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Evaluating the Effectiveness and Sensitivity of Forex Trading Robots

A thesis submitted in fulfillment of the requirements for the degree of Master of computing

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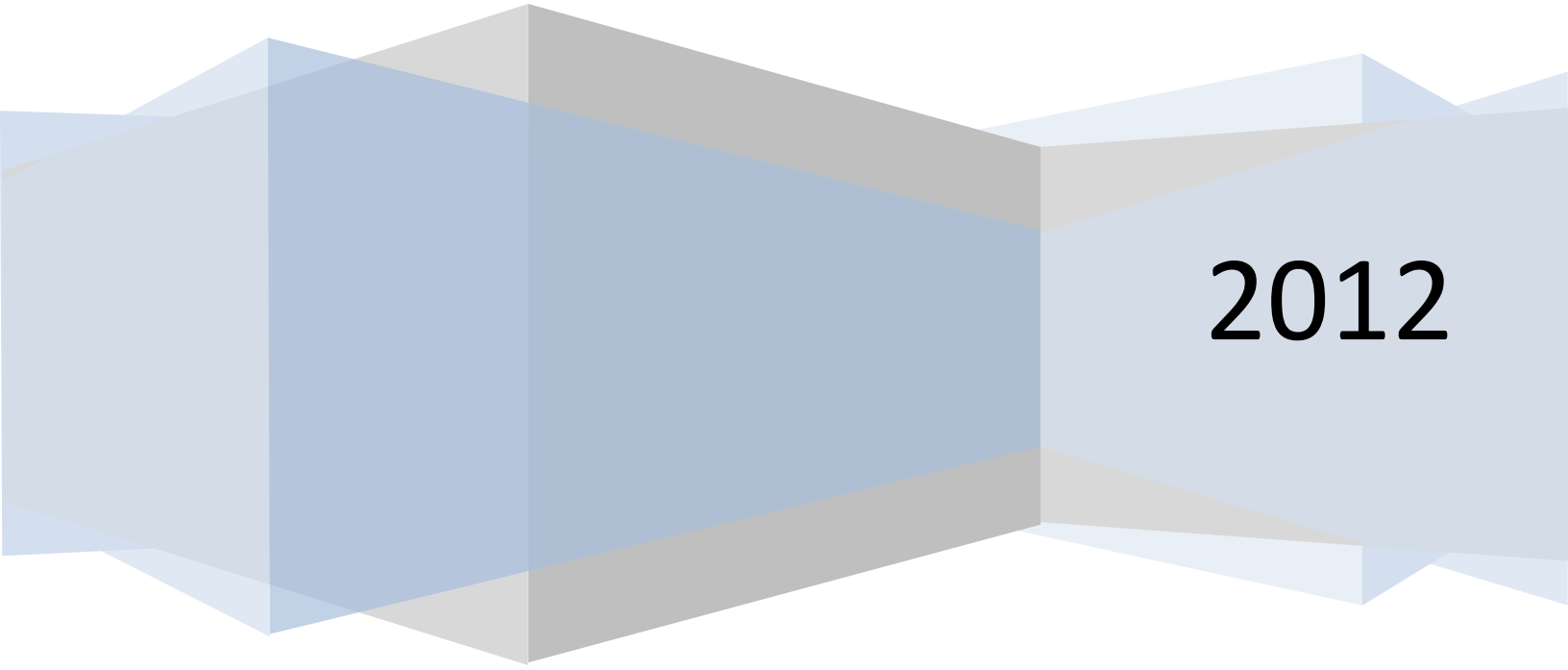

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Abstract

Robot trading, also known as algorithmic trading, has been widely used in financial markets in recent decades. The wide application of robot trading has brought significant benefits to transaction efficiency. A lot of developers have designed trading robots which can simulate their trading strategies, and they have claimed that these robots can keep making profits continuously in the place of human traders. However, their performance is usually not as satisfactory as human traders. Two factors could lead to this failure in trading: (1) programs cannot simulate all human behavior; and (2) most robots are over- sensitive, which may reduce their performance. To solve those problems, therefore, evaluating the effectiveness and sensitivity of trading robots is necessary.

The contribution of this research includes a study of trading robots and their algorithms, trading robot experiment design, data analysis and improvements to program design. The study focuses on the conceptual mechanism of trading robots, which includes trading applications and robots deployment.

This paper reports that forex trading robots are suitable for forex rates prediction. The evidence shows that trading robots can capture the underlying “rules” of the forex market trend by using time series, technical indicators and other factors. Traditional standards for robot trading analysis are used to evaluate the accuracy of forecasting currency price changes when traders are using their software for real trading. The results indicate that practical forecasting can be completed and paper profits be obtained, by using five different trading robots. However, the collection of sensitive analysis is incompatible with efficiency testing. Most testing results were

collected by chart review, and the test results show that the effectiveness and sensitivity of robot trading are both interrelated and contradictory. The more sensitive trading robots take more trading opportunities, but this reduces performance.

Further research is discussed in this paper. In future work, more data segments will be required in the analysis, and all experimental data should be analyzed in different time frames on the currency of JPY / USD.

Statement of Originality

This is to certify that the thesis is my own original work and it has been written by me. No part of this thesis has been submitted to any other institution other than Unitec as part of any other degree or diploma.

In addition, I certify that all information sources and literature used in the thesis are properly indicated. Any help and assistance that I have received in my research and the preparation of the thesis have been appropriately acknowledged.

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1. Introduction

The electronic foreign exchange (Forex) market is a global financial market for trading currencies and it was established in 1971. Since then, how one currency relates to another currency is expressed as foreign exchange, and it has naturally shifted from fixed to floating under the continuously trading environment. Unlike other markets, the foreign exchange market has a large trading volume, since it covers all the currency exchange transactions in the world. There is no physical trading location or a central market.

In the past, only large investment funds could trade currencies. This trading process is called "interbank" trading, and is established by large banks and major financial dealers. Spreads are generated from forex trading, and are presented by the gap between bids and ask. By the wide application of electronic forex trading, more and more retail foreign exchange brokers are providing individual trading services for ordinary traders. "***Retail foreign exchange trading is a small segment of the large foreign exchange market.***" (Wiki, 2011). Retail foreign exchange brokers earn money from spreads. Most of them are trust companies, small banks and other institutions. In the early 2000s, some software companies designed their own version of trading platforms. All this software includes trading interfaces and user terminals, and provides the functions to help traders design their own trading strategies.

Nowadays, trading robots are widely used in forex trading. Most of them are coded as programs, and they can automatically execute the trading by following trading signals. The greatest benefit of robot trading is the fast reaction to market sentiments. Usually, traders

must waste time considering market sentiments and then make decisions. Trading robots can use pre-wired thinking and save time which can be used to handle many trading opportunities. Also, trading robots can avoid the psychological factors of human traders. There is no need to consider such factors as greed and fear influencing the trading results in robot trading.

1.1. Robot trading on retail foreign exchange markets

Robot trading, also known as algorithmic trading, has been widely used in financial markets in recent decades. It is "***the use of computer programs for entering trading orders with the computer algorithm deciding on aspects of the order such as the timing, price, or quantity of the order, or in many cases initiating the order without human intervention.***" (Wiki, 2011). In algorithmic trading applications, trading robots instead of humans analyze the historical data and make the decision to enter the trading.

Currently, a complex trading robot has three functions, viz., fund management, risk control and analysis. Fund management is a part the of investment strategy. In forex trading, fund management is used to set the capital amount for each transaction. Unlike the fund management function, the risk control function helps traders set a stop and loss level, and it is able to delete transactions that go in the opposite direction from the current market. The analysis function is used to capture trading opportunities, and it is always programmed by a variety of trading methods. However, most trading robots cannot capture all the market sentiments, and the historical data cannot present all future movements.

The major factor that causes trading robots to make mistakes is the nature of the forex market. The forex market is dynamic, and it is continuously moving within three types of market

environments: up, down and sideways. Only real trading can make the change of price. Similar to other financial markets, changes in the forex rate is made by traders who are buying one currency and selling another, so historical data cannot determine future market movements.

To fix the problems of trading robots, Jamie (2008) provides two forex trading analysis methods: fundamental analysis and technical analysis. Technical analysis is based on historical data overview, which determines the future market movement. Fundamental analysis focuses on economic data and forecasts the potential market fluctuation. The economic information includes growth rates, interest rates and monetary policy, inflation, and unemployment**.** Jamie (2008) believes that both methods are important in forex trading analysis. He recommends that robot designers should pay more attention to collecting economic information, and that trading robots should be designed with a function that has the ability to close all transactions while the important economic messages are being released.

1.2. Motivation

The wide application of trading robots, including algorithmic trading, has brought considerable benefits to transaction efficiency. With regard to the effectiveness of forex trading, Martinez and Pappa (2009) assert that a profit system should have a high percentage of funds return rather than numbers of profitable orders. Nevertheless, in terms of the sensitivity aspect, Theodoros (2008) indicates that the robot should limit the number of noises, and that the total account could be increased but not be dependent on a profitable order percentage.

Many designers have developed trading robots, and have also claimed that these programs can replace human analysis and keep making profits by themselves. To evaluate the effectiveness

and sensitivity of trading robots, it is important to grasp how these programs work. Generally, human traders consider many market factors before they place an order. In electronic financial trading markets, these factors can be categorized into technical index, timeframe and market environment. In this research, I plan to investigate how these trading robots make decisions to place orders against the categorized indicators.

From a practical perspective, I particularly evaluated the effectiveness and sensitivity of trading robots. The effectiveness of trading robots is defined as their capability to make profits through trading, so I will focus on the accuracy of trading strategies, the reduction of the loss rate and the increase of the total amount of the account. In regard to sensitivity, this research will concentrate on "noise" from the testing of trading robots. In particular, Siam and Esfahanipour (2008) indicate that trading robots should be equipped with optimization rules, a flexible policy configuration, dynamic trading and risk monitoring.

1.3. Research Goals

In order to cover the research topic, the research questions focus on the effectiveness and sensitivity of trading robots. As the trading analysis takes into account many market factors before they place an order, my research will target the following questions:

- How does a trading robot respond to changing market conditions?
- How can the performance of these robots be evaluated?
- How can the algorithms used by trading robots be improved to enhance their performance?

Answers to those questions have been presented as follows.

The working mechanism of trading robots: A complex trading robot has three functions, which are fund management, risk control and analysis functions. In forex trading, the fund management function is used to set capital of money for each transaction, the risk control function helps traders set the support and resistance level, and the analyses function is used to capture trading opportunities.

Effectiveness and sensitivity of trading robots: Two standards have been used in trading robots evaluation. They are effectiveness and sensitivity. As algorithmic trading is one of artificial intelligence, a trading robot can simulate human traders' thinking under market changes. However, in some situations, the performance of trading robots is not as satisfactory as that of human traders. This is because of two factors: (1) computer programs cannot simulate all the mathematical algorithms that have been integrated into trading strategies, for example, the limitation of MQL4 programming influences the simulation of human behaviors; (2) Trading robots generate many noises, which reduce the percentage of profitable orders, and influence the trading performance. An effective robot should have a high percentage of funds return rather than numbers of profitable orders. In the sensitivity aspect, trading robots should limit the amount of noise, and the total account should be increased but not be dependent on a profitable order percentage. Thus, the relationship between effectiveness and sensitivity in robot trading is both interrelated and contradictory.

Designing an improved robot: This research conducts several factors that can influence the performance of trading robots. By improving those issues, the new robot can capture more trading opportunities and increase the success rate. After the new robot has been completely developed, a further effectiveness evaluation will be applied to this research.

1.4. Challenges of research

The details of trading strategies are not within the scope of this study. Instead, this work aims to imitate the process of trading strategies using programs, and improve a variety of implementation issues. The primary challenge of this research is the difficulty of applying fundamental analysis to robot programming. As market movement is decided by the publishing of economic events, this information is difficult to code as MQL4 to simulate human behaviors.

The second challenge is the simulation problem. In human trading, traders change their minds while following market environment changes. It is difficult for developers to code those complex behaviors into trading robots, and most robots cannot automatically change internal parameters. This will certainly influence the experiment results, and reduce the effectiveness of robots.

In addition, external factors also influence the robot trading experiment results. There are many retail forex trading brokers using MetaTrader networking services. However, using the same trading platform, different forex trading polices can make different experiment results. Firstly, each broker has their own spread policy, which could influence the transaction cost, and thus, the results in the deviation of effectiveness evaluation. Secondly, many retail forex brokers cannot provide a complete set of historical market data. This could seriously influence the experiment result.

1.5. Research Contributions

The contribution of this research includes the algorithm of trading robots, the approach for trading robot tests, data analysis and a design for an improved program. The framework of this

study provides basic information and a blueprint for operating procedures. In brief, each element of this framework is presented below.

- **Trading algorithm study**: this study focuses on the trading robots mechanism, which includes trading applications and robots deployment. Therefore, evaluating methods to promote effectiveness and guard against sensitivity are a particular concern in this study. To deploy trading robots, MT4 system was studied.
- **Data gathering**: Data gathering is the most important phase in this study. Gerald (2008) points out that future market movement can be determined by analyzing the histrionic data. Those data can be collected from document review, simulation tests and development tests. Software documents can be a guide to robot design, programming and implementation. However, they only reflect basic concepts of characteristics. To further evaluate trading robots, simulation testing is necessary. Simulation testing is the method that continuously runs the trading robot in forex trading and captures the experiment results. This is a direct method to get the robots' performance. Development testing is more complex, since it develops the system to be used in both real and simulated environments in order to provide all needed functions and comprehensive performance.
- **Data analysis and evaluation**: There are three types of data collected in this research; internal parameter, performance data and transaction data. Checking performance is the first stage of data analysis. The raw result data will be filtered and sorted to extract the key indicators, such as profit, triggering events, trading times, frequencies, order amounts and order size. Chart review is the second stage of trading robot evaluation. At

this stage of the data analysis, I intend to review the working procedure, which includes the three parts of placing an order: The pre-order procedure describes how a robot collects historic data, organizes time and selects a technical index. The ordering procedure indicates the monitoring of the trading process, for the purpose of reducing possible risk. Decision marking parameters will also be important at this stage. In the pre-order procedure, the trading robot will select some technical index to follow the market trend. In different market environments, the trading robot will dynamically change parameters to follow a trend. Calculations of the NMSE and gradient have been applied in this research. They are important standards for evaluating the effectiveness of robot trading.

- **Trading robot improvement**: After the previous analysis stages, a general result can be obtained. However, inference analysis can provide a further evaluation on robot reliability and accuracy, and an improved automatic trading robot can be generated. Compared with other trading robots, the new program improves many factors that can reduce the performance of the robot trading. Those factors are parameter modification, indicator modification, time frame selection and trading session selection. Furthermore, timeframe switcher was added to this program, which can filter out more trading opportunities and improve the forecasting performance.

1.6. Thesis Structure

This thesis consists of 7 chapters, six of which are listed below.

Chapter 2 describes the research background of this study, and lists the details of economic concepts and trading strategies. This chapter briefly reviews the history of robot trading and

the basic concepts of forex elements. Additional description of trading algorithms is given in this section, as they are essential parts of trading robots. Finally, to understand the process of trading robots evaluation, the simple concepts of effectiveness and sensitivity evaluation are introduced.

Chapter 3 introduces the process of forex trading and describes the working mechanism of trading robots. Firstly, Forex transaction by human traders can be divided into three steps and trading robots can simulate human traders' behaviors and apply this mechanism in forex trading. Secondly, the communication between three basic functions has been created in trading robots. Those functions are fund management, risk control and trading strategies function. The final stage is getting profit from robot trading. This chapter picks up several trading robots, and explains their algorithms one by one. These algorithms have been programmed as MQL4 script, running in the MT4 trading platform.

Chapter 4 focuses on the experiment's creation. Before the robot test, the pre-experiment is built for analyzing market environments. At this stage, only the value of the Hurst indicator is greater than 0.5 and the experiment result can proceed to further evaluation. The primary purpose of the experiment is to focus on the effectiveness and sensitivity evaluations. In the effectiveness area, the experimental data were presented as success rate and the increase of accounts. In the sensitivity test, the experimental data is completely conducted by chart review.

Chapter 5 analyses the experimental data that is generated from robot tests. The calculation of the NMSE and gradient was applied in this section. They are important standards for evaluating the effectiveness of the robot trading. To totally evaluate the effectiveness of the software, a

concept of fund return is used in this evaluation. In the calculation of fund return, a positive result can be considered as the robot conducts trading efficiently. To evaluate the sensitivity of the software, noises become the most important standard. More noises generated in experiments will lead to a higher loss in robot trading. Both effectiveness and sensitivity are important performance indicators for robot trading. The effectiveness evaluation focuses on a successful rate of transactions and the benefit of accounts, and the sensitivity evaluation concentrates on the number of transactions. This section indicates that effectiveness and sensitivity of robot trading are both interrelated and contradictory.

Chapter 6 designs an improved trading robot. The new program includes many factors that can reduce the performance of robot trading. Those factors are parameter modification, indicator modification, time frame selection and trading session selection. Furthermore, timeframe switcher has been added in this program, which can filter out more trading opportunities and improve the forecasting performance.

Chapter 7 is the final section which includes the discoveries of this research. The requirements of future work have been listed for further study.

2. Background

"***In electronic financial markets, algorithmic trading or automated trading, also known as black-box trading or robot trading, is the use of computer programs for entering trading orders with the computer algorithm deciding on aspects of the order (such as the timing, price, or quantity of the order), or in many cases initiating the order without human intervention***". (Wikipedia, 2011)

Algorithmic trading started in early 1970s in financial markets, with symbols that the New York Stock Exchange (NYSE) adopted: Designated Order Turnaround (DOT) and the Opening Automated Reporting System (OARS). The DOT system directly built a relationship between traders and trading desks, and executed electronic transactions at the trading. The OARS assisted traders to make decisions on settling orders.

Algorithmic trading was adopted by NYSE because MYSE market owned a value of more than 100 million dollars, with over 15 trading portfolios of baskets of orders. With such a large volume, computers are necessary to handle trading instead of humans. In the 1980s, algorithmic trading was widely used in financial markets. Stock index arbitrage trading meant that traders bought (or sold) stocks such as S&P500 futures and simultaneously bought (or sold) a series of NYSE stocks, where the portfolio was highly relevant to the futures. The NYSE trading robot was enacted by a computer. When the direct spread was large enough to be profitable, the computer executed orders automatically.

