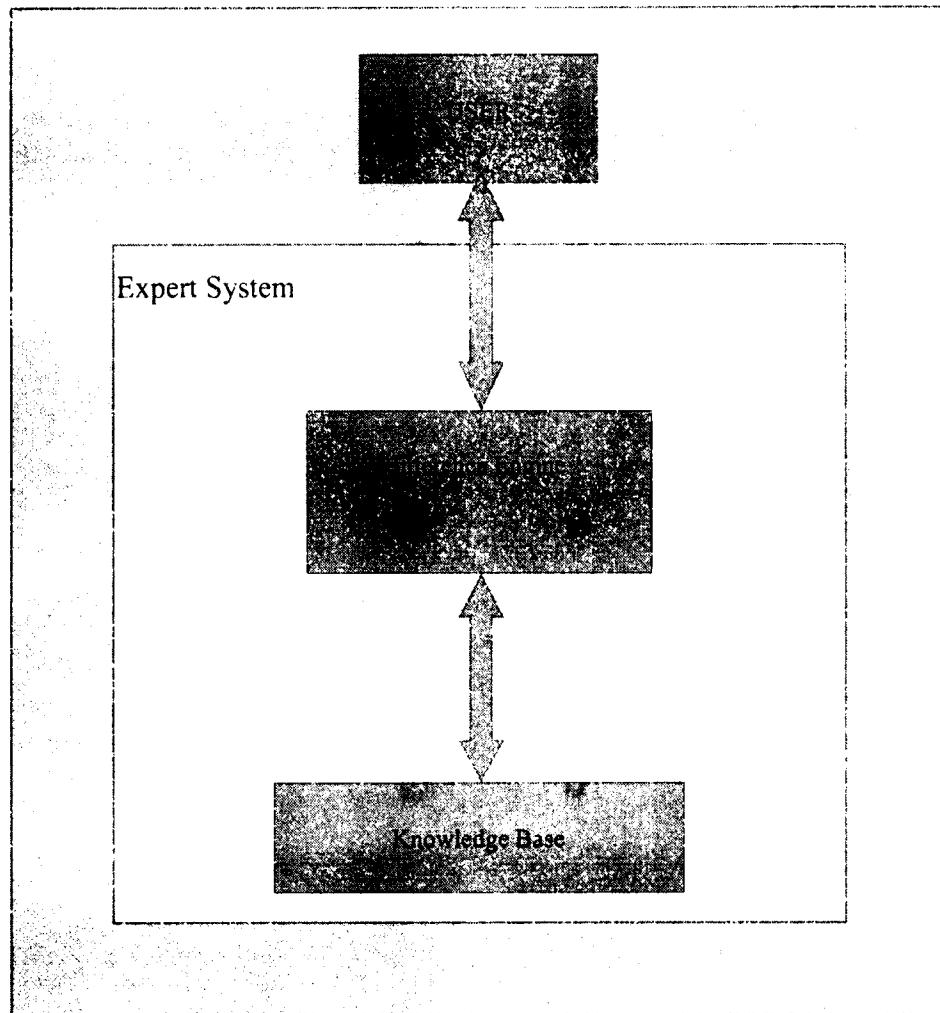
### MYCIN CERTAINTY FACTOR MODEL

#### Background

Originally, MYCIN system was developed by a group of physicians and computer scientists over two years to serve a primary goal. This goal was to help the physicians on diagnosis of and therapy for infection diseases by providing consultative advice [Kanel, Lemmer, 1986]. It is the first system that was run in the medical field. Also, this system (MYCIN) is considered one of the several noted programs that shows how artificial intelligence technology supports and helps people with real- world problems.

From the artificial intelligent concept, MYCIN certainty factor model is designed in a way that helps in solving problems of probabilistic reasoning and confirmation. The primary goal of this model is to provide a method for dealing with uncertainty. By this method, it is possible to avoid the need for large amounts of data and the computations that are related to the probabilistic reasoning [Kanel, Lemmer, 1986].

MYCIN is an expert system [Buchanan, Shortliffe, 1962] and as any expert system, there are two main parts in which MYCIN consisting of which are Knowledge base and inference engine as shown in Figure 1.



*Figure 1.* Structure of Expert System. From Expert systems concepts, retrieved from <http://home.agh.edu.pl/~wojnicki/thesis/node6.html>.

