PALACKÝ UNIVERSITY OLOMOUC

FACULTY OF ARTS

ALGORITHMIC TRADING STRATEGIES FOCUSSED ON CURRENCIES

Bachelor thesis

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Statement:

I hereby declare that I have elaborated my Bachelor Thesis on the topic: "Algorithmic trading strategies focussed on currencies" independently under the supervision of a bachelor thesis supervisor and I have listed all used materials and literature.

April 20 2019   Author's signature:

Acknowledgment

Content

Introduction:

From the beginning of time it is in very nature of men to keep finding a way how to facilitate unnecessarily complications and to pursue any designated goal. The financial markets are no exception, the allure of large potential profits bring more player into the game. Nowadays trading financial markets is more accessible than ever before which is gaining even greater public awareness and popularity. This trend has experienced an immersive grown and development thanks to the new tradable assets, which have been added to the market and the new technological improvements. For decades many people were trying to understand the true character of the financial markets and then monetize it, but in reality, they are more similar to untamed wilderness. Therefore various strategies and indicators were created to help identify the market's behavior and generate profit. Their purpose is to generate the biggest possible profits thought computer programs. The financial markets have the potential to adapt, that is why every day newly designed algorithms are being implemented. Outdated algorithms can prove insufficient on present day market. There exist many computer programs designed especially for backtesting algorithmic trading strategies, although these programs require enhanced knowledge in computer programing. In the order the strategy would prove to be adequate the user has to obtain usually very expensive historical data, for the precision of the whole process.

This thesis will implement the automated process of backtesting on much more available and publicly known program Microsoft Excel The strategies are going to be backtested on numerous types of indicators such as Stochastic oscillator, CMF indicator or ATR. The strategies are going to be backtested on time series of the length of one year. The performance of the chosen algorithmic trading strategies measured in Excel (in terms of total revenues/losses) will be compared in the respective time-period and overall and the buy and hold strategy will be used as a universal benchmark.

The first part of the research will discuss the FOREX exchange market. The paper will cover major currency pair FOREX and subchapters EUR vs UDS and UDS vs JPY. On the financial markets the most traded assets of all are currencies, traded primarily on the FOREX exchange market, representing the hottest traded topic on the market. The second part is

concluded by the best suitable times for trading. The second will explain algorithmic trading and it's advantages and disadvantages. The final part of will concern the implementation of algorithmic trading and the evaluation of results.

THEORETICAL PART

1 FOREX

The FOREX currency market is the largest investment market in the world. The FOREX (FX) exchange allows the possibility to trade almost any existing currency in the world, always trading one currency for another. On April 2010, the daily amount of traded capital in FX reached $4 trillion on the New York Stock Exchange (NYSE). A few years later the market has enlarged even more. In 2016 the amount of daily traded volume overstepped total $6.514 trillion and in April, 88% of executed trades were between the U.S. dollar and other currency pair. (K. Amadeo, 2018)

For finding arbitrage opportunities trading bots can be used as they scan the market. For example, these opportunities happen in situations when two trades are executed at the same time with one of them is for purchasing and the next for selling the same asset pair with different prices. For arbitrage exists because of the inefficiency the market, if the market would be perfectly efficient there would be no arbitrage. (T. Mancini-Griffoli, A. Ranaldo, 2011)

Trading pairs is determined as statistical arbitrage. It allows simultaneously to open both short and long position, taking advantage of irrelevant pricing in correlated securities. These instruments are naturally connected to one another or in some way they are influenced by each other. As for example the mutual relationship between Swiss franc and Gold. When a chart of the first asset moves the second moves the same way. The behavior of Swiss franc and Gold is very similar. (A. Pole, 2007)