In late 1980's and 1990's, the development of the telecom network made the financial market completely electronic. In the U.S. stock market, decimalization changes the minimum share

price from 1/16 dollar to 0.01 dollars. This regulation changes market microstructure and reduces price spread, and thus reduces market liquidity. Papadamou and Stephanides (2005) consider that this probably promoted the development of algorithmic trading.

With more and more electronic trading, more algorithmic trading strategies have become possible. These strategies include arbitrage, statistical arbitrage, trend following and regression. Computers can effectively implement these trading strategies by monitoring different markets and analyzing the historical data.

2.1. Forex elements

2.1.1. Expression of currency pairs

In forex trading, products are described as currency pairs, and the trading process is exchanging one currency to another. For example, the exchange rate of the British pound and the U.S. dollar are formed as GBP/USD. Obviously the exchange rate is constantly fluctuating, and it is based on the stronger currency being addressed in the current currency pair.

Some currency pairs are traded by traders frequently, and are called major currency pairs,especially if one side of those currency pairs is the U.S dollar. There are seven major currency pairs that are traded every day in the world.

Currency Pairs	Countries or regions of produce	Name of speech
EUR / USD	Europe / America	Euro dollar
USD / JPY	America / Japan	Dollar yen
GBP / USD	U.K. / America	Pound dollar
USD / CHF	America / Switzerland	Dollar swissy
USD / CAD	America / Canada	Dollar loonie
AUD / USD	Australia / America	Aussie dollar

NZD / USD	New Zealand / America	Kiwi dollar

Table 2-1 Currency pairs

Other currency pairs that are traded in the forex market are called cross-currency pairs, when the currency pair does not include the U.S. dollar. For example, GBP / JPY is one of the cross-currency pairs.

2.1.2. Trading sessions

The foreign exchange market runs continuously within networks between banks for 24 hours. There is no physical trading location or central market. However, prices do not dramatically fluctuate whole day. The forex market trading sessions can be categorized into four major ones: the New York session, the London session, the Tokyo session and the Sydney session. The timetable of the four sessions is presented below. (Babypisps, 2011).

Time Zone	Auckland Time Zone	GMT
Open of Sydney Session	10 AM	10 PM
Close of Sydney Session	7 PM	7 AM
Open of Tokyo Session	11 AM	11 PM
Close of Tokyo Session	8 PM	8 AM
Open of London Session	8 PM	8 AM
Close of London Session	5 AM	5 PM
Open of New York Session	12 AM	12 PM
Close of New York Session	9 AM	9 PM

Table 2-2Trading session

It can be seen from Table 2-2 that overlaps cross every two sessions. Typically, in each overlap, the forex trading activities are particularly busy, because transactions are being processed in two regions of the world. This creates greater volatility in the currencies' prices, and thus makes more trading opportunities. In robot trading, session overlaps are usually designed in programs so that they can assist traders in maximizing profits. Archer (2008) believes that fluctuation in

the forex market is different every week, and that this factor should be considered in robot programming.

2.1.3. The calculation in foreign exchange market

The basic calculation rules are usually performed by trading robots in forex market transactions, and human traders do not need to understand the principles. However, it is necessary to introduce these concepts in this research. Developers of robot programming must consider those factors since they will influence the effectiveness and sensitivity of the trading robot.

Unlike other financial markets, the foreign exchange market is traded with exchange rates. They are expressed as one currency relating to another, and are thus formed as currency pairs. Babypips (2011) states that transactions in forex markets are quoted as pairs because traders buy one currency and sell another. For example, EUR/USD is presented as the price of how many U.S dollars should be spent to buy a Euro. Wiki (2011) shows that the base currency is located to the left of the slash, and the counter currency is located to the right side. The table below is an example to show the calculation of trading GBP/USD.

Action of traders	Amount of GBP	Amount of USD
At the price of 1.5312, trader bought 100,000 Euros.	+ 100,000	- 153,120
A month later, the exchange rate went from 1.5312 to 1.5412, so you sold your Euros and exchanged them to U.S. dollars.	- 100,000	+ 154,120
Trader's account increase of $1,000	0	+ 1000

Table 2-3 The calculation for trading GBP / USD

In forex trading, the price of the exchange rates is presented as two prices. The bid price is used for the trader to purchase the base currency and sell the counter currency, and the definition of the ask price is the opposite. Therefore, spread is the gap between the bid and ask prices. In the

sensitivity evaluation, spread is the major factor that influences the performance of trading robots, and thus it can make many of losses in the transactions.

2.1.4. Leverage and fund management

Archer (2008) introduces the concept of leveraged transaction. It is an investment method that uses a small amount of money to make a trade at several times the amount. The purpose of using leverage is to obtain a greater amount of profit. In the past, the specific money that was used to carry out forex trading was called lots. Due to the tiny daily movement of the forex market, traders needed to trade large amounts of currency to take advantage of a forex transaction. Archer (2008) argued that the nature of the forex market drove up the entry requirement until the service of leverage emerged.

In human trading, the retail forex broker requires traders to have basic funds, which are called "margin funds". Once those initial funds have been deposited into a dealer's account, the service of forex trading can be opened. Usually, the trading position is calculated as lot size multiplied by the leverage, which can maximize the profit from the trading. However, any related loss would be carried out several times and decrease the traders account as well. An example is posted by Babypips (2011) and given below to show how leverage and lots work.

Steps	Actions of traders
1	Trader is buying USD / JPY at 92.59. Currently, the price is quoted as 92.56 / 92.59. Here, the spread is 3 pips. Due to the trader buying dollars, the trading price should be 92.59, which is called the ask price.
2	The trader sets a transaction by 1 standard lot, which is 100,000 units.
3	Then the price moves up to 92.78 and the trader closes his transaction.
4	At this moment, the new price of USD / JPY is quoted as 92.78 / 92.81. Once the trader closes the trade, the buy order would enter in the market. The trading price should be 92.78.
5	The trading platform which calculates the gap between 92.59 and 92.78 is 19

	pips
6	The profit of this trade should be (0.01 / 92.78) * 100,000 * 19 = $204.79

Table 2-4 Leverage and Lot

From Table 2-4, profit and loss from the trading can be calculated by the following formula:

*Profit / Loss = (pip value / price) * lot size * pips of movement*

Gerald (2008) indicates that leveraged forex trading increases the profit of transaction, but also expands the loss that is caused by analysis mistakes. Thus, fund management and risk control become more and more important. From the profit formula, resetting the capital of the lot size can reduce the risks that are taken by leverage. Babypips (2011) provides the formula of the relationship between leverage and lot size, as shown below.

*Lot size = leverage * actually amount of each transaction*

The above formula shows that regardless of how much leverage is regulated by retail brokers to control forex trading risk, the best method is to control the capital of the lot size. Therefore, most of the forex trading robots are programmed with fund management system, which has the ability to adjust the lot size.

2.2. Technical indices

Jamie (2008) indicates that there are three methods of forex trading analysis: fundamental analysis, sentiment analysis and technical analysis.

2.2.1. Fundamental analysis

Jamie (2008) considered that fundamental analysis is an efficient method to evaluate the economic, social and political factors, which focuses on money supply and demand. It is necessary to study economics factors, because only supply and demand can determine the

currency price. In addition, Babypips (2011) states that fundamental analysis focuses on the reaction to economic events. In particular, it guides traders to predict the future movements of the Forex market. However, fundamental analysis is formed by many indicators. Jamie (2008) provides an example, an economic report of U.S. employment data, which could have changed the monetary policy of the Fed in America. However, John (2009) points out that many economic events are not released as specific reports, but they could influence the reactions of traders, which can decide the future movement of the forex market. In all, Jamie (2008) considers there are several indicators that can be analyzed by traders: interest rates, inflation, monetary policy and economic growth.

Jamie (2008) indicates that the interest rate is the most important factor to help traders determine the forex market direction. Thus, it is necessary for traders to understand the monetary policy of central banks, such as new interest rate decisions. Furthermore, John (2009) states that inflation decides the stability of central bank monetary policies. Inflation can make investment in products and services, but too much inflation can damage the economy. Thus, as Babypips (2011) indicates, central banks always watch the indicators that are related to inflation, such as CPI and PCE. Usually, moderate inflation is accepted by central banks, because suppressing it could take the growth out of the economy. In order to keep inflation at a stable level, Babypips (2011) points out that central banks will change interest rates that lead to lower economic growth and inflation. But in the forex market, Jamie (2008) believes that higher interest rates can cause a stronger currency price. He defines a new concept of interest rate expectation, which can directly influence the movement of the forex market. Jamie (2008) considers that the forex market is moved by the different expectations of traders. So, as

interest rates are not changed very often, most of traders do not focus on current interest rates, because they have already been issued by central banks. More important is the movement of the interest rates, which is defined as interest expectation by Babypips (2011). This web tutorial indicates that interest rate expectation can determine the future movement of the forex market. To calculate the current interest rate, a formula is presented.

Real interest rate = nominal interest rate – expected inflation

Jamie (2008) also states that most used by traders use rate differentials, which can decide the future movement of a specific currency pair. The formula is presents as follows.

Rate differentials = base currency interest rate – counter currency interest rate

As well as interest rates, the monetary policy of central banks can influence future movements of the forex market. Jamie (2008) states that monetary policy is divided into contractionary and restrictive policies. They are used to increase or reduce the capital of the money supply, and can also make interest rates rise. Babypips (2011) believes that restrictive policy is also increasing interest rates and reducing economy growth. Also, the difficulty of getting bank loans will reduce the spending and investment of businesses. On the other hand, with contractionary policy, which is opposite to restrictive policy, it is easier to borrow money or expand the supply of funds, and this will increase spending and investment and increase economic growth.

Babypips (2011) states that enterprises will spend money with large amounts of funds, and thus the tax will be increased for the government. This action can cause the whole society to spend, and will tend to be a positive influence on the economy. Meanwhile, Jamie (2008) indicates that the balance of capital flow can cause movement in the forex market as well. He provides

an example of the positive aspects of capital flow to a country: in the situation of more investment from overseas, the government has to sell foreign currency to buy local currency. This action can lead to the value of local currency increasing. The related trade flow formula was posted by Babypips (2011) can be seen below.

Exports > Imports = Trade Surplus = Positive (+) Trade Balance

Imports > Exports = Trade Deficit = Negative (-) Trade Balance

In trading robot design, programmers usually select five economic indicators as parameters in their trading robot. However, depending on the trading environment, the selection of parameters will be different. For example, inflation can often be represented as CPI and PCE. The values of parameters are not expressed by economic data, instead a simple number can be better to predict the future market trend. The following diagram shows the economic indicator selection in trading robots.

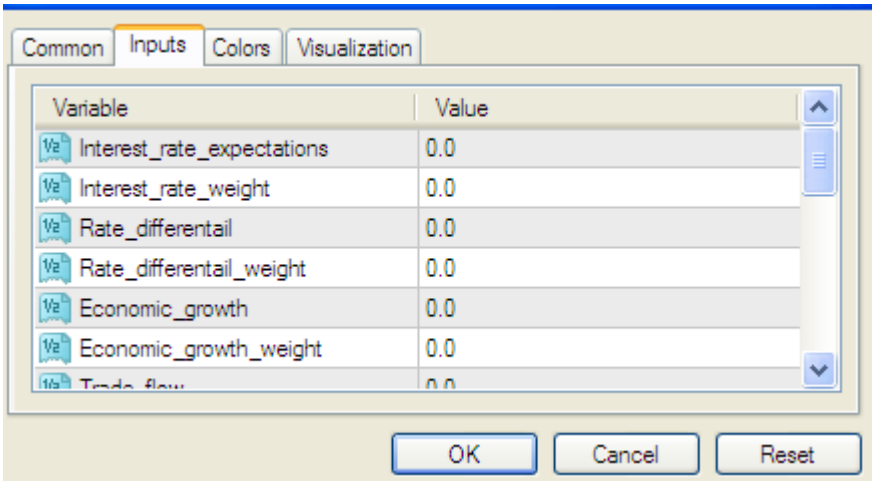

Figure 2-1 Economic indicator selection window

2.2.2. Sentiment analysis

In theory, price should reflect all the information of the forex market. However, it is not simple a simple matter for forex traders. The forex market does not reflect all the information, since it also includes the behavior of traders. Babypips (2011) states that traders have their own opinions on future market movements. The market is a combination of traders' reactions to economic news. Jamie (2008) considers that no matter how strong the personal feelings of a single trader, the forex market will be influenced by most of the traders' actions. Therefore, the market sentiment analysis contains some factors from both fundamental analysis and technical analysis, which focuses on the traders' psychological state.

As an interest rate expectation, market sentiment depends on the psychological state of most of the traders. Jamie (2008) believes that sentiment indicators are not unique, since they represent traders' psychological states. Usually, economic data makes traders take action. Thus, the role of sentiment indicators is to measure the importance of the economic data. In forex robot trading, these indicators are usually used to presents the weight of specific economic indices. The Figure 2-1 also shows the application of sentiment analysis in robot trading.

2.2.3. Technical analysis

Archer (2008) considers that technical analysis is the framework that traders use to determine forex market movement. He believes that historical data can determine current market conditions and potential movement. In theory, the present price can reflect all the information of the forex market, and thus trading can be made by that information.

"***History tends to repeat itself***" (Babypips, 2011).

Gerald (2008) indicates that technical analysis is basically following the support or resistance level in the past chart. Traders keep watching it and determine the trading around that price level. But Jamie (2008) believes there are many patterns which are all important for trading that should be analyzed.

2.2.3.1. *Japanese candlestick*

Babypips (2011) has created three basic charts to present historical movements in the forex market: line chart, bar chart and Japanese candlestick.

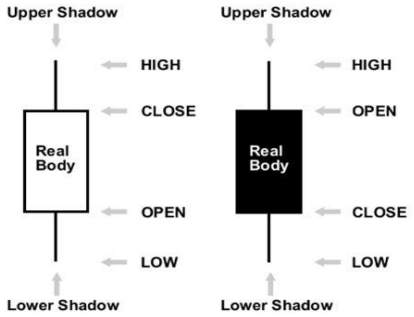

Figure 2-2 Candle sticks

Figure 2-2 presents the basic concept of the Japanese candlestick chart. Like the bar chart, the Japanese candlestick indicates the market direction in the period segment. “Open” presents the start price in the current period, “Close” presents the end of the price, and “Low” and “High” present the highest and lowest price at this moment. The Japanese candlestick is different from the bar chart. The reason is that it introduces the concept of “Body”, which presents current market direction.

2.2.3.2. *Moving average*

Moving average (MA) is based on the Dow Jones “average cost concept”. Similar to the “moving average” principle in the statistics, it aligns with the average financial market price in each of

the time segments to display historical price volatility, and thus reflect the potential trends. In fact, we calculate the average price value of a specific period when we use this indicator. As with changes of price, the moving average can increase or decrease. There are four types of moving average: simple moving average, exponential moving average, smoothed moving average and linear weighted moving average. Each of them has their own algorithm, but usually the formula of the moving average is presented as follows, because the most common application is simple moving average.

$$SMAn = (C1 + C2 + C3 + \ldots + Cn) / N$$

(C expresses the close price in the current period. N is present as the number of total periods.)

2.2.3.3. MACD

Moving Average Convergence / Divergence (MACD) is a dynamic index that is following the market trend. It is represented as a relationship between two moving averages. MACD indicator has three parameters. The first parameter presents the time period of the faster moving average, and the second presents the slower moving average's period number. The third parameter is calculating the moving average of the gap between the previous two MAs.

2.2.3.4. RSI

The Relative Strength Index Technical Indicator (RSI) is a price-following oscillator that ranges between 0 and 100. RSI is widely useful in forex trading. It does not only assist traders to determine the potential trend, but it also can help users distinguish the situation of oversold and overbought.

2.3. Trading robot Evaluation methods

There are many forex trading robots that can assist traders to determine their strategies. However, Forextraders (2011) indicates many retail forex traders suspect robot trading capabilities. This website tutorial believes many robots "***tend to be marketed by extreme sales pitches***" and always overstate their benefits when they are used in a real trading environment. Thus, it is necessary to evaluate the performance of those trading robots before traders decide to purchase the software.

A three-step test approach is issued by Forextraders (2011), which provides traders with a general concept of trading robots evaluation. The steps are described as below.

1. The backward test is the first step in robot evaluation. This often focuses on trading robot performance that was based on the currency pairs that were selected by traders and the historical price that was displayed in the trading platform. Forextraders (2011) reminds traders that the backward test may create a false prediction, because the historical data does not reflect future changes in the forex market.
2. A demo account should be created in the second stage. The trading robot is used in it so that a real-time test result can be conducted for further evaluation. Forextraders (2011) believes that experimental results can provide traders with a better sense than historical evaluation.
3. The third stage is based on a situation that assumes the test results from previous stages are satisfactory, and a micro account can be created for real-trading test. Forextraders (2011) believe that there are many differences between simulated tests

and real-trading tests. Normally, a satisfactory living test result can ensure a high performance with trading robots.

Furthermore, Forextraders (2011) indicates that most robot backward test results are not satisfactory because of the low quality of historical data in MT4. This web tutorial believes that there is no ideal way to get accurate backward test results unless the historical price data is 100 percent accurate. Thus, a forward test is necessary for robots evaluation.

2.3.1. Evaluation Criteria

Forex Day Trading (2011) lists several criteria of forex trading robots evaluation. This website believes that an efficient trading robot should have some features of fast reaction, high successful rate and low risk.

2.3.1.1. Fast reaction when signal is issued

Jamie (2008) describes that the process of forex trading as a continuous operation,which trades and manages accounts on the forex trading platform. Thus, trading robots can replace humans and simulate this action automatically. Forex Day Trading (2011) indicates that, compared with human traders, trading robots can capture more short-term trading opportunities. This is because the default procedure of trading robots can reduce the response time, which is used by human traders to determine the future market and place orders. Therefore, the response time becomes an important criterion for trading robots evaluation.

Instead of hi-speed network devices, Forex Day Trading (2011) believes that algorithm structure is the major factor that can influence the response time. Thus, this website tutorial indicates that the response time can be used as adjustable internal parameters for traders.