The knowledge base part can be considered as a store of facts and it is represented as rules in the form of “IF E THEN H” where H is a hypothesis and E is evidence that has relevance to the hypothesis. A hypothesis contains one or more conclusions while the evidence is constrained to be Boolean expression. Each rule has a value that is associated with it which is a certainty factor. A certainty factor measures the change of belief about hypothesis given some evidences and it is not responsible of measuring the absolute belief [Kanel, Lemmer, 1986].



The certainty factor is away of combining belief and disbelief into a single value [Giarratano, Riley, 2004]. The two main advantages of using the certainty factor model are to rank hypotheses according to their importance and to indicate the net belief in a hypothesis based on some evidences [Giarratano, Riley, 1998].

### Certainty Factor Calculations

The certainty factor CF for each rule in MYCIN is calculated as explained by [Giarratano, Riley, 2004]

$$CF(H, E) = MB(H, E) - MD(H, E)$$

Where:

CF(H, E) is the certainty factor in the hypothesis H due to evidence E.

MB(H, E) is the measurement of belief of hypothesis H due to evidence E.

MD(H, E) is the measurement of disbelief of hypothesis H due to evidence E

MB and MD are calculated as following:

$$MB(H, E) = \begin{cases} 1 & \text{if } P(H) = 1 \\ \frac{MAX[P(H, E), P(H)] - P(H)}{1 - P(H)} & \text{otherwise} \end{cases}$$

$$MD(H, E) = \begin{cases} 1 & \text{if } P(H) = 0 \\ \frac{MIN[P(H, E), P(H)] - P(H)}{-P(H)} & \text{otherwise} \end{cases}$$

The range of  $CF$  is  $-1 \leq CF \leq 1$

A positive  $CF$  (+  $CF$ ) means the evidence  $E$  supports the hypothesis  $H$ .

A negative  $CF$  (-  $CF$ ) means the evidence  $E$  supports the negation of the hypothesis  $H$ .

A  $CF=1$  means the evidence  $E$  proves the hypothesis  $H$ .

A  $CF=0$  means the  $MB$  and  $MD$  cancel each other by having the same value.

In 1977, the definition of  $CF$  was changed to be as explained by [Giarratano, Riley, 1998] as:

$$CF(H, E) = \frac{MB(H, E) - MD(H, E)}{1 - \min [MB(H, E), MD(H, E)]}$$

This change is made because the rule in MYCIN must have  $CF$  value that is greater than 0.2 to be activated and fired. This value is called threshold. Using threshold value is important to improve the efficiency of the system by minimizing of using the rules that weakly support the hypothesis [Giarratano, Riley, 1998].

If there are more than one rule that conclude the same hypothesis  $H$ , then the  $CF$  of these rules can be calculated as following

$$CF_{COMBINE} = \begin{cases} CF_1 + CF_2 * (1 - CF_1) & \text{both} > 0 \\ \frac{CF_1 + CF_2}{1 - \min(|CF_1|, |CF_2|)} & \text{one} < 0 \\ CF_1 + CF_2 * (1 + CF_1) & \text{both} < 0 \end{cases}$$

This combining function (finding  $CF_{COMBINE}$ ) depends whether the individual certainty factors  $CF_1$ ,  $CF_2$  greater than zero or less than zero. Furthermore, this formula can be applied incrementally for more than two rules [Giarratano, Riley, 1998]. To illustrate, if  $CF_{COMBINE}$  formula is used to combine the certainty factors of two rules that conclude the same hypothesis and there is a third rule that conclude the same hypothesis

too, then the combining function can be used again to combine the  $CF_{COMBINE}$  (of the two previous CFs) with the CF of the third rule.