As already mentioned, on Forex, the most traded are currencies. For trading also other categories, investors turn to Over the Counter Market (OTC). OTC represents every possibly tradable asset, it's a place where basically everything can be exchangeable. Traders invest their money into commodities, currencies, cryptocurrencies, stocks, bonds and plenty of others. There is no marketplace, with centrally fixed prices, meaning the execution of the trades is made online on a computer, phone or through other disposable devices. The markets

are spreaded all over the world and their current number is 82. The most essential ones would be for example the New York Stock Exchange (NYSE). Based in the City that never sleeps NYSE is the largest stock exchange of all the tracked OTCs. The first foundations for NYSE were drawn in March 1817 and shortly after the organization gained its official name: the New York Stock & Exchange Boar for physical trading stated NYSE in 1863. (New York Stock Exchange, NYSE Overview 2019) Next, there would be NASDAQ. Establish also in New York city, originally short for National Association of Securities Dealers Automated Quotations has a title of the first electronic stock market. Later, NASDAQ became the first market where automated trading and volume reporting was possible. For all listed times the NASDAQ uses the America/New York timezone. (NASDAQ Stock Exchange, NASDAQ Overview) Then there is The London Stock Exchange Group (LSE). It was created formally in 1801, experiencing problems in early years in 1812 a detailed document was constructed which became a trading bedrock. (London Stock Exchange, LSE Overview 2019) Trading assets is a bit different from Exchange markets Also what attracts traders is a fact that financial derivatives can be traded on the OTC too.

There are many players on the market, starting from individuals, people how to operate and execute trades for their own interests it can be work or hobby. Next, there are companies. They are always looking for a new way to invest but, for them the situation is a bit different, they do not only represent bulls and bears on the market, where bulls are standing for buyers and bears are representing sellers, but also their own stocks which are traded world wild. They contribute about 9 % of daily turnover. Then there are numerous organizations featuring on the market who represent multiple individuals or companies, other indispensable players on the market are banks. Banks are the biggest traders, representing 24% of daily turnover. The market is a very vast and complex place, therefore many countries have joined to global trading, they trade with multiple assets and they possess a lot of capital.

In trading there are basically only 3 options - buy, sell and hold. It is possible to make money even though the market stagnates. On the market, it is not important if the prices are going up, down or staying still, it is still possible to make a profit. It is possible to make money even though the market stagnates. Shorting a put option and a call option of an underlying asset at the same time is one of the possible ways of doing so (Figure 1.0). While trading, closing and opening time are crucial aspect to consider.
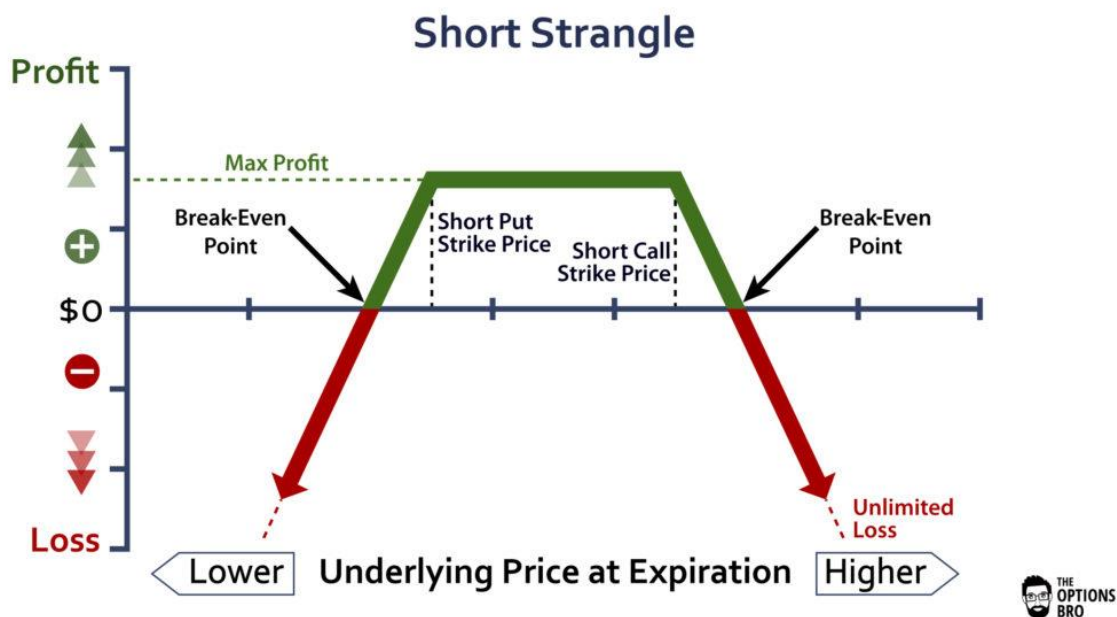
Figure 1.0: Short Strangl

The picture reference is https://www.optionsbro.com/short-strangle-option-strategy-example/

The FOREX currency market has 4 major markets, one of them is New York Exchange market where all trades are executed in USD, then there is London where we have GBP, Tokyo where dominates JPY and Sydney where traders use AUD. Forex market is open 24 hours a day. It provides a great opportunity for traders to trade at any time of the day or night. However, when it seems to be not so important at the beginning, the right time to trade is one of the most crucial points in becoming a successful Forex trader.