2.3.1.2. High success rate

Success rate has been widely mentioned in forex trading, and it is considered as one of the most important criteria for forex trading software evaluation. Forex Day Trading (2011) indicates that the success rate focuses on the total money amount and the number of profits orders.

The wide application of trading robots, including algorithmic trading, brings significant benefits to trading automation and transaction efficiency. With regard to the effectiveness of trading robots, Martinez and Pappa (2009) believe that a profitable system should have a high percentage of profitable orders instead of trading values. Nevertheless, in the sensitivity area, Theodoros (2008) has indicated that the robot will set a limit for each order, and the total account could be profitable but not dependent on a profitable order percentage.

2.3.1.3. Low risk

Martinez and Pappa (2009) indicate that high risk carried in forex trading might not be suitable for all traders. The Foreign Exchange Market Explained (2011) believes that every forex trader has his / her own trading methods that can help him / her to enter and exit forex trading and determine the expected movements. A complex trading robot that is designed by experienced traders could reduce the risks for new traders. However, even the most experienced traders cannot determine all forex market future movements. A minimum loss should be designed for every transaction in forex robot trading. Thus, low risk becomes an important requirement in the evaluation of forex trading robots.

3. Algorithm of Trading robot

Consistent profitability is considered to be important by Marta & Brusuelas (2009). They believe that an effective trading system should assist them to continuously benefit from forex trading. Babypips (2011) indicates that a trading system can involve three functions: fund management, risk control and market analysis function. These three functions share a complex relationship, which is believed by Marta & Brusuelas (2009) to be dependent on the forex trading mechanism.

3.1. Working mechanisms of trading robots

Fund management is a part of an investment strategy. In forex trading, traders always use fund management to set the capital for each transaction. Thus, capital size becomes more important in the trading process. Unlike the fund management function, the risk control function will help traders to set stop and loss levels, which can automatic close. The analysis function is used to make forex trading strategy, as it can make decisions to capture trading opportunities. However, most trading robots do not catch all the ever-changing market conditions. The foreign exchange market is dynamic, and it is continuously moving with three types of market environments: up, down and sideways. Trading robots cannot handle those complex movements by analyzing historical data. The risk control function monitors the whole process of transaction. Once a transaction has been cancelled, the analyze function will recalculate and search for new trading opportunities.

3.2. Rules of risk control function

In the human forex trading scenario, traders are always confusing the difference between risk control and fund management function. The reason is that risk control includes some important concepts of fund management. However, in the robot trading scenario, there is a clear boundary, in that risk control only pays attention to how much loss can be accepted in forex trading.

3.2.1. Maximum 30% Drawdown

The Foreign Exchange Market Explained (2011) indicates that even the most experienced trader cannot determine all future market movements. Therefore, the maximum drawdown is programmed in most trading robots, where "***A drawdown is the reduction of one's capital after a series of losing trades***." (Babypips, 2011). This is usually calculated as the gap between the initial capital and the remaining balance of the traders' account. In other words, traders normally focus on the percentage of drawdown against their accounts.

According to experience, Babypips (2011) believes that a 30 percent drawdown can be accepted by most traders. The reason is described as follows.

Loss of initial capital	Effort of getting back to breakeven
30%	0.3 / (1 – 0.3) * 100% = 43%
50%	0.5 / (1 – 0.5) * 100% = 100%

Table 3-1 Maximum 30% drawdown

The above example shows the reason for choosing a maximum of 30% drawdown as a basic concept for trading robots risk control design. Babypips (2011) indicates that a 30% loss of the total account can remain 70% money for traders, which means traders only require 43% of trading profits of the current account, and they can make the account get back to break even. It

is hard to imagine a 50% loss of the initial capital, because traders must trade 100% profits of the current account to get back to their original account balance. Babypips (2011) points out that the more traders' lose, the harder it is to get back to breakeven. Thus, a 30% maximum total drawdown can be accepted by most of traders.

The relationship between total loss of account and getting back to the original account balance can be presented by the formula below.

Pay back rate (Difficulty) of getting back to break even = Lost / (Account Size – Lost) * 100%

3.2.2. Maximum 2% Loss of Each Trade

A 30% maximum drawdown applied to traders' accounts can help them to limit risks, but the loss of each trade is difficult to identify. Babypips (2011) assumes an experienced trader who has the ability to handle 70% trades can also lose all the money in his account. The reason is he has applied a false calculation in his risk control system. This website tutorial uses a statistical method and indicates that a 30% loss is not evenly distributed in all the transactions. This means that in the first 30 losses out of 100 transactions, the loss can be continued. This situation can be more complex for risk control calculation.

However, Snellgrove (2008) notes that failure trades will tend to be averaged distributed in a large number of transactions, so the relationship between the maximum drawdown and the maximum loss of each trade can be presented by the formula below.

Total Loss Percentage = 100% – (1 – Lost Percentage of each trade) ^ Trades * 100%

Through experiments, Babypips (2011) considers that more than 20 continuous lost transactions is rare in real forex trading. According to the above formula, a maximum 2% lost from each trade is more acceptable for most of traders. The following examples prove this concept.

Trades No.	Account Size	2% risk control	Trades No.	Account Size	10% risk control
1	$10000	$200	1	$10000	$1000
2	$9800	$196	2	$9000	$900
3	$9604	$192	3	$8100	$810
4	$9412	$188	4	$7290	$729
5	$9224	$184	5	$6561	$656
6	$9040	$181	6	$5905	$591
7	$8859	$177	7	$5314	$531
8	$8742	$175	8	$4783	$478
9	$8567	$171	9	$4305	$430
10	$8396	$168	10	$3875	$388
11	$8228	$165	11	$3487	$348
12	$8063	$161	12	$3139	$314
13	$7902	$158	13	$2825	$283
14	$7744	$155	14	$2542	$254
15	$7589	$152	15	$2288	$229
16	$7434	$149	16	$2059	$206
17	$7285	$145	17	$1853	$186
18	$7140	$142	18	$1667	$167
19	$6998	$139	19	$1500	$150

Table 3-2 Minimum 2% loss calcualtion

Table 3-2 shows a huge gap between 2% maximum on each trade and 10% maximum on each trade. In the 10% risk control strategy, the total loss is high, up to 85% after 19 transactions. Based on the remaining account balance after 19 transactions, the trader must increase his account balance by 566% to compensate for the occurred loss. On the other side, a 2% maximum strategy is more acceptable for most traders, and total drawdown is close to 30%. Within this risk control method, traders can more easily get back to breakeven.

3.2.3. Previews High / Low Strategy

Price fluctuations in the foreign exchange market are unpredictable, and they are driven by every possible factor. These factors include global politics, major economic events and central banks' rumors. This means that every trader can take action in the opposite direction of the market movement. The "maximum 2% lost for each trading" strategy can help traders minimize the total lost. However, Babypips (2011) is against traders applying this method in all situations. This website tutorial recommends traders should set their stop loss according to the market environment. They provide an example of a newbie trader applying a "maximum 2% lost" strategy and failing in trading.

The newbie trader has an account with $500, which can use a $10,000 minimum lot size for each trade. In this situation, he can only set a 10 pips stop for a possible loss in GBP/USD trading. But the everyday movement of GBP/USD is over 100 pips. He could lose a potential opportunity by a narrow stop range.

Thus, using equity stops, like the "maximum 2% lost for each trading" strategy, he will be close to entry position and could take a loss in trading. Gerald (2008) indicates that the risk control function should use technical analysis while the system is using equity stop methods.

A more sensible method to apply to the risk control function is using chart stop. Babypips (2011) notices there are many times when the forex market cannot reach a certain price level or area. Those price levels or areas can be called support or resistance in human technical analysis. Gerald (2008) believes that applying stop levels beyond those areas can reduce potential risk efficiency, because once the currency price breaks support and resistance levels, there are

more traders who can be attracted and take action to push the price to further movement. This means the action of breaking those levels is unpredictable, and can tell traders that market direction has already changed. The following diagram shows how to apply the chart stop in human forex trading.

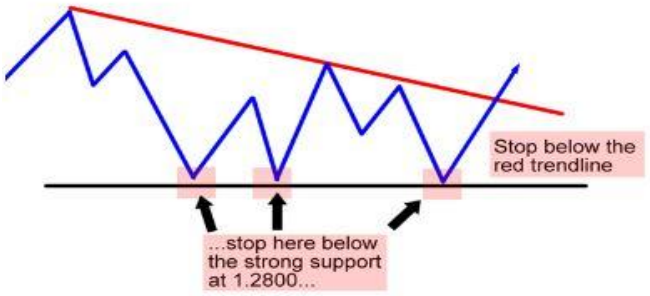

Figure 3-1 Stop level

Setting stops beyond support or resistance levels can clearly reduce trading risks. However, in the robot trading environment, it is hard to define a specific support or resistance level. Babypips (2011) indicates that there is no exact number to identify the support and resistance area. In candlestick charts, those areas are always tested by price. As the graphics cannot be digitized, the robots' programming becomes complicated.

An alternative solution is suggested by Babypips (2011), which is called "previews low / high strategy". They believe the previews stick's low / high is a better stop level in the same trend. However, the case becomes more complex in trends exchange, when the previews stick is certainly not good for setting support and resistance level. In this situation, the technical indicator which is called "fractals" can be used to replace the "previews low / high strategy".

3.2.4. ATR function

Another simple method to set stop loss is provided by Marta & Brusuelas (2009). They believe that market volatility is the potential movement range. Knowing how large the volatility of a currency pair is can assist traders to set a better stop level, and thus avoid many potential losses of the unpredictable movement.

For example, a 20 pips stop loss will fail a transaction in a small movement against you, while the everyday fluctuation of a specific currency pair is more than 100 pips.

"***One way to measure the volatility is by using Bollinger Bands. You can use Bollinger bands to give you an idea of how volatile the market is right now.***" (Babypips, 2011). The Bollinger bands stop loss method is presented by the following diagram.

Figure 3-2 Bollinger Bands stop loss setting

The above diagram indicates that Bollinger bands can provide default support and resistance levels by using Bollinger bounce. The best application is applied in ranging markets. Traders can set the long order when the price touches the lower band, and set the short order when the price touches the upper band. The formula for setting the stop loss level can be represented as below.

Stop Loss level = Upper bands + fluctuation

Stop Loss level = Lower bands - fluctuation

However, an exception is noted by Marta & Brusuelas (2009). The market always breakouts the current environment when the upper and lower bands squeeze together. In this situation, the stop loss levels are difficult to set up.

An improved strategy is issued by Babypips (2011), called an ATR function. They believe this indicator is more useful in both a large fluctuation and a ranging market environment.

3.3. Algorithm of fund management function

"***Money management is a strategic technique employed at making money yield the highest of interest-yielding value for any amount of it spent***." (Wiki, 2011). In forex trading, fund management usually is concerned with position size configuration. Babypips (2011) believes it is important to calculate the position size in forex trading, because like the risk control function, it can reduce the potential risk. There are five basic elements that are provided by this website tutorial. They are ***"(1) Account equity or balance. (2) Currency pair for trading. (3) The percentage lost for risk control. (4) Stop loss in pips. (5) Conversion currency pair exchange rates.***" (Babypips, 2011). Those elements can assist traders to calculate a suitable position size in future trading.

An example is given by Marta & Brusuelas (2009). A newbie trader applies for an account in the forex market with 10000 dollars. For currency EUR / USD, the risk of price fluctuation should be under 200 pips each transaction. As the previous section mentioned, 2% maximum loss for each trade can be accepted. So in this example, a 1% loss for each trade has been applied in the risk

control system, which is less than 2%. The risk percentage amount in the traders' account balance can be calculated as follows:

USD 10000 * 1% = $ 100

The risk value for every pip can be calculated as below:

$100 / 200 pips = $ 0.5 / pip

In this situation, it is better to set a mini lot or less in every transaction.

$ 0.5 each pip * (10000 units for EUR / USD) / $ 1 each pip = 5000 units for EUR / USD

Therefore, the calculation for risk comfort level should be represented as the follow formula.

Comfort level = (account balance * 1% / fluctuation) * (lot size / pip value)

3.4. Algorithm of market analysis function

3.4.1. Moving average crossover

"***A crossover describes the event price crossing through a moving average. It also refers to one moving average crossing over another moving average of a different time period. Both of these events are used as trading signals.***" (Traderslog, 2011). When using this technical indicator, traders have to use more than two moving averages in their trading charts. The entry signal can be conducted where the two lines cross. This means the trend will be switched soon. The detailed instructions are represented by the following diagram.

Figure 3-3 Moving average crossover

A suitable stop loss level can be set by the moving average as well. Babypips (2011) states that the slower moving average line is the best support and resistance level of a risk control system. The following diagram shows the price bounced off the MA at every time, and which one is the best time for setting stop loss levels.

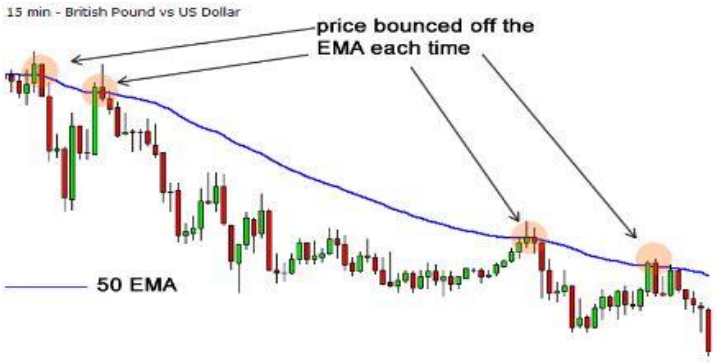

Figure 3-4 Stop loss setting of moving average crossover

The algorithm of moving average cross-over should be similar to the above descriptions. The robot has to set an entry point while two moving average lines cross over eachother. As the slower moving average line can be a good support or resistance level, the stop loss should be set at this point. Thus, the robot program should obey the following rules.

1. The entry signal of a moving average cross over can be set while one moving average crosses over another. If the fast line crosses over the slow line, the trading robots should issue the long signal. On the other hand, when the fast moving average crosses under the slow line, the short order should be issued.
2. For unpredictable reasons, the slower moving average line could be the support and resistance level. When the price hits the stop level, the robot should reset the new order at the middle of the space between the fast and lower moving averages. The direction of the new order should be the same as the previews orders.
3. The robots must close their orders when the next crossover has been made, or when the price hits the slower moving average.

The algorithm for MQL4 script can be represented as below.

```
//+------------------------------------------------------------------+
//| Main function                                                    |
//+------------------------------------------------------------------+
 for(int i=0;i<OrdersTotal();i++)
    {
     if(OrderSelect(i,SELECT_BY_POS,MODE_TRADES) == false) break;
     if(Ordersy() ==sy() && OrderMagicNumber() == MAGICMA)
       {
        if(OrderType() == OP_BUY)  buys++;
        if(OrderType() == OP_SELL) sells++;
       }

//+------------------------------------------------------------------+
//| Check for open order conditions                                  |
//+------------------------------------------------------------------+

//---- sell conditions
   if(Open[1] > average && Close[1] < average)
     {
      res=OrderSend(sy() , OP_SELL , sizeSize() , Bid , 3 , 0 , 0 , "" , MAGICMA , 0 , Red);
      return;
```

```
    }
//---- buy conditions
  if(Open[1] < average && Close[1] > average)
    {
     res=OrderSend(sy() , OP_BUY , sizeSize() , Ask , 3 , 0 , 0 ,"", MAGICMA , 0 , Blue);
     return;
    }
//----
 }
//+------------------------------------------------------------------+
//| Check for close order conditions                                 |
//+------------------------------------------------------------------+
     if(OrderType() == OP_BUY)
       {
        if(Open[1] > average && Close[1] < average) OrderClose(OrderTicket() , Ordercapital() ,
Bid , 3 , White);
        break;
       }
     if(OrderType() == OP_SELL)
       {
        if(Open[1] < average && Close[1] > average) OrderClose(OrderTicket() , Ordercapital() ,
Ask , 3 , White);
        break;
       }
```

3.4.2. Triple Moving average cross over

The triple moving average cross over can be generated entry by the signal as well. By using this strategy, the long and short signals are generated before the trend is defined. The third moving average line is different from the normal moving average cross over because it is used to confirm the trend, and thus avoid a false signal in forex trading.

According the algorithm of the moving average, the faster the time period, the closer the price trend. Thus, the short term moving average will start to move earlier than the long-term line. Trading robot programming should obey the following rules.

1. Like the normal moving average cross over, the entry signals are usually generated where two short term moving averages cross.
2. The longest term moving average can be used to confirm the trend.
3. Using this system, the stop loss setting is dependent on the slowest moving average line. , The robot should place the new order at the default support and resistance level when the price hits the longest term moving average.
4. The robot must close the orders when the trend has changed, or when the price hits the support and resistance level.

3.4.3. The Simple Indices combination

Babypips (2011) lists a lot of technical indicators which can be used for trading robot programming. However, this website tutorial believes that each of these indicators is not perfect when traders apply them to real forex trading. That means it is necessary to combine all kinds of technical indicators together, in order to make them cooperate with each other. Gerald (2008) suggests that the best solution is a robot which has more than three different technical indicators. The robots will not initialize the trading until all the indicators generate a signal at the same time.

An example is provided by Babypips (2011). The application includes two technical indicators, Bollinger bands and stochastic. In a 4-hour time frame chart, those two indicators perform differently. The following diagram shows that one entry signal is generated at the same time by both two indicators, which can take more than 300 pips profits in the sell orders. Later, another opportunity is also issued by this system which can take 400 pips profits.

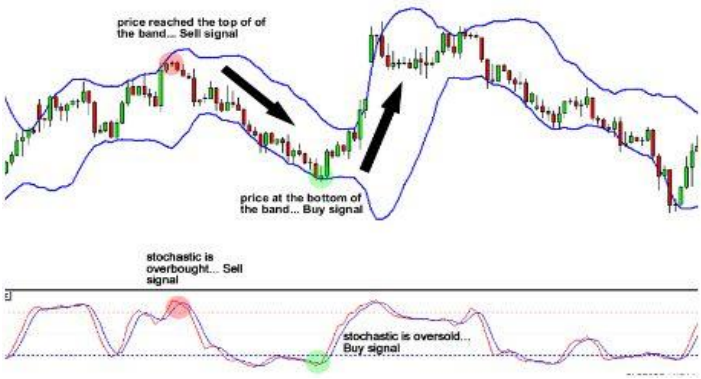

Figure 3-5 Simple indicators combination

Another example is given by Gerald (2008). Two technical indicators, i.e., RSI and MACD, are applied in this system. The picture shows that the RSI is located in the overbought zone and a short signal is generated. The MACD also provides a dead crossover, which is a signal for short as well. By following this signal, traders can gain at least 500 pips profit. Then a long signal is issued after the trend changes, which can also take more than 300 pips profit. The application can be presented by the following diagram.