For example: assuming there are two rules with CFs (0.21, 0.5) conclude the same hypothesis H, then the combining function calculation will be as

$$\begin{aligned} CF_{COMBINE}(0.21, 0.5) &= 0.21 + 0.5 * (1 - 0.21) \\ &= 0.605 \end{aligned}$$

And there is another rule that conclude the same hypothesis with CF = (- 0.4) then the second part of the combining function will be used as

$$\begin{aligned} CF_{COMBINE}(0.605, - 0.4) &= (0.605 - 0.4) / 1 - \text{MIN} [|0.605|, |- 0.4|] \\ &= 0.205 / 1 - 0.4 \\ &= 0.3 \end{aligned}$$

## CHAPTER 3

### A TRADING STRATEGY BASED ON MYCIN'S CERTAINTY FACTOR MODEL

#### Introduction

What is the best time to buy a stock? What is the best stock to buy? And many other questions that are needed to be answered to help the investors in making decisions in stock market. Many approaches have been used to serve this problem. In this work, a new approach is presented. This approach includes using MYCIN certainty factor model to help find the best time to invest by using some technical indicators as evidences. The technical indicators that are used are bollinger bands BB, commodity channel index CCI, chande momentum oscillator CMO, moving average convergence divergence MACD, force index F, money flow index MFI, momentum MOM, rate of change ROC, relative strength index RSI, and stochastic oscillator SO). Also, the data that is used for finding buy signals, sell signals, monthly returns regardless of buy signal and monthly returns upon buy signals is obtained from the Google finance and belongs to the 30 companies of Dow Jones to the years (2013,2014).

MYCIN certainty factor model is used to find the CF value for each technical indicator. Then the combining function is used to combine the rules that conclude the same hypothesis, which is in this thesis, is making gains for monthly investment. The rules that are combined have the CF values which are greater than 0.2.

### Simulation and Results

For every technical indicator, the following calculations are done:

1. % Monthly return regardless of buy signal =  $(\text{end of month close price} / \text{beginning of month close price} - 1) * 100$

For example:

- The close price of AXP company in JAN 2, 2013 was \$58.75
  - The close price of AXP company in JAN 31, 2013 was \$58.81
  - % Monthly return regardless of buy signal =  $(58.81 / 58.75 - 1) * 100 = 0.10\%$
2. % Monthly return upon buy signal =  $((\text{next month close price}) / (\text{day close price}) - 1) * 100$

For example:

- The close price of AXP company in APR 15, 2013 was \$64.1 (in that day the BB indicator showed buy signal)
  - The close price of AXP company in MAY 15, 2013 was \$72.78
  - % Monthly return upon buy signal =  $(72.78 / 64.1 - 1) * 100 = 13.54\%$
3. Probability of positive monthly return regardless of buy signal = no. of times when the % monthly return regardless of buy signal  $> 0$  / total no. of % monthly return regardless of buy signal.
    - In the all ten technical indicators, the no. of times when the %monthly return regardless of buy signal  $> 0$  for all the 30 companies = 459
    - Total no. of monthly return regardless of buy signal for all the 30 companies = 720
    - Probability of positive monthly return regardless of buy signal =  $459 / 720 = 0.64$

4. Probability of positive monthly return upon buy signal = no. of times when the % monthly return upon buy signal > 0 / Total no. of % monthly return upon buy signal

For example:

- In BB technical indicator the no. of times when the %monthly return upon buy signal > 0 for all the 30 companies = 524
- Total no. of %monthly return upon buy signal for all the 30 companies = 732
- Probability of positive monthly return upon buy signal for BB indicator = 524 / 732 = 0.72

5. MB (H, E), MD (H, E)

$$MB(H, E) = \frac{MAX[P(H, E), P(H)] - P(H)}{1 - P(H)} \quad [Giarratano, Riley, 1998]$$

$$MD(H, E) = \frac{MIN[P(H, E), P(H)] - P(H)}{-P(H)} \quad [Giarratano, Riley, 1998]$$

Where:

P (H|E) = probability of positive monthly return upon buy signal.

P (H) = probability of positive monthly return regardless of buy signal.

For example:

The MB (H, E) and MD (H, E) for BB indicator are calculated as:

$$MB(H, E) = (MAX[0.72, 0.64] - 0.64) / (1 - 0.64) = 0.22$$

$$MD(H, E) = (MIN[0.72, 0.64] - 0.64) / (-0.64) = 0$$

6. Certainty factor CF (H, E)

$$CF(H, E) = \frac{MB(H, E) - MD(H, E)}{1 - MIN[MB(H, E), MD(H, E)]} \quad [Giarratano, Riley, 1998]$$

For example:

The CF of BB indicator is calculated as:

$$CF = (0.22 - 0) / (1 - MIN(0.22, 0)) = 0.22$$

Table 1 shows the MB (H, E), MD (H, E), and CF (H, E) for each technical indicator.