The week starts with the Asia session (Tokyo, Hong Kong, Seoul, Singapore). Just before the Asian session closes, the European session opens (London, Paris, Zurich, Frankfurt,). Halfway through the European trading day, the Americas session takes over (New York, Chicago, Toronto). (Foreign exchange market (Forex) centres with a corresponding time zone, 2019)

One of the reasons why is FOREX so enormous is because of decreasing volatility. In comparison with the late 1990s where it rose above 20 percent with U.S. dollar versus Japanese yen trades, nowadays volatility is below 10 percent. With low volatility the risk for investors is reducing. There are two major implements why is volatility low. First is that inflation has been low and stable in most world economies and second is a high transparency of policies of central banks. Also the newest technology helps traders to have faster responses from the market. This leads to unnecessarily complex currency adjustments. (C. Garner, 2012)

2   Currencies

Currencies are traded on forex market 24h a day, that is only closed from friday evening to sunday evening. There for 24-hour trading sessions are confusing and sometimes causing that certain currency pairs will have more volume during certain sessions. All currencies are traded in pairs. On contrary to the Global Stock Market, where a single stock can be bought, in FOREX there is no other way than to buy one currency and sell another currency. All currency pairs have the same rules - the first currency in a pair is called the major currency, and the other is called the minor currency. Taking EUR/USD currency pair as an example, where the EUR (euro) is the major currency and the USD (US dollar) is the minor currency. For example, you can see the EUR / USD price is around 1.1250. This means that 1.1250 sub-currency units are necessary to get one unit of the base currency. In other words, for $ 1,250 can be bought one euro.

There exist many currency pairs because most countries use their own currency. Because foreign currencies are always sought by foreign traders, there is usually a great

demand for any currency pair. The Major currency pairs are the most liquid ones. (Douglas S. Ehrman, 2006)

2.1 Major currency pairs in Forex trading

Exchange rates on the foreign exchange market are constantly being taken from currency pairs. Not all currencies in the world are traded worldwide, there are several countries whose currencies are traded more. These are countries that are both politically and economically stable. Currency pairs are almost the same amount as Forex in the world, but only a few are called major currency pairs. The most traded and most liquid pairs have the US dollar as a minor currency and are called major currency pairs. The US dollar accounts for more than 95% of the foreign exchange market. (Perry, 2012) states the most traded and the most liquid currency pairs as following:

• US Dollar (USD) and British Pounds (GBP) - GBP/USD

• Euro (EUR) and US Dollar (USD) - EUR/USD

• Japanese Yen (JPY) and US Dollar (USD) - USD/JPY

• Swiss Franc (CHF) and US Dollar (USD) - USD/CHF

Taking the main currency like the US dollar, the euro, the Japanese yen or the British pound and comparing it to each other, we get something that is known in the market as 'FX pairs'. It is a growing market where traders prefer to buy or sell a currency for a 'regular rate' rather than sell it for a better rate, resulting in a rise or fall in value the next day or week. (Jianxin Wang, 2003). Currency pairs are most active when the sessions for their region are active and can be traded online at any hour of each weekday. Traders of FX pairs need to pay attention to every announcement, news or any other valuable information to determine which factors could affect the growth or decline in currency value. For example, monitoring one of the most popular FX currency pairs, such as GBP/USD, then the trader should follow the UK announcements. Data such as a fall in unemployment or an increase in interest rates in the UK are all factors that would normally strengthen the pound. It is also worth paying

attention to when the government is taking measures such as quantitative easing - when it pours money into the economy to boost growth - because traders can find that a related currency weakens slightly.) Klein (1991) denotes that, news explain about 40 percent of FX price changes, back in those days. This claim is later supported by Eddelbuttel, D., and T. McCurdy (1998). Other also often exchanged currencies that appear on the currency market are the Australian dollar (AUD), the Canadian dollar (CAD) and the New Zealand dollar (NZD).