Figure 3-6 Using the simple indicators combination to capture the trend

Based on th above two samples, a simple indicator combination system is created by Babypips (2011). In this system, the robot will work on the daily chart, and thus the moving averages can easily define the trend for further prediction. The stochastic indicator is applied in this system

as well, because it can assist traders in determining the entry point when the current trend is defined. Moreover, the oversold and overbought function of stochastic can notify traders if the price reaches the trend's end. The RSI is used for confirmation of the entry signal, which can avoid most of the noise and improve the success rate. The basic rules of this system are presented below:

1. To define the current trend, two moving average lines are applied in this system. When MA (5) crosses over MA (10), the uptrend can be considered to have started. On the other hand, the dead cross will define the down trend in the future.
2. Stochastic (14, 3, 3) has been applied for the entry signal. Normally, the long signal will be generated while fast KD line crosses over the lower KD line. However, an exception is noted by Babypips (2011). The long signal will be ignored by system when the stochastic line breaks into the overbought area. On the other hand, the short signal can be generated by the dead cross of stochastic lines while both faster and slower lines are not in the oversold area.
3. RSI (9) is used to confirm the entry signal. Only in the situation of RSI above 50 can the buy signal be acted. Otherwise, the system will avoid potential signals. Similar cases also occur with the sell signal. The short action can be implemented only when the RSI is below 50.
4. The previews high / low strategy is used by this system for setting default stop loss.

3.4.4. The Cowabunga trading method

The Cowabunga method was developed by Pip My System (2011), which mostly improves some issues based on the simple indicators system. The authors believe that it can help traders to avoid noisy signals and increase the success rate. This website tutorial points out that the original system is simple and profitable at the same time frame. But an additional time frame function can fix some problems of trend determination.

The basic theory of the Cowabunga method is to follow small trends within the larger trends and avoid fake signals. However, the real action in trading is complex. The author of the website tutorial recommends that traders should use two different timeframes, for instance, a 15-minute chart and a 4-hour chart. When traders determine the trend under the 15-minute chart, the system reminds traders to review the trends in a 4-hours chart first. Thus, the main trend will be noticed by traders, and that can give opportunities for catching the market direction. The basic rules of this system are presented as follows:

1. To identify the trend, the cowabunga method applied four indicators in the 4-hour chart. They are 5 EMA, 10 EMA, stochastic (10, 3, 3) and RSI (9). In the up trend, the 5 EMA must be above the 10 EMA, and the stochastic line should be heading up and the RSI value must be larger than 50. On the other side, to confirm the down trend, both the EMAs and stochastic should be heading down, and the RSI value must be less than 50.
2. The 15-minute chart is used to determine the entry signal. There are five indicators that have been applied to this trading system. They are 5 EMA, 10 EMA, stochastic (10, 3, 3), RSI (9) and MACD (12, 26, 9). To generate the long signal, the 5 EMA should cross above the 10 EMA, the KD indicators should head up and the RSI value needs to be greater

than 50. Also, the MACD value should cross over the MACD signal and it must move from negative to positive. For short signals, the triggering condition must be opposite to the triggering condition of long signals.

3. The stop loss setting is similar with a simple indicators combination system. The Cowabunga method chooses the previews high / low strategy as a support and resistances configuration.

3.4.5. Dolphin trading method

The Dolphin method was developed by Zhang (2008), and is based on Dow's Theory. Dow believes that stock indexes can be divided into three trends: short term, medium term and long term trends. These three situations exist in any financial markets, where their directions can be different from each other. Thus, multiple time frame analysis is often deployed for forex trading robot development.

"***Multiple time frame analysis is simply the process of looking at the same pair and the same price, but on different time frames***." (Babypips, 2011). The trading platform can provide many time frame charts for traders' analysis. There are many choices for them –daily, hourly, per 30 minutes, per 5 minutes and even 1 minute. That means every trader can get different ideas from different charts. Fortunately, multiple time frame analysis can define a personal time frame strategy to every trader. The following table presents feature of different time frames.

Time frame	Description	Advantage	Disadvantage
Long term	Dow's theory believes the long-term time frame usually refers to daily and weekly charts.	Traders do not care about the change in short term charts. There is little chance to trade and the	Considerable price changes may cause large losses. A high requirement for the initial amount

	The weekly time frame will help traders to focus on long term trends, which will assist them in determining entry points in medium term. The long term trading persists for a few weeks or months, or even up to one year.	spread can be ignored. There is much time to consider before entering the market. Traders do not worry about the lost trading opportunities.	of the trader's account, which can protect against losses from the low validity market environment. Not enough opportunities to trade.
Medium term (Swing)	The 4-hour chart and hourly chart are the best choices for traders' analysis in swing markets. The trading can last several days.	More transactions in trading, and less spread fee in months.	More spread fee. Traders must consider the overnight and over week risk.
Short term (Intraday)	The minute charts can be selected by short term traders to catch any possible opportunities. The short term trading only persists intraday.	There is no risk for overnight market environment change. Traders can get more opportunities to trade.	Too much high spread fee. Traders have little time to think before they get trading opportunities. Low profit for each transaction.

Table 3-3 Time frame selection

Zhang (2008) believes the long-term chart can help traders to determine the main trend. Medium term it will assist them in predicting both the lower time frame and the higher time frame, and short term it will issue the potential entry point. Therefore the concept of time frame combination is provided by Babypips (2011). The suitable time frame combination is presented below.

- 1-minute chart for short term, 5-minute chart for medium term, and 30-minute chart for main trend determination.

- 5-minute chart for short term, 30-minute chart for medium term, and 4-hour chart for main trend determination.
- 1-hour chart for short term analysis, 4-hour chart for medium term, and daily chart for main trend determination.

The basic rule of this system is presented below:

The dolphin system applies 5 major technical indicators in forex robot trading. They are MACD (5, 34, 5), KD (8, 5, 5), MA (26, 52, 104, 360), Envelope (26 – 0.62%, 0.31%) and Time (M5 – M30 – 4H).

The time frame selection is based on trader's habits, and thus determines their main trading session. This means that the principle of determining the main session is decided by traders. The trends determination is used to move to the larger time frame, and the smaller time frame is used to issue the entry point.

1. The principle of trend determination is based on technical indicators MA (26) and MACD (5, 34, 5). When the price is greater than MA (26) and the MACD value is greater than signal, the current trend is considered bullish. As the price is less than MA (26) and the MACD value is greater than signal, the current trend is considered bullish too. If the price is greater than MA (26) and the MACD value is less than signal, the current trend is considered bearish. While the price is less than MA (26) and the MACD value is greater than signal, the current trend is considered bearish.
2. The position size calculation of the dolphin system follows the formula, Comfort level = (account balance * 1% / fluctuation) * (lot size / pip value)

3. The rule of entry point selection is based on the indicator of KD (8, 5, 5). The long signal is generated when the value line crosses above the signal line. On the other side, the short signal is conducted by the dead cross of the KDs.
4. This trading system uses the golden channel as a profit determination tool. When the price hits the boundary of the golden channel, the transaction will be closed for taking profits. The related technical indicators of the golden channel is Envelope (26 – 0.62%, 0.31%).
5. The stop loss setting is special in this trading system. Zhang (2008) believes that when the price moves more than 9 candles in the current chart, the trend will be going to end. Therefore, traders should close the current trading after 9 sticks are completed.

The algorithm for MQL4 script can be represented as below.

```
extern int distance = 10;
//---- time frames
extern int mainframe = 240;
extern int currentframe = 30;
extern int entryframe = 5;

//---- data buffers
double maintrendline[];
double currenttrendline[];
double currentlma[];
double upstop[];
double downstop[];
double buy[];
double sell[];
filter = iMACD(NULL , 0 , 14 , 84 , 5 , PRICE_CLOSE , MODE_MAIN , pos+1);
    f_s = iMACD(NULL , 0 , 14 , 84 , 5 , PRICE_CLOSE , MODE_MAIN , pos+2);

    kd = iStochastic(NULL , 0 , 8 , 5 , 3 , MODE_SMA , 1 ,MODE_MAIN , pos);
    kdp = iStochastic(NULL , 0 , 8 , 5 , 3 , MODE_SMA , 1 , MODE_MAIN , pos+1);
    kd_s = iStochastic(NULL , 0 , 8 , 5 , 3 , MODE_SMA , 1 , MODE_SIGNAL , pos);
    kdp_s = iStochastic(NULL , 0 , 8 , 5 , 3 , MODE_SMA , 1 , MODE_SIGNAL , pos+1);
```

```
    if(kd > kd_s && kdp < kdp_s && Open[pos] < upline && Open[pos] > currenttrendline[pos]
     && Open[pos] > maintrendline[pos])
    {
      buy[pos] = line_bottom;
    }
    else if(kd < kd_s && kdp > kdp_s && Open[pos] > downline && Open[pos] <
currenttrendline[pos]
    &&Open[pos] < maintrendline[pos])
    {
      sell[pos] = line_top;
    }

    else if(Close[pos+1] < maintrendline[pos] && Open[pos+1] > maintrendline[pos] &&
Open[pos] < upline && Open[pos] > currenttrendline[pos]
    && Open[pos] > maintrendline[pos] && filter > f_s)
    {
      buy[pos] = line_bottom;
    }
    else if(Close[pos+1] > maintrendline[pos] && Open[pos+1] < maintrendline[pos] &&
Open[pos] > downline && Open[pos] < currenttrendline[pos]
    && Open[pos] < maintrendline[pos] && filter < f_s)
    {
      sell[pos] = line_top;
    }
    else if(Close[pos+1] < currenttrendline[pos] && Open[pos+1] >currenttrendline[pos] &&
Open[pos] > currenttrendline[pos]
    &&Open[pos] > maintrendline[pos] && filter > f_s)
    {
      buy[pos] = line_bottom;
    }
    else if(Close[pos+1] > currenttrendline[pos] && Open[pos+1] < currenttrendline[pos] &&
Open[pos] < currenttrendline[pos]
    &&Open[pos] < maintrendline[pos] && filter < f_s)
    {
      sell[pos] = line_top;
    }
```

4. Experiments on Trading Robots

This section presents the application of forex trading robots in the forecast process between US Dollar and other major currencies including includes JPY, GBP, NZD, EUR and AUD. During the experiment, all kinds of technical indicators and historical data were applied to trading robots to catch potential trading opportunities in each currency pair. In this paper, the rescaled range analysis is used to evaluate the effectiveness and sensitivity of each trading robot in different market environments.

4.1. Pre experiments creation

The pre experiment processing is not simple, as it follows the "***rescaled range analysis and market efficiency testing"***. This is a common method but is only used by a few applications, such as "***Random walk Hypothesis and efficient market hypothesis***". (Yao, 2000). Yao states that the random walk hypothesis, presenting currency pair prices, always moves randomly and its direction is unpredictable. The efficient market hypothesis refers to market reflection, which can take all potential opportunities and fully reflect the new information. In the forex trading market, some traders place orders immediately once they get economic messages from other persons. However, other traders will wait for confirmation, unless the current trend is clear.

Yao (2000) mentions the Hurst exponent, which is a criterion of the bias in fractional Brownian motion. He believes that that Hurst exponent could be applied in forex market historical data to decide whether that information can be "***biased random walks***" following the prediction.

Before the experiment, the rescaled range analysis is introduced into the evaluation process, and this can be used to categorize a random data series from a fractal series and a basic series.

The value of those random data series can be marked as Gaussian and non Gaussian. Yao indicates that rescaled range analysis is a statistic for testing the volume of noise of each trading robot, which can be used to determine the trend persistence and the average period's number for market environment cycles. The formula of noise measurement can be presented as below.

$$R_N = \max_{1 \le t \le N} [x_{t,N}] - \min_{1 \le t \le N} [x_{t,N}],$$

In the above expression, R is conducted by the deviations between the maximal and minimal prices. The expression of $[X_{t,n}]$ is presented as the cumulative deviation during the previews *N* candle sticks. It can be presented as the following formula.

$$x_{t,N} = \sum_{u=1}^{t} (x_u - \mu_N),$$

In the above expression, μ n is the average price in previews n periods for a specific currency pair.

Yao (2000) states that the R/S ratio can be transferred as the formula of $R/S = N \hat{} H$. In this expression, *S* is the value of standard deviation and *H* is the value of the Hurst exponent. Thus, the Hurst exponent can be calculated using the following formula.

$$H = \log(R/S)/\log(N), \quad 0 < H < 1$$

An experiment description is described by Yao (2000), which uses computers to generate a random time series. In this experiment, a computer conducts the Hurst exponent index using a series of random numbers, whose values are very close to 0.5. The application of the H

exponent used in financial markets will probably results in two different events. Thus, there are three situations to define the Hurst exponent using the above calculation.

1. $H = 0.5$,
2. $0 \leq H < 0.5$,
3. $0.5 < H < 1$,

In the case of $H = 0.5$, the evaluation over the random data series cannot be considered as the "***Gaussian random walk***". (Yao, 2000). The only instruction of the evaluation is to present "there is no persistent trend" in the forex market. When the Hurst value changes from 0.5, it indicates that the trading robot cannot identify the strength of bullish and bearish. In the case of $0 \leq H < 0.5$, the market environment could be an anti-persistent movement in the future. The price volatility could be higher than ever before and the reversals could be frequent. Despite the prevalence of reverse trading strategies in forex trading, only a few anti-persistent market environments have been identified. For the other cases, i.e., $0.5 < H < 1$, it presents the persistent trend forces. The persistent strength depends on the distance between the value of the Hurst exponent and 0.5. Yao (2000) indicates that bias could change suddenly, even if the Hurst exponent points to a biased random series. Thus the data can only be estimated in a specific time period. In this period, the lower the value of Hurst is, the more noise could be detected by the system. On the other hand, a higher value of the Hurst exponent will indicate a higher persistent trend, and thus will reduce the occurance of noise.

An application of the Hurst exponent was given by Yao (2000). By following this application, this paper conducted a similar experiment for the evaluation. There were five currency pairs applied in this study, which collected 240 daily candle datasets for the test sample from March to October of 2011. The data calculation is presented below.

Currency Pairs	Mean	Standard deviation	Variance	Max	Min
AUD / USD	1.0303	0.0931	0.008667	1.0977	0.9386
NZD / USD	0.7897	0.1219	0.01485	0.8842	0.7116
GBP / USD	1.6074	0.2415	0.05832	1.6746	1.5235
EUR / USD	1.3953	0.2112	0.04122	1.4940	1.2625
USD / JPY	80.93	34.2218	1171.1316	75.98	85.52

Table 4-1 Pre experiment setting

The value of the Hurst exponent and correlation for five currency pairs is presented in the table below.

Currency Pairs	The Hurst exponent
AUD / USD	0.5135
NZD / USD	0.5430
GBP / USD	0.5285
EUR / USD	0.5111
USD / JPY	0.5326

Table 4-2 Calculation of the Hurst exponent

The above statistical results show that the value of the H exponent for a recent 240 day forex market environment is greater than 0.5. This means that all the five currency pair products are fractal, and will not cause a random market environment. According to the above market analysis, the current market environment can be applied into a trading robot experiment, and there are no random factors that can disturb the test process.

4.2. Test environment setup

The MetaTrader is an electronic online trading platform developed by MetaQuotes Corp. The main application of this software is used for online forex trading. The MetaTrader terminal is a part of the MetaTrader system, which consists of a charting system, an online transaction function and a trading robots management function. Among them, the trading robots

management function has a feature of a C–like programme which is called MQL programming. This feature allows traders to develop their own technical indicators and trading robots.

Recently, the MetaQuotes Corp has released two versions of their products. They are MetaTrader 4 and MetaTrader 5. Compared with MetaTrader 4, the latest version has the following improvements.

1. MetaTrader 5 has improved MQL programming features. Unlike the MQL4, the MQL5 script has added more features of OO programming languages in the trading robot design.
2. The MetaTrader 5 improves compatibility in all kinds of trading environments. The Hedge orders, which is a trading policy and allows traders to set both the long and short transactions at the same time, are no longer applied in the fifth version,. In the new version of this trading platform, the previews order with the opposite direction will be offset by the current order. That means that the first in and first out policy is applied in the MetaTrader 5 trading platform, and thus it will create more inconvenience in the real world of forex trading.

The MetaTrader 4 trading platform is selected in this paper as the experiment resource. The reason for giving up the higher version is most trading robots still using the hedge strategy, which could crash in the MetaTrader 5 experiments. Also, the lack of application of the fifth version was considered before the start of this research. Because most forex dealers are still using the MetaTrader 4 trading platform, the older version is considered to

be suitable for most trading environments. In this research, the following robots are applied in the evaluation.

Number	Strategies	Number of parameters	Name of important parameters	Signal Delay
Robot 1	Moving Average Crossover	2	Fast average, slow average	1 – 3 candle sticks
Robot 2	Triple Moving Average Crossover	3	Fast average, slow average, main line	1 – 3 candle sticks
Robot 3	The Simple Indices combination	7	Fast average, slow average, fast kd, slow kd, RSI line, overbuy and oversold level	1 – 3 candle sticks
Robot 4	The Cowabunga System	9	Fast average, slow average, fast kd, slow kd, RSI line, overbuy and oversold level, MACD result and signal, timeframes	1 – 3 candle sticks
Robot 5	The Dolphin System	6	Fast kd, slow kd, timeframes, MACD result and signal, the golden channel	1 – 3 candle sticks

Table 4-3 Trading robots selection

To apply the above trading robots, MQL4 script must be used in the software programming. MQL4 Book (2011) indicates that MT4 terminal is a development tool, which includes MQL4 programming editor, and can help customers design their robots. The MT4 server is a part of the MT4 system as well, but it is always installed in the dealer's server, that is, the connection

between financial institutions and traders. MQL4 Book (2011) believes that MT4 terminal has an information system that can create a series of parameters and thus catch the market environment and the communication between dealers and traders. This information system can present the forex price, the regulation of order sizes, and the limitations of the stop loss level. It can also switch between trading robots, and other statements of forex environments. The information system updates frequently when new candle-sticks are changed by MT4 terminal. The following diagram shows the working mechanism of MT4 terminal.