Table 1. Calculation Values of Each Technical Indicator

Technical indicator	Probability of positive monthly return regardless of buy signal	Probability of positive monthly return upon buy signal	MB (H, E)	MD (H, E)	CF (H, E)
BB	0.64	0.72	0.22	0	0.22
CCI	0.64	0.69	0.16	0	0.16
CMO	0.64	0.76	0.35	0	0.35
MACD	0.64	0.66	0	0.03	-0.03
F	0.64	0.62	0	0.03	-0.03
MFI	0.64	0.79	0.43	0	0.43
MOM	0.64	0.63	0	0.02	-0.02
ROC	0.64	0.64	0.02	0	0.02
RSI	0.64	0.8	0.44	0	0.44
SO	0.64	0.62	0	0.03	-0.03

According to the CF value for each technical indicator the following rules are defined:

1. IF BB indicator shows a buy signal for a specific stock  
Then there is a suggestive evidence (0.22) to get gains when selling the stock after one month.
2. IF CCI indicator shows a buy signal for a specific stock  
Then there is a suggestive evidence (0.16) to get gains when selling the stock after one month.
3. IF CMO indicator shows a buy signal for a specific stock  
Then there is a suggestive evidence (0.35) to get gains when selling the stock after one month.

4. IF MACD indicator shows a buy signal for a specific stock  
Then there is a suggestive evidence (- 0.03) to get gains when selling the stock after one month.
5. IF F indicator shows a buy signal for a specific stock  
Then there is a suggestive evidence (- 0.03) to get gains when selling the stock after one month.
6. IF MFI indicator shows a buy signal for a specific stock  
Then there is a suggestive evidence (0.43) to get gains when selling the stock after one month.
7. IF MOM indicator shows a buy signal for a specific stock  
Then there is a suggestive evidence (- 0.02) to get gains when selling the stock after one month.
8. IF ROC indicator shows a buy signal for a specific stock  
Then there is a suggestive evidence (0.02) to get gains when selling the stock after one month.
9. IF RSI indicator shows a buy signal for a specific stock  
Then there is a suggestive evidence (0.44) to get gains when selling the stock after one month.
10. IF SO indicator shows a buy signal for a specific stock  
Then there is a suggestive evidence (- 0.03) to get gains when selling the stock after one month.

After that, the combining function formula is used to combine the technical indicators that conclude the same hypothesis, which is getting gain for monthly investment. These technical indicators have CF values that are greater than 0.2, which are RSI, MFI, CMO, and BB.

$$CF_{COMBINED} = CF1 + CF2 * (1 - CF1) \quad [Giarratano, Riley, 1998]$$

From rules (6,9)

$$\begin{aligned} CF1_{COMBINED} &= 0.44 + 0.43 * (1 - 0.44) \\ &= 0.68 \end{aligned}$$

The CF of the rule 3 with the previous CF ( $CF1_{COMBINED}$ ) are used to find the

$$CF2_{COMBINED}$$



$$\begin{aligned} CF2_{COMBINED} &= 0.68 + 0.35 * (1 - 0.68) \\ &= 0.79 \end{aligned}$$

Finally, the CF of the rule 1 with the previous CF ( $CF2_{COMBINED}$ ) are used to find the

$CF3_{COMBINED}$ .

$$\begin{aligned} CF3_{COMBINED} &= 0.79 + 0.22 * (1 - 0.79) \\ &= 0.84 \end{aligned}$$

So:

IF BB indicator show a buy signal for a specific stock

And

IF CMO indicator show a buy signal for the same stock

And

IF MFI indicator show a buy signal for the same stock

And

IF RSI indicator show a buy signal for the same stock

THEN you will get gains with  $CF = 0.84$  when selling the stock after one month of buying that stock.

## CHAPTER 4

### BACKTESTING

#### Introduction

Backtesting is a method that can be used to determine if the trading strategy works or not by implementing the strategy using past data. This method assumes that what happened in the past will happen in the future [Backtesting, 2015].

Backtesting can provides valuable information about the trading strategy and can be done by calculating the following metrics [Kuepper, 2015]:

1. Annual return
2. Excess return
3. Volatility
4. Portfolio drawdown
5. Sharpe ratio

In this thesis all the previous metrics are used to backtest the presented approach. These metrics are applied using the 30 companies of Dow Jones data to the years (2011-2014) and calculated when the combined technical indicators show the buy signal at the same time. Following is the explanation of each metric and how it is calculated.