This paper will only consider EUR/USD, USD/JPY currency pairs.

2.2   EUR vs USD

The US dollar and the Euro are two of the most significant and best-known currencies in the world. The EUR/USD currency pair has globally the largest trading volume and is, therefore, the most traded currency pair. This pair cannot be overlooked because of its daily volatility and price movement.

US Dollar (USD) and Euro (EUR) are the official currencies of the respective US economic zones and countries in the European Union. The FOMC (Federal Open Market Committee) is the Federal Reserve Department (FED) that determines the direction of monetary policy for the US, which in turn affects the value and perceived value of the US dollar. The European Central Bank (ECB) is the main central bank for the euro and the eurozone and the impact on currency is similar. Both currency pairs are part of the FOREX exchange market. In the Forex market, the price of one currency moves up, down, or side to another currency. Both EUR and USD also generate currency pairs with other currencies such as the Euro against the British Pound (EUR/GBP) or the US Dollar versus the Canadian Dollar (USD/CAD). (Michael D. Archer, 2008)

According to a Triennial Central Bank survey published by Bank for International Settlements and conducted in April 2016, the US dollar (USD) is the most traded currency in the world and the euro is claiming second place. The USD daily share is 87.6% of all currency-related business activity, which is almost 3 times more than the EUR 31.4% share. The rest of the top five consists the shares of the Japanese Yen with 21.6%, British pound

12.8% and the Australian Dollar 6.9%, the Canadian Dollar 5.1% and the Swiss Franc with 4.8%. The price movement EUR/USD reflects the change between the euro and the dollar. Explaining on an example:

- When the price of the euro-dollar increases from 1.15 to 1.17, the euro becomes more valuable and the USD becomes less valuable.
- When the price of the euro-dollar falls from 1.22 to 1.19 the euro becomes less valuable and the USD becomes more valuable.
- In the opposite case, movements of USD/EUR are alike, when the USD versus the euro increases, the USD becomes more valuable. It is important to note that this version of the abbreviation is not common.

(Gatev, Evan, William N. Goetzmann, 2006)

When the price moves up or down, it means that one currency becomes stronger or the other weaker, or even both. If the EUR/USD exchange rate is higher, it could mean that the euro is strengthening against the US dollar, or that it may weaken the US dollar - or both. No matter what price change is, the fact is that traders can monitor the current balance of power by simply tracking price movements on the euro-dollar currency pair. Euro-dollar is either listed by the broker at 4 decimal places, which is 0.0001 pip, or some brokers are able to list EUR/USD at 5 decimal places, 0.00001 pip. An example is the Euro-dollar exchange rate, with EUR/USD fluctuating at an average of 87 pips a day from the beginning of the year on 30 August 2018 (MT5 source on 30 August 2018). This represents many business opportunities for EUR/USD traders. Where volatility is an important factor because there is no movement on FOREX without volatility. Volatility is often associated with risks, but the trader must not forget that it also can easily turn into opportunity! These opportunities can be risky if the trader applies risk management and when the business strategy is poorly

planned. On the other hand, for a trader who follows risk management and has a well-established business plan, trading EUR/USD can become a very rewarding activity.

Figure 2.0: EUR/USD Daily price chart movement

2.3 USD vs JPY

The couple dollar-yen is the second most liquid currency pair in the world. The Japanese Yen denotes the third major international currency and represents the globe's second largest economy in the account of its GDP, after the United States. The interest rate differential between the Federal Reserve (Fed) and the Bank of Japan (BoJ) affects the value of USD/JPY when compared to each other. Additionally, correlations between the U.S. and Asian equity markets are a key determinant of the exchange rate. The dollar-yen pair has a positive interrelationship with the USD/CHF along with USD/CAD currency pairs as they both conclude the U.S. dollar as the base currency. USD/JPY has the largest range of traders among the majors and also tends to trade with a higher degree of volatility across all trading sessions. (R. Lee, 2018)

Comparing the saving rates of both countries, where the U.S. stands at -1% and Japan move around 15%. This is a hint that Japanese traders and banks are in possession of a larger amount of funds that they can invest. (Chen, Kaiji, İmrohoroğlu, 2006)

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The pair USD/JPY is extremely liquid and it has a tendency to move around a particular price level before there is a sudden rapid movement to a different price level. A trader who wishes to trade USD/JPY pair has to pay attention to the daily or monthly Yen price chart to observe the overall trend of the currency in order to determine in which direction it might move. Taking into the historical scale consideration the USD/JPY pair can range from an average low of 120 to a high of around 85, meaning that the currency pair is most frequently moving to meet 120 or it can decline to 85. Following chart shows daily price movement of USD/JPY, it can be seen that the price moves around 111. The reference fot his chart is to DailyFX.com.