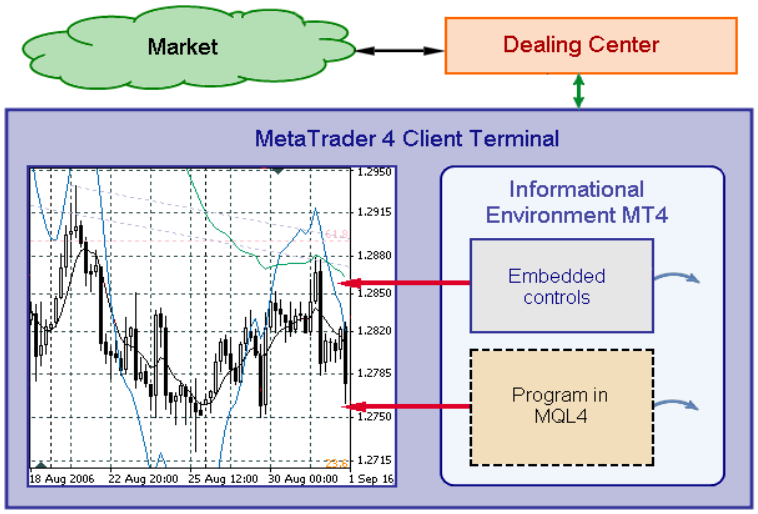

Figure 4-1 Working mechanism of MT4 terminal

The built–in tools are an important function of MT4 terminal. This package provides many kits to improve the experiment results. These tools can assist traders in conducting technical analysis and thus evaluate the accuracy of trading robots. The technical analysis includes drawing stop loss level, channels and Fibonacci levels. Traders can set, cancel or modify transactions manually in order to protect the exception caused by automatic trading. In MT4

terminal, stop orders can be automatically generated by the system, and the only thing traders have to do is to monitor the market environment and the status of the networking connection.

MQL4 Book (2011) indicates that there are three types of applications that can be developed for trading robot experiments. They are custom indicators, expert advisor (EA) and scripts. Normally, most trading robots are programmed as EAs that allow fully automatic trading in the MT4 environment. However, custom indicators are designed for sensitivity evaluation, which are important tools for displaying possible noises.

4.2.1. Custom indicators design

"***Custom indicator is a technical indicator written independently in addition to those already integrated into the client terminal. Like built-in indicators, they cannot trade automatically and are intended for implementing of analytical functions only***." (MQL4 Book, 2011).

Besides EA tests, all trading robots are designed as custom indicators for noise experiments. The method of evaluation is a type of diagram review, which is the way to attach trading signals to the forex chart window and notify possible entry opportunities. In this research, entry opportunities can be presented as cross symbols. If the symbol direction is opposite to the market movement, a noise can be confirmed by traders and this situation can be recorded for the sensitivity evaluation.

MQL4 Book (2011) provides the criteria to distinguish custom indicators and EAs. Both EAs and custom indicators are the scripts that are walking in the same window for several candle sticks in a specific time period. "***This is their run duration***". (MQL4 Book, 2011).

Both custom indicator and EAs should be attached to the chart window. Once the terminal is following the market movement, the EAs will execute the order automatically. This action will take real profit and loss, and thus affect the balance of accounts. By launching custom indicators, there is no effect on order execution. Once a possible signal occurs, the program marks the symbol on the chart and transfers it into the continuously running mode. Unlike EAs and indicators, the script will be generated immediately once it is attached to a forex chart. It does not need to wait for any market movement. The following diagram shows the difference between three types of trading robots.

Program parameters	EAs	Scripts	Custom Indicators
Waiting for market movement	Waiting for price changed	immediately	Waiting for price changed
Orders	Allow execution	Allow execution	Prohibited
Show symbol on the chart	No	No	Yes
Simultaneous	Prohibited	Prohibited	Prohibited
Automatically issue the signal	Prohibited	Prohibited	Prohibited

Table 4-4 Three types of MQL4 scripts

"***The main principle underlying custom indicators is passing values of indicator arrays to a client terminal (for drawing indicator lines) via exchange buffers.***" (MQL4 Book, 2011). In MQL4 programming, buffers are used to locate indicator arrays as numeric values. Normally, a custom indicator can include eight symbols. Each symbol connects to a buffer so that the indicator can communicate between market movement and the chart window. According to the MQL4 programming standard, each buffer has been assigned with an index. The number of the index can be marked from 0 to 7. The following diagram shows how the assigned index for a custom indicator and their relationship between the candles stick update and the forex chart window.

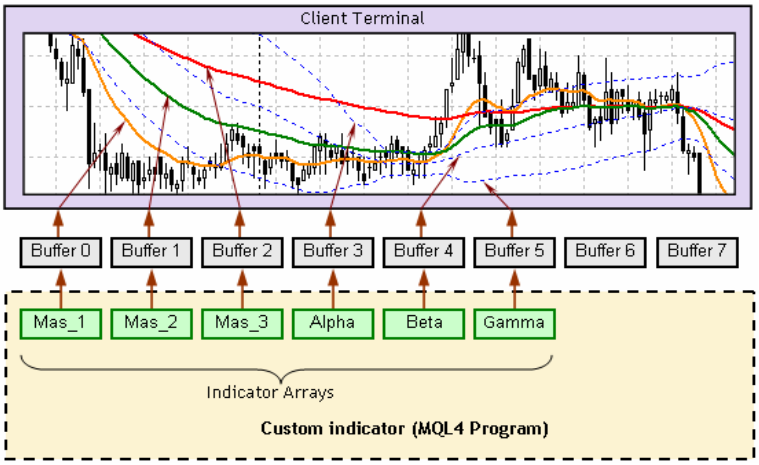

Figure 4-2 Relationship between the candles stick update and the forex chart window

The components of a custom indicator are different from EA. In most situations, the first step should describe which window will display the indicator symbols. The MQL4 script code is presented below.

```
#property indicator_chart_window
```

In the next step, the custom indicator should define the number of buffers, which can store the information of symbols. The MQL4 script code is presented below.

```
#property indicator_buffers 3
```

In the above script, the custom indicator defined 3 symbols, which can display in the current chart.

The third step shows the color of each indicator. The MQL4 script code is presented below.

```
#property indicator_color1 Blue
#property indicator_color2 Red
#property indicator_color3 Green
```

The above script is about the parameter definitions. This process is setting a color for each corresponding buffer, which means the system assigns blue, red and green to the index 1, 2 and 3. Thus, in the chart display, traders will show three indicators with three different colors. These parameters are kinds of variables to set buffers. In the user interface, traders can modify the value before applying this custom indicator to the chart window.

The fourth step is to identify the indicator arrays. The MQL4 script code is presented below.

```
double Buffer_0[], Buffer_1[], Buffer_2[];
```

This custom indicator has three indexes, so that three indicator arrays should be declared. Once the indicator arrays are defined, an important action should be generated, as below.

```
SetIndexBuffer(0, Buffer _0);
SetIndexBuffer(1, Buffer _1);
SetIndexBuffer(2, Buffer _2);
```

Function SetIndexBuffer() is used to connect a buffer to the related array, so this custom indicator should be coded by three script sentences for the above action. Finally, the index style should be identified. The MQL4 script code is presented below.

```
SetIndexStyle (0, DRAW_LINE, STYLE_SOLID, 2);
SetIndexStyle (1, DRAW_LINE, STYLE_SOLID, 2);
SetIndexStyle (2, DRAW_LINE, STYLE_SOLID, 2);
```

4.2.2. The Indicators filter design

There are many technical indicators that are applied in financial analysis. These indicators can help traders find potential trends and opportunities. However, each indicator has its strengths and weaknesses. Traders should have the ability to determine which indicator can suit the current market environment. Babypips (2011) provides a concept for the category: leading and lagging. The leading indicator should be issued before the trend reversal or the beginning of a strong market movement. The lagging indicator should be generated after the trend reversal or when a strong market movement has started. In theory, Babypips (2011) identifies them as oscillator and momentum indicators. This website tutorial believes that each indicator can have a different effect on the entire trading system. These effects could be both positive and negative.

To evaluate the effectiveness of a single trading robot, it is necessary to understand how its indicators affect real trading. To realize this purpose, the indicators filter should be designed before the experiments. The indicators filter is a kind of trading robot, which is a collection of many technical indicators. In this trading robot, the system switches all indicators running in the market environment one by one. The test result can be recorded by traders for an effective evaluation. The MQL4 algorithm code of the indicators filter is presented below.

```
extern int MA_crosser = 0;
extern int MACD_crosser = 0;
extern int AD_crosser = 0;
extern int KD_crosser = 0;
extern int SAR = 0;
extern int RSI = 0;

init(); //init declare
```

```
int MAcrosser (int par1, int par2, stop, profit, trail)
{
// indicator 1 statement;
}

int MACDcrosser (int par1, int par2, stop, profit, trail)
{
// indicator 2 statement;
}

Int AD_crosser(int par1, int par2, stop, profit, trail)
{
// indicator 3 statement;
}
Int KD_crosser(int par1, int par2, stop, profit, trail)
{
// indicator 4 statement;
}

Int SAR(int step, double par2, stop, profit, trail)
{
// indicator 5 statement;
}

Int RSI(int par1, int par2, stop, profit, trail)
{
// indicator 6 statement;
}

Start()
{
//start running indicator filter;
//declare any variables;
Switch ( indicators )
{
    Case 1: //doing function MAcrosser();
    Case 2: //doing function MACDcrosser ();
    Case 3: //doing function AD_crosser ();
    Case 4: //doing function KD_crosser ();
    Case 5: //doing function SAR ();
    Case 6: //doing function RSI ();
    Break;
}
}
```

4.2.3. Modeling quality discussion

During the experiments, a barrier, which is called modeling quality, could affect the evaluations,. Modeling quality will directly affect the experiment results. This is an index that is issued by Metatrader 4. Metaquotes invented this number, and it is used by traders to measure the lower time period while they are running a trading robot. The idea of using modeling quality is to simulate the lower time period, and improve the test quality. “Higher quality” is always defined as a more detailed description of a candle stick. The formula of a modeling quality calculation is presented below.

Modeling Quality = ((0.25 * (Start Gen – Start Bar) + 0.5 * (Start GenM1 – Start Gen) + 0.9 * (History Total – Start GenM1)) / (History Total – Start Bar)) * 100%;

Completeness is the most important component of MetaTrader 4 robot experiments. Mechanical Forex (2011) states that completeness does not focus on a single time frame. This means that 80% modeling quality within the minutes chart window should be more accurate in a robot test. But the case of a 99% total modeling quality with only 20% maximum quality in a 1 minute time frame could issue an inaccurate experiment result.

Mechanical Forex (2011) believes that test accuracy is dependent on the robot and what strategies traders apply in forex trading. For example, a simple trading system with trading at the end of a day, which does not contain stop loss, trail stop and profit level, and even no pending orders, will be able to conduct an accurate experiment result. This simple experiment only needs limited market data, which includes open, high, low and close information at the

end of the day. This indicates that low modeling quality may not have a negative effect on experiments.

On the other hand, the 99% modeling quality does not make an accurate simulation; traders can build an experiment with an inaccurate simulation in a lower time frame. Therefore, modeling quality has no relation to the simulation accuracy of a specific trading system. "***Real modeling quality depends on the characteristics of the system being tested and whether or not the system is able to adequately address the limitations of the testing software being used***." (Mechanical Forex, 2011). A trading robot should have a suitable configuration to consider possible data loss. Sometimes, a 99% modeling quality may not bring an accurate experiment result. The following table shows the effect of modeling quality.

Trading strategies	Low modeling quality	Account statues	High modeling quality	Account statues
Robot 1 AUD / USD	24%	-73%	99%	2%
Robot 2 AUD / USD	45%	-64%	99%	12%
Robot 3 AUD / USD	43%	-23%	99%	31%
Robot 4 AUD / USD	65%	-10%	99%	6%
Robot 5 AUD / USD	28%	5%	99%	12%
Robot 1 NZD / USD	25%	-43%	99%	71%
Robot 2 NZD / USD	65%	-34%	99%	56%
Robot 3 NZD / USD	78%	-22%	99%	21%
Robot 4 NZD / USD	20%	-6%	99%	23%
Robot 5 NZD / USD	76%	12%	99%	10%
Robot 1 EUR / USD	85%	-89%	99%	-12%
Robot 2 EUR / USD	23%	-68%	99%	56%
Robot 3 EUR / USD	65%	-39%	99%	21%
Robot 4 EUR / USD	47%	-12%	99%	-5%
Robot 5 EUR / USD	47%	-32%	99%	11%
Robot 1 GBP / USD	86%	-67%	99%	-34%
Robot 2 GBP / USD	91%	-71%	99%	-5%
Robot 3 GBP / USD	16%	-45%	99%	27%
Robot 4 GBP / USD	36%	-37%	99%	20%
Robot 5 GBP / USD	28%	-23%	99%	19%

Robot 1 USD / JPY	54%	-35%	99%	-3%
Robot 2 USD / JPY	68%	-56%	99%	7%
Robot 3 USD / JPY	34%	-12%	99%	6%
Robot 4 USD / JPY	65%	23%	99%	15%
Robot 5 USD / JPY	38%	19%	99%	22%

Table 4-5 Effect of modeling quality

The above table shows that modeling quality heavily affects the experiment results. With a 99% modeling quality, the test results become more comfortable to traders. However, according to the Mechanical Forex (2011) description, a high modeling quality can increase the experiment's accuracy, but cannot provide the real test process. Therefore, the forward test is also launched in this research.

4.3. Data gathering

The robot experiments continued for 8 months. During the test, there were five currency pairs applied in this study, which collected 240 day candle dataset for the test sample from March to October of 2011. According to the limitation of modeling quality, both backward test and forward test were launched in this study.

To conduct an accurate result, I downloaded historical data from the trading server of Alpari. This forex dealer can provide a complete dataset. The forward test is different from the backward test. There are many limitations that may have negative effects on the experiment. Firstly, it is impossible to continuously run a computer for 240 days. The rest time should not count in the test process. Secondly, human activity may stop the experiment from time to time, for example, in the holidays. Therefore, this research may not issue a 100% accurate 24-hour experiment result.

The following table presents the backward test results.

Trading strategies for back test (10000$ init deposit), minimum lot size 0.01.	Total orders	Profit orders	Maximum drawdown	Maximum profit	Account status
Robot 1 AUD / USD	179	101	2%	1%	2%
Robot 2 AUD / USD	156	88	1.1%	2%	12%
Robot 3 AUD / USD	213	102	1.2%	1%	31%
Robot 4 AUD / USD	450	301	0.3%	0.4%	6%
Robot 5 AUD / USD	1301	799	0.3%	0.5%	12%
Robot 1 NZD / USD	163	77	0.8%	0.6%	71%
Robot 2 NZD / USD	135	69	0.1%	5%	56%
Robot 3 NZD / USD	297	176	2%	1%	21%
Robot 4 NZD / USD	643	412	1.2%	4%	23%
Robot 5 NZD / USD	1832	1087	0.4%	3%	10%
Robot 1 EUR / USD	173	45	3%	5%	-12%
Robot 2 EUR / USD	129	90	1.2%	1%	56%
Robot 3 EUR / USD	191	133	1.3%	1.1%	21%
Robot 4 EUR / USD	720	401	5%	2%	-5%
Robot 5 EUR / USD	2016	1311	2%	3%	11%
Robot 1 GBP / USD	298	79	1.2%	0.9%	-34%
Robot 2 GBP / USD	231	101	1%	1%	-5%
Robot 3 GBP / USD	312	201	1.1%	0.9%	27%
Robot 4 GBP / USD	871	547	1%	1.5%	20%
Robot 5 GBP / USD	4194	2671	0.8%	1.3%	19%
Robot 1 USD / JPY	119	55	0.4%	0.3%	-3%
Robot 2 USD / JPY	191	112	0.8%	0.9%	7%
Robot 3 USD / JPY	132	65	1%	2%	6%
Robot 4 USD / JPY	375	199	2.3%	0.9%	15%
Robot 5 USD / JPY	971	512	2%	1.7%	22%

Table 4-6 Backward test

The following table presents the forward test results.

Trading strategies for forward test (10000$ init deposit), minimum lot size 0.01.	Total orders	Profit orders	Maximum drawdown	Maximum profit	Account status
Robot 1 AUD / USD	59	45	2%	1.1%	14%
Robot 2 AUD / USD	81	32	1%	0.3%	22%
Robot 3 AUD / USD	71	51	2%	1.2%	12%
Robot 4 AUD / USD	211	131	1%	2%	34%
Robot 5 AUD / USD	405	238	1%	3%	32%

Robot 1 NZD / USD	46	31	1.4%	2%	34%
Robot 2 NZD / USD	70	47	1.1%	0.9%	51%
Robot 3 NZD / USD	34	19	0.9%	1.5%	13%
Robot 4 NZD / USD	101	61	1%	2%	32%
Robot 5 NZD / USD	322	189	1%	1.9%	49%
Robot 1 EUR / USD	57	32	1%	1%	14%
Robot 2 EUR / USD	81	57	0.7%	0.6%	16%
Robot 3 EUR / USD	62	31	1%	1%	31%
Robot 4 EUR / USD	113	60	0.7%	1.2%	25%
Robot 5 EUR / USD	265	161	1%	3%	33%
Robot 1 GBP / USD	46	21	1%	1%	24%
Robot 2 GBP / USD	52	31	0.8%	0.7%	15%
Robot 3 GBP / USD	61	47	1%	0.9%	21%
Robot 4 GBP / USD	111	61	0.5%	2%	10%
Robot 5 GBP / USD	281	187	1%	6%	31%
Robot 1 USD / JPY	46	23	1%	2%	12%
Robot 2 USD / JPY	43	25	0.8%	2%	39%
Robot 3 USD / JPY	37	28	0.4%	1.9%	32%
Robot 4 USD / JPY	101	79	1%	1.3%	35%
Robot 5 USD / JPY	151	102	0.7%	2%	52%

Table 4-7 Forward test

5. Evaluating the Effectiveness and Sensitivity of Trading Robots

According to Yao (2000), a profitable forex trading robot should be able to deal with a large number of data. These data can be divided into three categories: training data, confirming data and experiment data. Yao (2000) believe that training data should occupy a 70% weight in the total data, set which includes data selection. Confirming data and experiment data comprise 20% and 10% of the total data set, respectively. This theory is based on Yao (2000)'s experience and it has already become a common regulation. With this knowledge, if the error of one robot is the lowest compared with the other trading robots, this software can be considered the best. When a best trained trading robot gets the best experiment result, this trading robot can be considered suitable for future forecasting. Yao (2000) indicates that the best experiment should separate data collection from time frame. In other words, the backward test can launch as trading robot training, the validation can be formed as a forward test, and the testing process can be launched in the period of the newest time frame. The purpose of this evaluation method is to determine the internal "structure" of the current market environment. Thus we can discover the "***relationship between present, past and future observations***". (Yao, 2000).