### Annual Return

Annual return is the total return of an investment over a period of time and expressed as yearly percentage.

$$\% \text{ Annual return} = (\text{next year close price} / \text{day close price} - 1) * 100$$

For example, in August 28, 2013, all combined technical indicators show buy signal for the CSCO company and the close price for that day was = \$23.44

$$\text{August 28, 2014 close price was} = \$ 24.85$$

$$\begin{aligned} \% \text{ Annual return} &= 24.85 / 23.44 - 1 * 100 \\ &= 6.02\% \end{aligned}$$

Also, probability of positive annual return upon buy signal is calculated to help in backtesting.

$$\text{Probability of positive annual return upon buy signal} = \text{no. of times when the \% annual return} > 0 / \text{the total no. of \% annual return} * 100$$

$$\begin{aligned} \text{So, the probability of positive annual return upon buy signal for CSCO company} \\ &= 8 / 8 * 100 \\ &= 100\% \end{aligned}$$

### Excess Return

Excess return can be defined as the difference between the investment return and the risk-free return like S&P 500 index. It is considered one of the tools that are used in backtesting.

$$\text{Excess return} = \text{average of annual return upon buy signal} - \text{average of annual return regardless of buy signal for S\&P 500 index}$$

For example, the excess return for CSCO company is calculated as:

- Average of annual return upon buy signal = 21.75
- Average of annual return regardless of buy signal for S&P 500 index = 13.32
- Excess return = 21.75 - 13.3 = 8.43

## Volatility

Volatility is one of the backtesting tools and it measures how the return disperses.

To calculate the volatility for each company the following calculations are followed:

1. Deviation = annual return - average of annual return
2. Squared deviation = deviation <sup>2</sup>
3. Average of squared deviation = (sum of squared deviation) / no. of squared deviation
4. Volatility = root square (Average of squared deviation)

For example, the volatility for CSCO company is calculated as:

$$\begin{aligned} \text{Deviation1} &= \text{annual return1} - \text{average of annual return} \\ &= 46.47 - 21.75 \\ &= 24.72 \end{aligned}$$

$$\begin{aligned} \text{Squared deviation1} &= 24.72^2 \\ &= 611.0784 \end{aligned}$$

$$\begin{aligned} \text{Deviation2} &= \text{annual return2} - \text{average of annual return} \\ &= 47.18 - 21.75 \\ &= 25.43 \end{aligned}$$

$$\begin{aligned} \text{Squared deviation2} &= 25.43^2 \\ &= 646.6849 \end{aligned}$$

$$\begin{aligned} \text{Deviation3} &= \text{annual return3} - \text{average of annual return} \\ &= 44.03 - 21.75 \\ &= 22.28 \end{aligned}$$

$$\begin{aligned} \text{Squared deviation3} &= 22.28^2 \\ &= 496.3984 \end{aligned}$$

And the same calculation for (deviation 4, deviation 5, deviation 6, deviation 7, and deviation 8)

$$\text{Average of squared deviation} = \frac{\text{sum (squared deviation 1,.....,squared deviation 8)}}{8}$$

$$\begin{aligned}\text{Volatility} &= \text{SQRT (Average of squared deviation)} \\ &= 0.19\end{aligned}$$

### Portfolio Drawdown

This backtesting tool determines the investment risk by measuring the decline of the stock from a historical peak. To calculate the Maximum drawdown for each company the following calculations are followed:

1.  $\text{NAV}_n = \text{NAV}_{n-1} * (1 + \% \text{ annual return})$
2.  $\text{Drawdown} = \text{NAV} / \text{MAX} (\text{NAV}_1, \dots, \text{NAV}_n) - 1$
3.  $\text{Maximum drawdown} = \text{MIN} (\text{drawdown}_1, \dots, \text{drawdown}_n)$