Figure 2.1: USD/JPY Daily price movement

Simon Baptist (2018) states that one of the pleasant surprises in the global economy in 2017 was the strong performance of yen, which originated from strong global demand for exports of Japan, plus government spending and lots of liquidity from the Bank of Japan.

Since Japan's exports are all contracted in U.S. dollar, strong yen with an upper hand over U.S. dollar has the potential to cause profit difficulties for Japanese exporters. (H. Taguchi, 2017). In the case, the yen would sustain its strength, it would mean a delay for Japan's efforts to meet its 2 percent inflation target. Japan has the smallest share of its denominated

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exports in its industrialized countries. Japanese exports denominated in its currency, according to Bacchett and Van Wincoop (2002), are approximately 23%, compared to US exports (over 90%).

2.4   The best time to trade EUR/USD, USD/JPY

The best time to trade the euro-dollar, dollar-yen and like any other currency pair, is when the market is active, which means that there is a decent price volatility and movement. Currency pairs tend to be more active when session for one or both currencies is open, in a given country or economic zone. EUR/USD pair is most active from 12:00 GMT to 20:00 GMT. (Michael D. Archer, 2008)

USD/JPY does not follow the consecutive-opening sessions. For this particular pair is a bit tricky with regard to best suitable time for a trade. Let's have a look at times when it is best to avoid to trade dollar-yen and than on best suitable ones for the execution of the trade. The following volatility chart shows for how many pips the USD/JPY moves hourly throughout the day. As can be seen, movement throughout the day is mostly stable, although there are periods with noticeable drops in volatility, traders should avoid low-volatility hours. The USD/JPY is sedated between 21:00 GMT and at 24.00 GMT. As Tokyo begins to fade, and before London rises, the pair sees yet another drop in volatility between 03:00 GMT and 05:00 GMT. On the contrary, if traders are able to, day trade the USD/JPY between 12:00 GMT and 15:00 GMT it maximizes their trading efficiency, as the increased volatility provides more opportunities to trade. New York and London sessions are both open for almost hole time of this period. Even though Tokyo is not opened yet, in this two to three hour window sometimes volatility preserves high up till 16:00. (C. Mitchell, August 2017)