5.1. Measurement of trading robots

Normally, the measurement of trading robots is defined as evaluating and comparing the prediction capability of each robot, and this process was declared as normalized mean square error (NMSE) by Yao (2000). He indicates that NMSE is "***used to evaluate entries into the Santa Fe Time Series Competition***." In this theory, parameter *P* is given as comprising pairs of targets that can be presented as X_k. Besides target value, the predicted values are also noted by Yao

(2000). This parameter is presented as $\tilde{X}_k$. The NMSE is presented by the division between MSE and its normalized value. This description can be presented as the following formula.

$$NMSE = \frac{\sum_{k\in P}(x_k - \hat{x}_k)^2}{\sum_{k\in P}(x_k - \bar{x}_k)^2} = \frac{1}{\sigma_P^2}\frac{1}{N}\sum_{k\in P}(x_k - \hat{x}_k)^2,$$

In the above formula, 6^2 presents the estimated variance of historical data, x_k presents the average value, and *N* presents the amount of a series of *P*. When traders predict the market environment using the average value of historical data, the value NMSE can be calculated as 1.0. The NMSE is communicated to R_2. This is the relation measurement between predict values pairs and the expected calculation, which is presented as NMSE = 1 – R_2. The above formula includes additional measurements of calculation between the actual value by correcting the generated and predicted content. The values include x_k andx_k. These two elements are assigned for testing configuration and the change of direction. The related expression can be presented as below.

$$S_{\text{stat}} = \frac{1}{N}\sum_{k\in P} a_k,$$

The above calculation can be transacted as the expression below.

$$D_{\text{stat}} = \frac{1}{N}\sum_{k\in P} b_k,$$

These data are acceptable, because the NMSE only measures the prediction level. Thus, traders always use R_2 to measure the forecast quality. As a result, the correctness of gradient can be presented as D_{start}. The backward test measurement can be presented as in the following tables.

Trading strategies applied	Test NMSE (R2)	Return	Gradient

in currency pairs			
Robot 1 AUD / USD	0.0562 (1.0102)	11%	77.45%
Robot 2 AUD / USD	0.0621 (1.0121)	9%	75.55%
Robot 3 AUD / USD	0.0571 (1.0151)	21%	73.21%
Robot 4 AUD / USD	0.0554 (1.0274)	13%	76.43%
Robot 5 AUD / USD	0.0479 (1.0185)	12%	77.32%
Robot 1 NZD / USD	0.0618 (0.7991)	-9%	51.75%
Robot 2 NZD / USD	0.0533 (0.8211)	12%	53.56%
Robot 3 NZD / USD	0.0624 (0.8076)	5%	57.23%
Robot 4 NZD / USD	0.0659 (0.8122)	13%	51.86%
Robot 5 NZD / USD	0.0553 (0.8111)	10%	60.53%
Robot 1 EUR / USD	0.1219 (1.3312)	9%	69.29%
Robot 2 EUR / USD	0.1125 (1.2988)	31%	68.97%
Robot 3 EUR / USD	0.1178 (1.3321)	13%	67.91%
Robot 4 EUR / USD	0.1211 (1.3219)	22%	68.40%
Robot 5 EUR / USD	0.1198 (1.3222)	6%	67.31%
Robot 1 GBP / USD	0.1311 (1.4921)	-1%	77.23%
Robot 2 GBP / USD	0.1321 (1.5212)	-10%	71.29%
Robot 3 GBP / USD	0.1398 (1.5123)	13%	73.81%
Robot 4 GBP / USD	0.1299 (1.5411)	-15%	76.13%
Robot 5 GBP / USD	0.1291(1.5121)	7%	70.90%
Robot 1 USD / JPY	0.1101 (0.7922)	38%	33.59%
Robot 2 USD / JPY	0.1191 (0.8211)	19%	39.42%
Robot 3 USD / JPY	0.1129 (0.8321)	-12%	33.76%
Robot 4 USD / JPY	0.1211 (0.8411)	-9%	31.21%
Robot 5 USD / JPY	0.1198 (0.8512)	-2%	35.64%

Table 5-1 Back test measurement

The forward test measurement can be presented as in the following tables.

Trading strategies applied in currency pairs	Test NMSE (R2)	Return	Gradient
Robot 1 AUD / USD	0.0562 (1.0102)	7%	70.15%
Robot 2 AUD / USD	0.0621 (1.0121)	12%	65.15%
Robot 3 AUD / USD	0.0571 (1.0151)	8%	67.21%
Robot 4 AUD / USD	0.0554 (1.0274)	19%	58.53%
Robot 5 AUD / USD	0.0479 (1.0185)	21%	72.55%
Robot 1 NZD / USD	0.0618 (0.7991)	19%	50.67%
Robot 2 NZD / USD	0.0533 (0.8211)	22%	52.96%
Robot 3 NZD / USD	0.0624 (0.8076)	15%	58.37%
Robot 4 NZD / USD	0.0659 (0.8122)	23%	52.34%
Robot 5 NZD / USD	0.0553 (0.8111)	45%	60.53%
Robot 1 EUR / USD	0.1219 (1.3312)	8%	64.61%

Robot 2 EUR / USD	0.1125 (1.2988)	11%	68.75%
Robot 3 EUR / USD	0.1178 (1.3321)	11%	59.77%
Robot 4 EUR / USD	0.1211 (1.3219)	35%	64.98%
Robot 5 EUR / USD	0.1198 (1.3222)	56%	66.44%
Robot 1 GBP / USD	0.1311 (1.4921)	19%	76.49%
Robot 2 GBP / USD	0.1321 (1.5212)	24%	77.86%
Robot 3 GBP / USD	0.1398 (1.5123)	21%	75.19%
Robot 4 GBP / USD	0.1299 (1.5411)	12%	74.22%
Robot 5 GBP / USD	0.1291(1.5121)	89%	71.69%
Robot 1 USD / JPY	0.1101 (0.7922)	21%	34.22%
Robot 2 USD / JPY	0.1191 (0.8211)	19%	33.59%
Robot 3 USD / JPY	0.1129 (0.8321)	7%	35.62%
Robot 4 USD / JPY	0.1211 (0.8411)	10%	33.42%
Robot 5 USD / JPY	0.1198 (0.8512)	12%	39.21%

Table 5-2 Forward test measurement

The effectiveness of robot trading is the number of profit orders and the financial increase based on the forecasting outcome. Yao (2000) believes that the accuracy of the prediction or the value of the NMSE and gradient is not important for traders. After experiment results were gained from back and forward test, the simulations of real trading were created and possible profits were calculated. However, this process was not real forex robot trading; Yao (2000) defined this as "***paper profits***".

The calculation of the paper profit is based on the account increase percentage. In most MT4 trading robots, the initial deposit amount is programmed in the fund management. This deposit amount is called seed money. When the trading robot starts running, the seed money is used to purchase another currency by following the prediction. After the experiments, the profits should be transferred in the same currency as the seed money, and this transaction should be calculated by the current cross rate. These results can be shown as in the above two tables. The formula of paper profit calculation can be presented as below.

$$Return = \left(\frac{MoneyObatined}{SeedMoney}\right)^{52/w} - 1$$

In the above formula, the money obtained presents the final amount of the trading account after the experiments. The seed money is presenting the initial fund while robot trading is starting. And the *w* presents how many weeks the robot has been trading.

5.1.1. Involved indicators

"***Trading is an art***." (Yao, 2011). Babypips (2011) believes that no trading robot can be perfectly applied in every trading environment. To ensure a trading profit, the only method is selecting the "full" advantage of each indicator when they are applied in the current trading strategies. Therefore, the indicators filter has been designed to calculate the effect of each indicator. The theory of the indicators filter programme is simple: apply indicators to current forex trading one by one, and record each profit. The results of the indicators experiments can be analyzed for further trading robot design or current software improvement.

Indicator 1: Moving Average
    If fast line cross over slow line then long else short.
Indicator 2: MACD Crossover
    If MACD line cross over single line then long else short.
Indicator 3: AD Crossover
    If fast line cross over slow line then long else short.
Indicator 4: KD Crossover
    If fast KD cross over slow KD then long else short.
Indicator 5: RSI line
    If RSI great than 50 then long else short.
Indicator 6: SAR
    If SAR point under the current price then long else short.

In the above description, using the indicator of moving average trading in EUR / USD as a sample, if the example shows that the currency price is increasing and the initial account is

formed with US dollar, then the indicator is designed for the "long" action. If the robot issues the "down" signal and the currency price is going down, then the indicator is taking the "short" action Otherwise, the indicators filter will hold for the next signal.

The transaction cost has been considered in this evaluation. In this situation, 0.5 percentage transaction cost had been calculated by extra account decrease. Yao (2000) believes that a huge fund forex trading with no more than 0.5% transaction cost can have an effect on the currency price, and thus could affect the final result of real trading. Under most forex dealers' services, the transaction costs are calculated in spread. Therefore, the calculation of spread is also considered in the effectiveness evaluation. The following table shows the effect of each indicator in forex robot trading.

Currency Pair	Indicators	Profit Rate	Transaction Cost	Return
EUR / USD	Moving Average	8%	0.2%	12%
EUR / USD	MACD Crossover	11%	0.4%	22%
EUR / USD	KD Crossover	13%	0.3%	11%
EUR / USD	AD Crossover	9%	0.3%	24%
EUR / USD	RSI line	7%	0.4%	31%
EUR / USD	SAR	10%	0.1%	30%
GBP / USD	Moving Average	12%	0.4%	11%
GBP / USD	MACD Crossover	22%	0.2%	24%
GBP / USD	KD Crossover	27%	0.5%	13%
GBP / USD	AD Crossover	19%	0.4%	26%
GBP / USD	RSI line	21%	0.2%	33%
GBP / USD	SAR	10%	0.1%	29%
AUD / USD	Moving Average	12%	0.2%	11%
AUD / USD	MACD Crossover	9%	0.2%	9%
AUD / USD	KD Crossover	15%	0.3%	7%
AUD / USD	AD Crossover	17%	0.3%	11%
AUD / USD	RSI line	16%	0.3%	19%
AUD / USD	SAR	14%	0.1%	15%
NZD / USD	Moving Average	11%	0.1%	11%
NZD / USD	MACD Crossover	12%	0.2%	13%
NZD / USD	KD Crossover	8%	0.1%	17%

NZD / USD	AD Crossover	12%	0.4%	7%
NZD / USD	RSI line	23%	0.2%	9%
NZD / USD	SAR	22%	0.2%	12%
USD / JPY	Moving Average	11%	0.3%	8%
USD / JPY	MACD Crossover	9%	0.2%	7%
USD / JPY	KD Crossover	10%	0.1%	14%
USD / JPY	AD Crossover	7%	0.4%	22%
USD / JPY	RSI line	13%	0.1%	21%
USD / JPY	SAR	15%	0.1%	19%

Table 5-3 Indicators evaluation

Yao (2000) states that the criteria can determine market movement by testing the indicators filter. The above table provides the criteria of profit percentage. By checking the account changes, we can determine the movement of the current currency price. The outcome of the six different indicators depends on the testing, which can follow the example of the EUR / USD experiments. The traders outline the six different indicators. According to the test, the profit return can be increased by 12% annually by using the moving average; the annual return can be achieved at 22% by using MACD; the annual return can be achieved at 11% by using KD; the annual return can be achieved at 24% by using AD; the annual return can be achieved at 31% by using RSI line; and the annual return can be achieved at 30% by using SAR. Therefore, in theory, the RSI is the best choice for the currency of EUR / USD, because there is a high return from the indicators filter experiments. At the same time, the transaction cost should be considered in real trading, and thus the indicator of SAR which has a 0.1% spread fee with a 30% return should be a good choice as well.

5.1.2. Evaluation process

Basically, there are two experiments that generate effective evaluation. First, this research created a back test model to capture the relationship between the historical data and the future movement forecast of the trading robot. The back experiment is the simplest technical

test method. The MetaTrader 4 downloads the historical data and simulates the real market movement. The trading robot can follow the simulation and forecast the past market environment, and thus can derivate the performance. In this research, five trading robots are applied in trading currency EUR, GBP, AUD, NZD and JPY. Thus, the output of those experiments is fund return. In those experiments, up to 240 days of back test historical data have been used. The result indicates that there is no apparent change of the NMSE, although five robots have been inputted into the evaluation model. Sometimes the outputs are worse than before, which means that the amount of the trading account could be decreased. This indicates that the improvement of the trading robots may not have a positive effect. A reason mentioned in the last chapter is that the low modeling quality may decrease the success rate of robot trading. In the case of the worse performance trading robots, too many parameter inputs may cause too much noise in the experiment. Only after improving the parameter input can the best result be considered as paper profit.

The back test experiment can generate different prediction results, which are based on the modeling quality, and thus the forward test becomes more important and accurate. During the chart review under the back test window, potential noise can be found by traders, which can assist in fixing parameters and improve the performance of robots.

The trend can be divided into three levels: primary time frame, mainly trend frame and minor time frame. This theory is developed by Charles Dow, who indicates that trends can be likened to waves of the sea. In his idea, the moving average is the most important indicator for smoothing out the current price chart and issuing the general direction of the market movement. Thus, he always uses the moving average to determine the major trend. However,

this method has some disadvantages, because the moving average line drawing is always behind the current movement, and there must be some delay. Dow estimates that the major trend always persists more than one year, and the intermediate trend can persist more than three months. Yao (2000) believes that the secondary time frame is meaningless in itself, but a connection of three intermediate trends can confirm the major trend and fix the possible trend reversal of a major trend. The minor time frame is usually used to set the entry point. Under this time frame, the major trend can be ignored by traders. The robot can select possible trading opportunities for placing orders that have the same direction as the secondary trend. Dow's theory indicates that time frame is the most important parameter of trading strategies. In this paper, there are two robots that have been designed using multi time frames. Therefore, the factor of time frames is considered in effectiveness evaluation.

Finally, more evaluations have emerged in this research. Sensitivity evaluation is base on chart review, which compares the difference between the chart symbol and the trading signal. The improvement can generate the best trading strategy for the current market environment.

5.2. Prediction results and discussion

The prediction results discussion includes effectiveness and sensitivity evaluation. The effectiveness evaluation mainly focuses on the performance of each trading robot, and the sensitivity evaluation concentrates on noise improvement.

5.2.1. Discussion on effectiveness

The measurement of effectiveness evaluation is show in Table 5-1 and Table 5-2. Table 5-3 presents the back test performance for each trading robot. These experiments are applied in

five different currency pairs. Those financial products are AUD / USD, NZD / USD, EUR / USD, GBP / USD, and JPY / USD. The historical data were selected from 1st March to 1st October.

From the results of Table 5-1, the research finds that the NMSE level is suitable for each trading application. However, the gradients show that all programs that are applied in JPY / USD market are lower than 50%, which means the prediction is worse than the chances that are provided in other financial products. No doubt that performance can be accepted for back test. Thus, the fund return should be generated and is required for depth evaluation. In the diagram of Table 5-1, some of trading robot performances are not good, because the value of fund return is negative. This means the system always fails the trading in the period of 240 days.

As shown in Table 5-2, the NMSE level is also suitable for each trading robot. As in Table 5-1, the gradients value indicates that all the programs that are applied in JPY / USD currency are lower than 50%, which also means the prediction is worse than the chances which are provided in other financial products. In the fund return section, all trading robots get positive results, which means the software performance can be accepted. in particular, two trading robots have gained much higher results in fund return. The details of those two robots are presented in the following table.

Currency	Trading robots	Time frame for trend	Fund return
AUD / USD	The cowabunga system	Major, Intermediate, minor	19%
AUD / USD	The Dolpin system	Major, minor	21%
NZD / USD	The cowabunga system	Major, Intermediate, minor	13%
NZD / USD	The Dolpin system	Major, minor	10%
EUR / USD	The cowabunga system	Major, Intermediate, minor	22%
EUR / USD	The Dolpin system	Major, minor	6%

GBP / USD	The cowabunga system	Major, Intermediate, minor	-15%
GBP / USD	The Dolpin system	Major, minor	7%
USD / JPY	The cowabunga system	Major, Intermediate, minor	-9%
USD / JPY	The Dolpin system	Major, minor	-2%

Table 5-4 Evaluation discussion

The above table shows that time frame can take more profit in forex trading, because the lower trend time frame can confirm the major trend and fix the possible trend reversal of the major trend. Table 5-3 shows the effect of each indicator. Those technical indicators are internal parameters of each trading strategy, which means they can directly affect the performance of the trading robot. The table indicates that indicator SAR can take a stable profit, especially running in the large time frame.

5.2.2. Discussion on Sensitivity

The sensitivity evaluation is worked as a chart review, which results in a comparison between the trading signal and the real market direction. Therefore, the result of the experiment cannot be presented as value. The result of the sensitivity experiment is presented below.