For example, the maximum drawdown for DD company is calculated as:

$$\begin{aligned}\text{NAV}_1 &= 100 * (1 + \% \text{annual return}) \\ &= 100 * (1 + 14.43) \\ &= 114.43\end{aligned}$$

$$\begin{aligned}\text{NAV}_2 &= 114.43 * (1 + \% \text{annual return}) \\ &= 114.43 * (1 + 16.51) \\ &= 133.32\end{aligned}$$

$$\begin{aligned}\text{Drawdown}_1 &= \text{NAV} / \text{MAX} (\text{NAV}_1, \text{NAV}_2) - 1 \\ &= 114.43 / 133.32 - 1 \\ &= - 0.14\end{aligned}$$

$$\begin{aligned}\text{Drawdown}_2 &= 133.32 / 133.32 - 1 \\ &= 0\end{aligned}$$

$$\begin{aligned}\text{Maximum drawdown} &= \text{MIN} (\text{drawdown}_1, \text{drawdown}_2) \\ &= - 0.14\end{aligned}$$

### Sharpe Ratio

This metric is used to examine the performance of the investment. It measures the risk of the adjusted return and it is calculated as:

$$\text{Sharpe ratio} = \text{excess return} / \text{volatility}$$

The following tables (Tables 2 and 3 ) show the backtesting results for all 30 companies, and indicate the successful of using the presented approach by this thesis in the trading. The results show that most of the companies have 100% for probability of positive annual return, positive excess returns, and negative or small values for volatility, drawdown, and sharpe ratio and that proves the hypothesis of using the proposed approach in the trading for monthly investment.

Table 2. Backtesting Results

Company	Probability of positive annual return	Excess Return	Volatility	Maximum Drawdown	Sharpe ratio
AXP	1	17.17	0	0	0
BA	-	-	-	-	-
CAT	0	-13.96	0.004	-0.01	-28.18
CSCO	1	8.43	0.187	-0.66	0.44
CVX	0.6	-7.92	0.09	-0.14	-0.86
DD	1	2.15	0.01	-0.14	2.07
DIS	-	-	-	-	-
GE	1	26.51	0	0	0
GS	1	52.02	0.12	-0.39	43.24
HD	1	38.62	0.16	-0.8	2.35
IBM	-	-	-	-	-
INTC	0.5	-2.88	0.19	-0.23	-0.14
JMP	0.9	-0.69	0.09	-0.18	-0.07
JNJ	1	-1.72	0.02	-0.2	-0.8
KO	1	-4.72	0.01	-0.3	-4.1
MCD	1	-1.29	0	0	0
MMM	1	4.65	0	0	0
MRK	1	35.02	0.01	-0.3	29.7
MSFT	-	-	-	-	-
NKE	-	-	-	-	-
PFE	-	-	-	-	-
PG	1	-1.12	0.01	-0.2	-0.6
T	-	-	-	-	-
TRV	-	-	-	-	-
UNH	-	-	-	-	-
UTX	0.8	-2.20	0.12	-0.6	-0.17
V	-	-	-	-	-
VZ	-	-	-	-	-
WMT	1	-2.66	0.05	-0.04	-0.4
XOM	1	7.39	0.06	-0.4	1.16

NOTE: the companies that have (-) value do not have any day in which combined indicators show buy signal at the same time.





## CHAPTER FIVE

### CONCLUSION AND FUTURE WORKS

#### Conclusion

In this thesis, a certainty factor model based trading approach is presented. This approach can help the investors to decide when and which stock to trade based on ten technical indicators. These technical indicators, which affect trading decision, are used as evidences in MYCIN certainty factor model after calculating the monthly return for each technical indicator to find the best time to trade. As a result, four technical indicators, which are BB, RSI, MFI, and CMO, are combined to find the best time to buy a stock for monthly investment as explained in Chapter 3. These four technical indicators are chosen because they support the hypothesis, which is to get gains when selling a stock after one month of buying that stock, with CF value that is greater than the threshold value. To test if this strategy works or not, chapter 4 clarifies how the five-backtesting metrics are applied to historical data using the proposed work. As shown in the testing results (Table 2 and Table 3), applying this strategy on the HD, XOM, MRK, GS, and CSCO companies assures the successful of using this approach in trading. In conclusion, using the presented approach by this thesis assures getting gains with  $CF = 0.85$  or more for monthly investment.

### Future Works

Some topics from this work can be developed into a separate study; therefore, suggestions for future works are included below:

1. Finding optimal combination of technical indicators using evolutionary approach such as genetic algorithm.
2. Using MYCIN certainty factor model to find the best time to trade based on different interval (weekly, six months, or annual) instead of monthly return that is used in this work.

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