Currency	Trading robots	Total number of signal	Noise
EUR / USD	Robot 1	173	34
EUR / USD	Robot 2	129	41
EUR / USD	Robot 3	191	87
EUR / USD	Robot 4	720	187
EUR / USD	Robot 5	2016	612
GBP / USD	Robot 1	298	101
GBP / USD	Robot 2	231	106
GBP / USD	Robot 3	312	102
GBP / USD	Robot 4	871	331
GBP / USD	Robot 5	4194	1991
AUD / USD	Robot 1	179	62
AUD / USD	Robot 2	156	61
AUD / USD	Robot 3	213	79

AUD / USD	Robot 4	450	191
AUD / USD	Robot 5	1301	511
NZD / USD	Robot 1	163	79
NZD / USD	Robot 2	135	44
NZD / USD	Robot 3	297	112
NZD / USD	Robot 4	643	219
NZD / USD	Robot 5	1832	612
USD / JPY	Robot 1	119	56
USD / JPY	Robot 2	191	98
USD / JPY	Robot 3	132	68
USD / JPY	Robot 4	375	166
USD / JPY	Robot 5	971	522

Table 5-5 Sensitivity experiment

The above table shows the relationship between the total number of orders and noises. In theory, the total numbers of orders depends on the sensitivity of the forex trading robots. The higher the sensitivity of the robot, the higher the number of transactions that will be generated. However, too frequent trading will make more false entry signals, and thus will decrease the success rate, and consequently the number of profit orders. Furthermore, the features of the currency pairs will affect the sensitivity of the trading robots. Babypips (2011) believes that greater market volatility can bring more trading opportunities, improve the trading success rate and thus increase the account. In this research, an experiment has been set up for evaluating the relationship between market volatility and total profit. The following table presents the effect of currency features.

Day volatility of currency	Trading robots	Trading Opportunities For each week	Noise Rate
Approximately 30 – 50 pips	Robot 1	15	81%
Approximately 50 – 80 pips	Robot 1	19	55%
Approximately 80 - 100 pips	Robot 1	22	32%
Approximately 100 -150 pips	Robot 1	27	21%
Above 150 pips	Robot 1	33	7%
Approximately 30 – 50 pips	Robot 2	9	76%
Approximately 50 – 80 pips	Robot 2	11	45%

Approximately 80 - 100 pips	Robot 2	17	30%
Approximately 100 -150 pips	Robot 2	19	12%
Above 150 pips	Robot 2	27	9%
Approximately 30 – 50 pips	Robot 3	7	79%
Approximately 50 – 80 pips	Robot 3	11	43%
Approximately 80 - 100 pips	Robot 3	19	39%
Approximately 100 -150 pips	Robot 3	16	23%
Above 150 pips	Robot 3	22	11%
Approximately 30 – 50 pips	Robot 4	6	65%
Approximately 50 – 80 pips	Robot 4	8	55%
Approximately 80 - 100 pips	Robot 4	11	39%
Approximately 100 -150 pips	Robot 4	12	21%
Above 150 pips	Robot 4	17	6%
Approximately 30 – 50 pips	Robot 5	22	61%
Approximately 50 – 80 pips	Robot 5	31	32%
Approximately 80 - 100 pips	Robot 5	37	29%
Approximately 100 -150 pips	Robot 5	48	17%
Above 150 pips	Robot 5	69	16%

Table 5-6 Effect of Market volatility

The above table indicates that higher market volatility can improve the trading results. According to the experiments, this research indicates that the best trading session is the London time frame, which can provide up to 150 pips of daily volatility. The currency pair of GBP / USD is the best product for robot trading, since it has the highest volatility in each trading day.

To increase the sensitivity of the trading robot, two methods can be applied to software development. Selecting the appropriate parameters can effectively increase trading opportunities. The following table shows an example on how to increase the number of orders in a specific period by changing the parameter moving average crossover strategy.

Parameter of fast average	Parameter of slow average	Trading opportunities in a week by using 1 hour time frame
25	50	15

5	50	22
5	10	36

Table 5-7 Effect of parameters modification

From the above chart, it can be seen that decreasing the value of each parameter can effectively increase the number of transactions, and thus improve the sensitivity of trading robots. However, the success rate may be reduced by noise increases.

Another method is entry delay, which is using a set of time to confirm the trend and then placing the order. To apply this concept to real trading, the moving average crossover has also been set into the test. In this experiment, I selected 90 days historical data for the backward test, the moving average crossover was added into the MT4 terminal for chart review. The results are shown in the following table.

Currency Pairs	Trading immediately (Noise Rate)	Delay 1 candle stick (Noise Rate)	Delay 2 candle stick (Noise Rate)
EUR / USD	21%	20%	17%
GBP / USD	12%	15%	16%
AUD / USD	33%	28%	29%
NZD / USD	35%	22%	26%
USD / JPY	44%	31%	38%

Table 5-8 Effect of entry delay

The above table shows that entry delay can have positive effects on robot trading. However, the experiment result indicates that an overlong waiting time could also reduce the success rate, because the trading robot misses the opportunity and places orders at the end of the trend. Therefore, the best way to improve both the effectiveness and sensitivity of a trading robot is to choose a trading session that has higher market volatility.

5.3. The relationship between effectiveness and sensitivity

Yao (2000) indicates that the effectiveness and sensitivity of robot trading are both interrelated and contradictory. The effectiveness of robot trading is the number of profit orders and financial increase based on the forecasting outcome. The sensitivity evaluation is worked as a chart review, from which the result is the comparison between the trading signals and real market directions. Over sensitive trading robots can take more trading opportunities, but they also can reduce the performance, and thus affect the trading profitability.

5.3.1. Interrelation

A more sensitive trading robot can take more chances in trading. In most market environments, a higher fund return can be generated by many orders in a specific period. The following example shows the interrelation between effectiveness and sensitivity.

Trading opportunities in a week by using a 1-hour time frame	Return
15	12%
22	14%
36	23%

Table 5-9 Interrelation analysis

The above table shows that trading opportunities are increased by changing parameters. According to the experiment, narrowing the parameter setting will increase the sensitivity of the moving average crossover. Following improved transaction volumes, more and more profits are injected into the trading account, and also some noise is generated by the wrong trend direction. In total, the fund return is increased because of huge market volatility. On the other hand, decreasing the sensitivity of trading strategy could lose potential trading opportunities and thus affect the performance of the software.

5.3.2. Contradiction

The contradiction between effectiveness and sensitivity is based on the value of noise. A huge number of noises will have a negative effect on the robot performance, and a lower fund return could be issued. Furthermore, too many transactions will take more spread fees, which will hit the trader's account frequently. The following table presents the contradiction between effectiveness and sensitivity.

Trading opportunities in a week by using a 1-hour time frame	Noises
15	2
22	3
36	6

Table 5-10 Contradictory analysis

The above table shows that too many orders were placed by narrowing down the parameter setting. The experiment shows that increasing the sensitivity of the moving average crossover will cause more noises, and many of them will be opposite to the current market trend in the side ways market environment. In total, the trading account will decrease because of low market volatility. Besides that, too many transaction fees are caused by those noises. The performance of the trading robot will drop, and the contradiction between effectiveness and sensitivity is confirmed.

6. Approach for Improving Trading Robots

During evaluation, the relationship between effectiveness and sensitivity becomes clear. Yao (2000) states that there is no perfect forecast model that can be found in real trading. Since there are too many unpredictable market environments that can affect the performance of trading robots, the improved trading robot should catch all the trends found in past trading. In the evaluation section, this paper discovered several factors that can affect the performance of trading robots. These factors can have both negative and positive effects. The details of those factors are presented in the following table.

Factors	Positive effect	Negative effect	Advantage	Disadvantage
Entry delay	15%	14%	Entry delay can have positive effects in robot trading. It reduces noise and can cause the successful trading to continue.	Too much time spent waiting could also reduce the success rate, because the trading robot misses the opportunity and places the order at the end of the trend.
Change indicators	32%	20%	The RSI is the best choice for the currency of EUR / USD, because there is a higher return from indicator filter experiments. The indicator of SAR that has a 0.1% spread fee with 30% return should be a good choice as well.	The market environment can affect the performance of each indicator. That means the performance is not stable under different market environments. In particular, trading may fail when important economic data is issued.
Modify parameters	22%	16%	Select appropriate parameters that can effectively increase trading opportunities, thus improving the sensitivity of trading robots.	The performance of robot trading could decrease by increasing the number of noises.

Using time frame	35%	15%	A connection of three intermediate trends can confirm the major trend and fix the possible trend reversal of the major trend. The minor time frame is usually used to set an entry point. Time frame can be a filter to avoid possible noises and thus improve the performance.	In robot programming, a higher time frame indicator could cause much time delay. That means the reversal of the trend could be delayed and thus missed in real trading. This will have a negative effect in forex robot trading.
Choice the best trading session	42%	7%	Higher market volatility can improve trading results. Robot trading in GBP / USD within the London session can take higher profits.	The publishing of important economic data and banking information could cause some trading failures, which could cause huge market volatilities.

Table 6-1 Factors that can influence the robot trading

The above table presents factors that can affect trading robot performance. Among them, the entry delay can be ignored for improving robot design, since it has a similar percentage of positive and negative effects. Therefore, the new program considers four elements that can take advantages in real trading. They are indicators modified, parameters modified, time frame selection and trading session selection.

6.1. Change indicators

In this research, the dolphin system results in the highest performance compared with the others. The principles of trend determination are based on the technical indicators of MA (26) and MACD (5, 34, 5). When the price is greater than MA (26) and the MACD value is larger than the signal, and the current trend can be considered as bullish. In the case of the price being lower than MA (26) and the MACD value larger than the signal, the primary trend can be

determined as bullish too. If the price is greater than MA (26) and the MACD value smaller than the signal, the trend is bearish. While the price is smaller than MA (26) and the MACD value larger than the signal, the current trend can be considered as bearish as well.

The above description is complex and it causes much delay when the robot is focusing on the next time frame. In the experiments, many noises were found while the trend was in reverse. Because of the nature of MACD, internal entry delays are unavoidable, nor are the parameters modifiable. The only solution is changing indicators. In this paper, the indicator of Heiken Ashi is recommended to replace the MACD. The MQL4 script is presented as below.

```
Current = iTime(NULL ,  0 ,  pos);
    mainPos = iBarShift(NULL,  mframe , current , true);
    mainTime = iTime(NULL , mframe , mainPos);
    mPos = iBarShift(NULL , 0 , mainTime , true);
    mCount = mPos-pos;

    if(mCount <= 0)
    {
      Mopen = Open[pos];
      Mclose = Open[pos];
      Mhigh = Open[pos];
      Mlow = Open[pos];
      mhaOpen = (tempopne + tempclose) / 2;
    }
    else{
      mopen = iOpen(0 , mframe , mainPos);
      mclose = Close[pos+1];
      mhigh = High[iHighest(NULL , 0 , MODE_HIGH , mCount , pos+1)];
      mlow = Low[iLowest(NULL , 0 , MODE_LOW , mCount , pos+1)];
    }

    mhaClose = (mopen + mhigh + mlow + mclose) / 4;
    mhaHigh = MathMax(mhigh , MathMax(mhaOpen , mhaClose));
    mhaLow = MathMin(mlow , MathMin(mhaOpen , mhaClose));

    tempopne = mhaOpen;
    tempclose = mhaClose;
```

```
    currentPos = iBarShift(NULL , cframe , current , true);
    currentTime = iTime(NULL , cframe , currentPos);
    cPos = iBarShift(NULL , 0 , currentTime , true);
    cCount = cPos - pos;
    if(cCount <= 0)
    {
      Copen = Open[pos];
      Cclose = Open[pos];
      Chigh = Open[pos];
      Clow = Open[pos];
      chaOpen = (tempcopen + tempcclose) / 2;
    }
    else{
      copen = iOpen(0 , cframe , currentPos);
      cclose = Close[pos+1];
      chigh = High[iHighest(NULL , 0 , MODE_HIGH , cCount , pos+1)];
      clow = Low[iLowest(NULL , 0 , MODE_LOW , cCount , pos+1)];
    }
    chaClose = (copen + chigh + clow + cclose)/4;
    chaHigh = MathMax( chigh , MathMax(chaOpen , chaClose));
    chaLow = MathMin(clow , MathMin(chaOpen , chaClose));

    tempcopen = chaOpen;
    tempcclose = chaClose;

    clma = iMA(NULL , cframe , 14 , 0 , MODE_SMA , PRICE_CLOSE , currentPos);
    upstopline = iEnvelopes(NULL , cframe , 14, MODE_SMA , 0 , PRICE_CLOSE , 0.38 ,
MODE_UPPER , currentPos);
    downstopline = iEnvelopes(NULL, cframe, 14, MODE_SMA, 0, PRICE_CLOSE, 0.38,
MODE_LOWER,currentPos);
    upline = iEnvelopes(NULL, cframe, 14, MODE_SMA , 0 , PRICE_CLOSE , 0.15 , MODE_UPPER ,
currentPos);
    downline = iEnvelopes(NULL , cframe , 14 , MODE_SMA , 0 , PRICE_CLOSE , 0.15 ,
MODE_LOWER , currentPos);

    maintrendline[pos] = mhaOpen;
    currenttrendline[pos] = chaOpen;
    currentlma[pos] = clma;
    upstop[pos] = upstopline;
    downstop[pos] = downstopline;
```

6.2. Session selection

The experiment results of this research show that the London session should be the best for robot trading. However, Babypips (2011) provides the concept of session overlaps, which is usually designed in programs so that it can assist traders in getting maximal profits. The session overlaps can be designed as the window for interacting with traders.

6.3. Parameter modification

The parameter selection is similar to the dolphin system. They are KD (8, 5, 5), MA (26, 52, 104, 360), Envelope (26 – 0.62%, 0.31%) and Time (M5 – M30 – 4H). The description can be presented as follows.

1. The formula of the dolphin system for the position size calculation is followed by :

   Comfort level = (account balance * 1% / fluctuation) * (lot size / pip value)
2. The regulation of entry point setting is based on the indicators of KD (8, 5, 5). The buy signal is generated when the current KD value crosses above the signal line. On the other hand, the short signal is generated by the dead cross of the KDs.
3. This trading system uses the golden channel as the profit determination. When the price hits the boundary of the golden channel, the transaction will be closed for taking profits. The related technical indicators of the golden channel are Envelope (26 – 0.62%, 0.31%).
4. The stop loss setting is special in this trading system. If the price continues to move more than 9 candles in the current chart, the trend will be ending. Therefore, traders should enforce the closure of the current trading after 9 candle sticks are finished.

The MQL4 script can be presented as below.

```
extern int distance = 10;
extern int mainframe = 240;
extern int currentframe = 30;
extern int entryframe = 5;
double maintrendline[];
double currenttrendline[];
double currentlma[];
double upstop[];
double downstop[];
double buy[];
double sell[];
filter = iMACD(NULL , 0 , 14 , 84 , 5 , PRICE_CLOSE , MODE_MAIN , pos+1);
    f_s = iMACD(NULL , 0 , 14 , 84 , 5 , PRICE_CLOSE , MODE_MAIN , pos+2);
    kd = iStochastic(NULL , 0 , 8 , 5 , 3 , MODE_SMA , 1 ,MODE_MAIN , pos);
    kdp = iStochastic(NULL , 0 , 8 , 5 , 3 , MODE_SMA , 1 , MODE_MAIN , pos+1);
    kd_s = iStochastic(NULL , 0 , 8 , 5 , 3 , MODE_SMA , 1 , MODE_SIGNAL , pos);
    kdp_s = iStochastic(NULL , 0 , 8 , 5 , 3 , MODE_SMA , 1 , MODE_SIGNAL , pos+1);
    if(kd > kd_s && kdp < kdp_s && Open[pos] < upline && Open[pos] > currenttrendline[pos]
     && Open[pos] > maintrendline[pos])
    {
      buy[pos] = line_bottom;
    }
    else if(kd < kd_s && kdp > kdp_s && Open[pos] > downline && Open[pos] <
currenttrendline[pos]
    &&Open[pos] < maintrendline[pos])
    {
      sell[pos] = line_top;
    }
    else if(Close[pos+1] < maintrendline[pos] && Open[pos+1] > maintrendline[pos] &&
Open[pos] < upline && Open[pos] > currenttrendline[pos]
    && Open[pos] > maintrendline[pos] && filter > f_s)
    {
      buy[pos] = line_bottom;
    }
    else if(Close[pos+1] > maintrendline[pos] && Open[pos+1] < maintrendline[pos] &&
Open[pos] > downline && Open[pos] < currenttrendline[pos]
    && Open[pos] < maintrendline[pos] && filter < f_s)
    {
      sell[pos] = line_top;
    }
    else if(Close[pos+1] < currenttrendline[pos] && Open[pos+1] >currenttrendline[pos] &&
Open[pos] > currenttrendline[pos]
    &&Open[pos] > maintrendline[pos] && filter > f_s)
    {
```

```
      buy[pos] = line_bottom;
    }
    else if(Close[pos+1] > currenttrendline[pos] && Open[pos+1] < currenttrendline[pos] &&
Open[pos] < currenttrendline[pos]
    &&Open[pos] < maintrendline[pos] && filter < f_s)
    {
      sell[pos] = line_top;
    }
```

6.4. Evaluation of the improved program

Yao (2000) believes a profitable forex trading robot should be able to deal with a large amount of data. In this improved program, the effectiveness of a trading robot is related to these data, which can be divided into three categories: training data, confirming data and experiment data. The previous experiment shows that training information should occupy a 70% weighting, and confirmation and experiment should be 20% and 10% respectively. If the error of one robot is the lowest compared with other trading robots, this software should be considered the best. When a best-trained trading robot gets the best experiment result, this trading robot can be considered suitable for future forecasting. Similar to the previous evaluation, two parameters are applied into the experiment. They are NMSE and gradient. The accuracy of the prediction or the value of the NMSE and gradient is not a matter for traders. After experiment results are gained from backward and forward tests, the simulations of real trading are created and possible profits are calculated. The test results are shown in the following table.

Trading strategies	Low modeling quality	Account statues	High modeling quality	Account statues
Robot 1 AUD / USD	24%	-73%	99%	2%
Robot 2 AUD / USD	45%	-64%	99%	12%
Robot 3 AUD / USD	43%	-23%	99%	31%
Robot 4 AUD / USD	65%	-10%	99%	6%

Robot 5 AUD / USD	28%	5%	99%	12%
Robot 6 AUD / USD	34%	6%	99%	23%
Robot 1 NZD / USD	25%	-43%	99%	71%
Robot 2 NZD / USD	65%	-34%	99%	56%
Robot 3 NZD / USD	78%	-22%	99%	21%
Robot 4 NZD / USD	20%	-6%	99%	23%
Robot 5 NZD / USD	76%	12%	99%	10%
Robot 6 NZD / USD	33%	7%	99%	17%
Robot 1 EUR / USD	85%	-89%	99%	-12%
Robot 2 EUR / USD	23%	-68%	99%	56%
Robot 3 EUR / USD	65%	-39%	99%	21%
Robot 4 EUR / USD	47%	-12%	99%	-5%
Robot 5 EUR / USD	47%	-32%	99%	11%
Robot 6 EUR / USD	54%	4%	99%	51%
Robot 1 GBP / USD	86%	-67%	99%	-34%
Robot 2 GBP / USD	91%	-71%	99%	-5%
Robot 3 GBP / USD	16%	-45%	99%	27%
Robot 4 GBP / USD	36%	-37%	99%	20%
Robot 5 GBP / USD	28%	-23%	99%	19%
Robot 6 GBP / USD	61%	11%	99%	21%
Robot 1 USD / JPY	54%	-35%	99%	-3%
Robot 2 USD / JPY	68%	-56%	99%	7%
Robot 3 USD / JPY	34%	-12%	99%	6%
Robot 4 USD / JPY	65%	23%	99%	15%
Robot 5 USD / JPY	38%	19%	99%	22%
Robot 6 USD / JPY	49%	8%	99%	11%

Table 6-2 Backward test for an improved robot

According to the evaluation formula, the NMSE and gradient value are calculated as follows.

Trading strategies applied in currency pairs	Test NMSE (R2)	Return	Gradient
Robot 1 AUD / USD	0.0562 (1.0102)	11%	77.45%
Robot 2 AUD / USD	0.0621 (1.0121)	9%	75.55%
Robot 3 AUD / USD	0.0571 (1.0151)	21%	73.21%
Robot 4 AUD / USD	0.0554 (1.0274)	13%	76.43%
Robot 5 AUD / USD	0.0479 (1.0185)	12%	77.32%
Robot 6 AUD / USD	0.0512 (1.0122)	14%	71.45%
Robot 1 NZD / USD	0.0618 (0.7991)	-9%	51.75%
Robot 2 NZD / USD	0.0533 (0.8211)	12%	53.56%
Robot 3 NZD / USD	0.0624 (0.8076)	5%	57.23%
Robot 4 NZD / USD	0.0659 (0.8122)	13%	51.86%
Robot 5 NZD / USD	0.0553 (0.8111)	10%	60.53%

Robot 6 NZD / USD	0.0593 (0.8201)	14%	56.34%
Robot 1 EUR / USD	0.1219 (1.3312)	9%	69.29%
Robot 2 EUR / USD	0.1125 (1.2988)	31%	68.97%
Robot 3 EUR / USD	0.1178 (1.3321)	13%	67.91%
Robot 4 EUR / USD	0.1211 (1.3219)	22%	68.40%
Robot 5 EUR / USD	0.1198 (1.3222)	6%	67.31%
Robot 6 EUR / USD	0.1213 (1.3231)	15%	71.32%
Robot 1 GBP / USD	0.1311 (1.4921)	-1%	77.23%
Robot 2 GBP / USD	0.1321 (1.5212)	-10%	71.29%
Robot 3 GBP / USD	0.1398 (1.5123)	13%	73.81%
Robot 4 GBP / USD	0.1299 (1.5411)	-15%	76.13%
Robot 5 GBP / USD	0.1291(1.5121)	7%	70.90%
Robot 6 GBP / USD	0.1233 (1.4912)	11%	72.43%
Robot 1 USD / JPY	0.1101 (0.7922)	38%	33.59%
Robot 2 USD / JPY	0.1191 (0.8211)	19%	39.42%
Robot 3 USD / JPY	0.1129 (0.8321)	-12%	33.76%
Robot 4 USD / JPY	0.1211 (0.8411)	-9%	31.21%
Robot 5 USD / JPY	0.1198 (0.8512)	-2%	35.64%
Robot 6 USD / JPY	0.1219 (0.8322)	2%	37.45%

Table 6-3 Effectiveness evaluation for an improved robot

The above table presents the backward test result for each trading robot. I measured five different currency pairs in this experiment. Those investment products are AUD / USD, NZD / USD, EUR / USD, GBP / USD, and JPY / USD. I selected the historical data in a time series, which is within the range of 1st October to 1st February. After testing, the experiment result shows that the value of NMSE is acceptable for each trading robot evaluation. However, the value of the gradient is lower than 50% in the JPY / USD currency experiment, which means the improved robot forecast is not acceptable in JPY / USD trading. In the tests for other currency pairs, the improved software has made better results. The backward test results indicate that the improved program is acceptable in most market environments. Compared to other trading robots, the new robot can generate greater fund returns. Therefore, the improvement is successful and the new software can take more profits in future trading.

7. Conclusion and Future Work

From the evaluation, this research has drawn the following conclusions:

1. In this research, robot designers are recommended to pay close attention to time frame setting, as this could improve the forecasting performance by 35%, as shown in my experiments. This recommendation can be applied in most forex forecasting, except USD / JPY. Because the gradient is lower than 50% in the JPY / USD experiment, the robot forecast is not acceptable in JPY / USD trading. In the experiments for other currencies, in order to get better prediction results, trading robot designers should consider five factors, viz., entry delay, indicator modification, parameter modification, time frame setting and trading session selection. Among them, trading session selection is the most beneficial. According to the experiment results, higher market volatility can improve trading results. To get higher market volatility, selecting appropriate trading sessions can help traders to avoid side-ways market environments and filter out potential trends.
2. I have applied the random walk hypothesis and the efficient market hypothesis in the pre experiment section. The random walk hypothesis presents currencies moves randomly, and the markets' directions are uncertain. The efficient market hypothesis is referring to market reflection, which can hold all possible opportunities and fully reflect the latest information. Both hypotheses can be presented as Hurst exponent (H). In financial markets, the application of H exponent can output three cases. In the case of H = 0.5, the evaluation over the random data set cannot be considered as Gaussian random walk. In the case of $0 \leq H < 0.5$, the market movement may be opposite to the

current direction in the future. In the case of $0.5 < H < 1$, the current trend will continue. The trend strength depends on the deviation between Hurst exponent value and 0.5. In the pre-experiment phase, I have tested the Hurst exponent value for all five currency pairs. The Hurst exponent value is always in the range of 0.5 to 1, which indicates they are suitable for sensitivity and effectiveness evaluation.

3. The performance measurement model is designed for analyzing trading robots' forecast ability, which is called as normalized mean square error (NMSE). Normally, traders should not be concerned with NMSE. Instead, the value of paper profits is more important, where the paper profit calculation is based on the percentage of the account increasing. During experiments, data segments of fund return indicate that a robot designed by complex indicators could obtain more profits.
4. The sensitivity analysis is based on chart reviews, which present the correlation between found trading signals and market trends. A greater market volatility can produce more trading opportunities and can also increase the trading success rate, thus increasing the account. Parameter selection increases trading opportunities, but it also reduces the success rate because of increased noise.
5. The effectiveness and sensitivity of robot trading is both interrelated and contradictory. Excessive sensitivity of trading robots makes more trading opportunities, but is also likely to reduce profit performance.

The above summaries conclude the overall discoveries of this research. However, there are some other issues that need to be addressed. It is expected that an automatic trading robot will

be developed that can reduce noise yet increase trading success rates. The requirements of future work are addressed and listed below.

1. Improved trading software should be able to work with any potential time frames. In this research, the indicator modification only focused on the major time frame instead of medium or minor time frames. The future work will cover more time frames.
2. In future work, more parameters will be involved in performance analysis, such as the relationship between modeling quality, paper profit, and transaction cost.
3. Future study should create a forward test for the improved trading robot. In this research, the test results show that the performance of each robot in the forward test is better than the one in the backward test. The reason is that the forward test can avoid some potential trading noises by selecting trading sessions. Therefore, the results of forward tests make more sense of the robots' performance.
4. As the gradient value is lower than 50%, this research has ignored all evaluation results related to Japanese currency. In the future, all experiment data should be analyzed in different time frames of the currency pair JPY / USD.

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Appendix

Candle Sticks

Babypips (2011) states that there are four basic candlesticks that can help traders determine the potential movement of the forex market. They are hammer, hanging man, inverted hammer and shooting star. The common point of the four graphs is a candle with a short body and a long shadow. The color of the body is decided by the direction of the future market. The difference is the direction of the shadow. In mql4 programming, the length of the body is usually not more than one third of the shadow. The basic candlesticks are displayed in the diagram below.

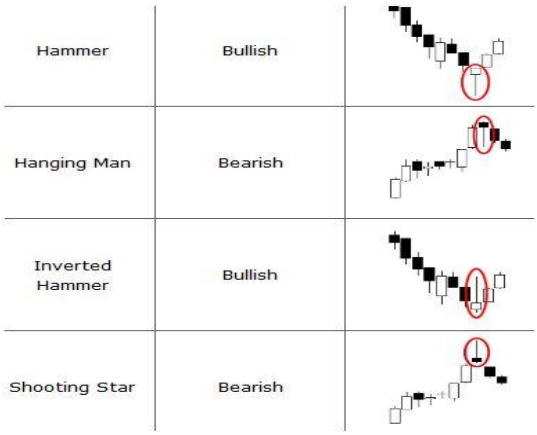

Figure 0-1 Basic candlesticks

Gerald (2008) believes that candlesticks can effectively assist traders to determine the future movement of the forex market, especially the changing of the trend. However, a single candle is too simple and could produce too many trading signals, which can cause traders to make mistakes when they are determining the market direction. Thus, Babypips (2011) proposes the

concept of candle patterns, which is a combination of patterns and composed of two or three candlesticks.

Compared with single candlesticks, the concept of double candlesticks is more complex. 'Engulfing' is composed of two candles of different sized bodies. Gerald (2008) defines bullish engulfing candles as the result of a down candle followed by a long up candle, which predicts that a potential bullish trend could occur. A bearish engulfing is opposite to a bullish engulfing, which is described as a short up candle followed by a long bearish candle. The engulfing candles are presented in the following diagrams.

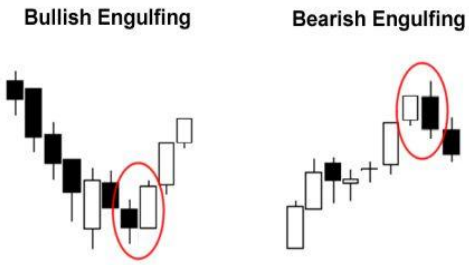

Figure 0-2 Bullish Engulfing and Bearish Engulfing

Another pattern of double candles was proposed by Babypips (2011), which is called Tweezer. Tweezer is presented by two reserved candles, whose body color shows that these two candles point in different directions. Gerald (2008) considers that the second candle could determine the future trend of the forex market. In Tweezer candles, the length of the shadow and body should be similar, but the body color should be different. The Tweezer candles are presented in the following diagram.

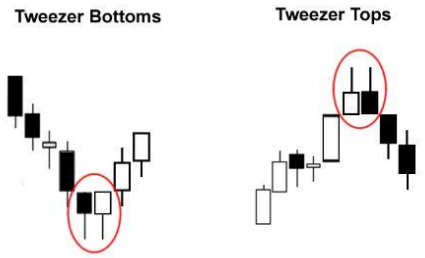

Figure 0-3 Tweezer Bottoms and Tweezer Tops

Triple candlesticks are more complex and difficult to distinguish, but Babypips (2011) considers that they would be more accurate than the previous two types of charts. Of course, a complex pattern will cause some delay when traders are determining the future movement of the forex market. This web tutorial states that triple candlesticks can be categorized as the below three types.

- Evening and Morning Stars
- Three White Soldiers and Black Crows
- Three Inside Up and Down

Bigalow (2011) believes the common point of evening and morning stars is that the first candle should be a continuation of the previous trend. It presents a long body to determine the strong previews trend. However, after second candle emerges, the situation indicates that there is an indecision factor in the current market, and the trend could change. Bigalow (2011) states that the second candle has a small body, but the direction could be either up or down. The third candle is the confirmation of the trend reversal, which must be completed beyond the middle point of the first candle. Evening and morning stars are presented in the following diagrams.

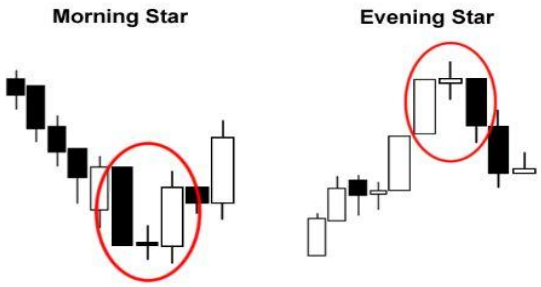

Figure 0-4 Morning Star and Evening Star

The concept of the three soldiers and crows was posted by Babypips (2011). It defines the first candle as a reversal candle, which indicates the end of the previous trend and that the following trend could have started. Usually, the second candle of the three white soldiers and black crows should be longer than the first candle's body, and the upper shadow of the second stick should be small or nonexistent. The third candle should be a confirmation of a new trend, which is the last candle of these triple patterns and is similar to the second stick. Compared with the evening and morning stars, the three soldiers and crows need more delays to confirm the next movement after the previews trend reversal, but Bigalow (2011) believes they are more accurate. The diagram of the three white soldiers and black crows is presented below.

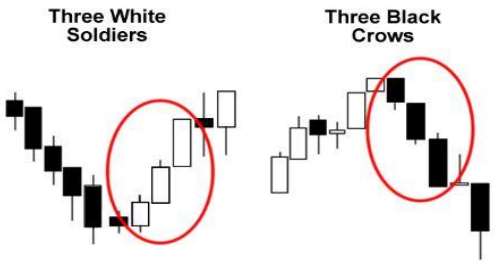

Figure 0-5 Three White Soldiers and Three Black Crows

Bigalow (2011) posted improved patterns, which were called three inside up and down. Similar to morning and evening stars, the first candle of this chart should be the end of the previous

trend. However, the second candle of three inside up and down should be started beyond the midpoint of the previous stick. The final candle is the confirmation of the new trend and should be completed above the opening of the first candle. The diagrams of three inside up and down are presented as below.

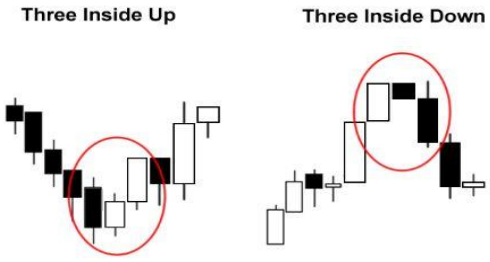

Figure 0-6 Three Inside Up and Three Inside Down

Due to the triple candle patterns being more complex and hard to categorize, it is necessary to distinguish their advantages and disadvantages when traders are determining the future market environment. Bigalow (2011) showed the concepts in the following table.

Name of triple candle chart	Advantage	Disadvantage
Evening and Morning Stars	Can determine the trend reversal as fast as possible.	It is too early to identify the trend reversal, and easy to make mistake in a sideways market environment.
Three White Soldiers and Black Crows	More accurate for trend reversal confirmation.	It is too late to identify the trend reversal, and thus it is easy to miss trading opportunities.
Three Inside Up and Down	Can determine the trend reversal efficiently in a short time period.	It is more complex, and easy to confuse with other candlestick patterns.

Table 0-1 Concepts of triple candle chart

Moving Average

Marta & Brusuelas (2009) believe the moving average has three basic features, which can effectively assist traders to determine the future price movement in the forex market. Firstly, the moving average can track the market trend because it aligns with the average price in each period, the resulting linear chart can express the basic trend. Secondly, compared with the forex market price, Babypips (2011) indicates that the moving average is more stable. Usually, the time periods decide the stable characteristics of the moving average. That means there is no volatility while the price trend is clearing. Finally, the moving average can help traders to set the support and resistance level for risk control. Archer (2008) believes that those support and resistance levels can be dynamic and can be easy to program in MQL4 scripts. In total, Bigalow (2011) indicates that moving averages have advantages and disadvantages in forex trading; the following table concludes the experience of using MAs.

Moving average features	Advantage	Disadvantage
Trend following	Compared with market price, the smoothness of moving average can help traders identify the current trend of forex market.	Because moving average was generated by the past prices, it only reflects the current or past market trends. Bigalow (2011) indicates that hysteresis of trend following by using moving average must be noticed by traders. Usually, the start of the trend is displayed by moving average, and the actual price is already going into reverse by the completion of the previous trend.
Stable	Bigalow (2011) believes that price always fluctuates along the moving averages. It provides a general idea to	Marta & Brusuelas (2009) believes that using moving average may lose many trading opportunities.

	traders to determine the floating space.	
Dynamic support and resistance	When the price is too far away from the moving average, it will be a better support and resistance to traders.	The price often crosses the moving average by changing the market environment.

Table 0-2 Moving average features

MACD

Moving Average Convergence / Divergence (MACD) is a dynamic index that follows the market trend. It is represented as a relationship between two moving averages. MACD indicator has three parameters. The first parameter presents the time period of the faster moving average, and the second presents the slower moving average's period number. The third parameter calculates the moving average of the gap between the previews two MAs. Normally, MACD indicates the difference between the 26 and 12 periods exponential moving average. In order to provide trading opportunities, the signal line is shown in an MACD chart.

Algorithm:

MACD = EMA (CLOSE, 12)-EMA (CLOSE, 26) SIGNAL = SMA (MACD, 9)

Parameters:

EMA — Simple moving average

SMA — Exponential moving average

SIGNAL — Signal line

RSI

The Relative Strength Index Technical Indicator (RSI) is a price-following oscillator that ranges between 0 and 100. When Wilder introduced the Relative Strength Index, he recommended using a 14-day RSI. Since then, the 9-day and 25-day RSI indicators have also gained popularity.

RSI is widely used in forex trading. It does not only assists traders determine the potential trend.

It also helps users distinguish the situation of oversold and overbought.

Algorithm

RSI = 100-(100 / (1+U / D))

Parameters:

U — is the average number of positive price changes;

D — is the average number of negative price changes.