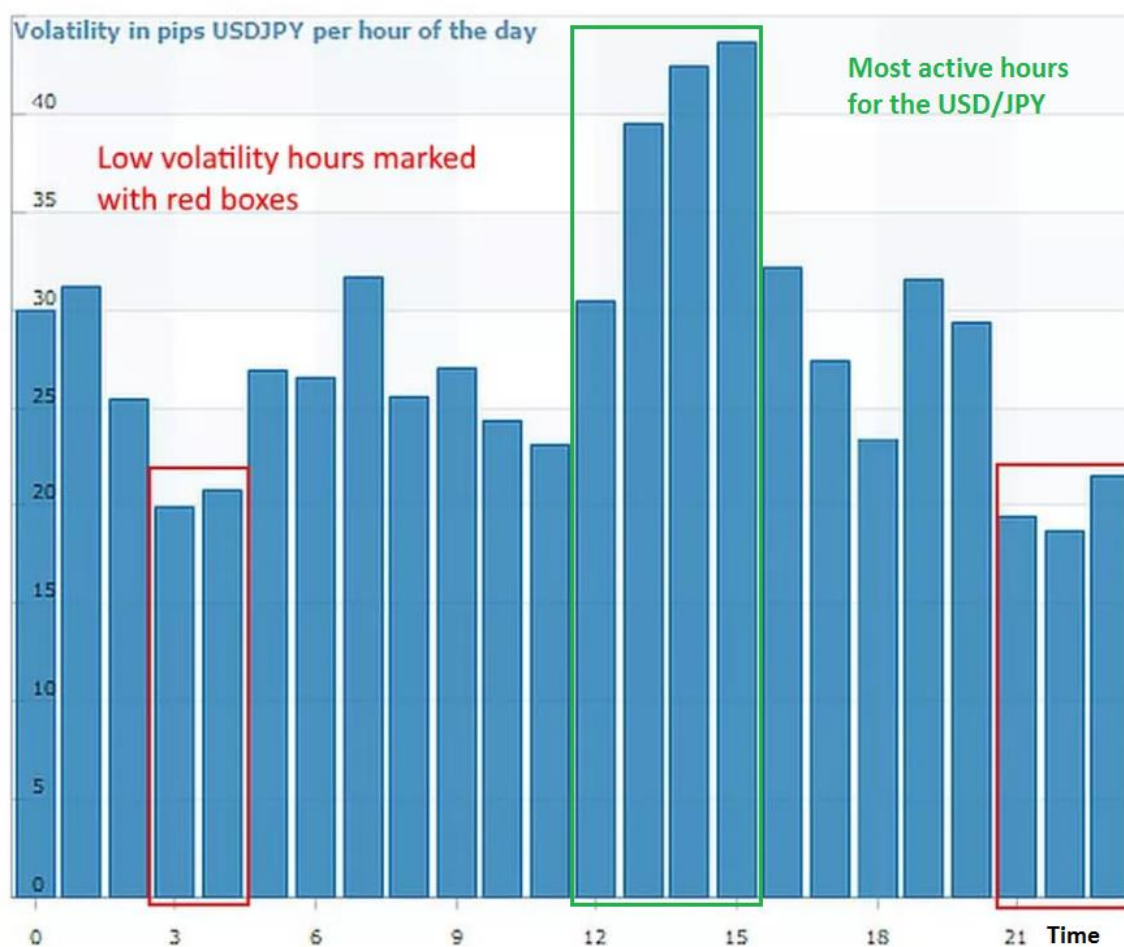The following figure provides a graphical representation:

Figure 2.2: Volatility in pips USD/JPY per hour

3 Algorithmic trading

Algorithmic trading is a type of trading which involves performing a trade on a efficient computer using complex mathematical formulas (algorithms) based on the buy and sell decisions

Although history on financial market has a tendency to repeat itself. (K. Rangappa, 2018) It was in 1970s where right after the introduction of computer trading systems the usage of algorithmic trading increased, but the real expansion algorithmic trading experienced in 1990s.

AT is capable to send buy and sell signals much faster than human trader, which gives AT distinct advantage over the personal execution of trades. Algorithmic trading comprehends a large number of strategies. This paper will be describing some subdivisions of strategies operating only with technical analysis based strategies, involving indicators such as Ichimoku cloud, Fibonacci sequence, moving average or relative strength index. (Ravi Kashyap, 2017)

Chapter 3 will cover characterization of trading indicators and will give more information about strategies.

Algorithmic trading contains High-frequency trading (HFT) and Ultra high-frequency trading. In these areas trades are executed in very small time series. High-frequency trading is characterized by extremely short time period of holding position. Trades are closed in few seconds or milliseconds. In 2011 already 77% of transactions in the UK market according were done through HFT (Jones, Charles M. 2013). Ultra high-frequency trading also known as low-latency trading work on a same principle like HFT though executions of trades are performed in sub-millisecond. (Rosenbaum M. 2017)

HFT is not a strategy in itself, but rather a set of techniques to trade. As it trades frequently, the pressure on very good market knowledge, mathematics and statistics is growing. Infrastructure and people are worth a lot of money and the chosen strategy must justify these costs. HFT is therefore logically appropriate for strategies where it is often traded, for example, for creating markets where stock exchange quotes need to be changed very quickly and often. Some types of statistical arbitrage, where the trader is trying to exploit the slight correlations between traded assets, or for classical speculation, where the trader is targeting once again minute, rapidly disappearing market inefficiencies, can also make good use of HFT. On the contrary, it is not important for long-term investors to invest in HFT technology. The advent of HFT undoubtedly pushed some traders out of the market, and it is humanly understandable that these subjects cannot name it. (Ravi Kashyap. 2017)

What are the advantages and disadvantages of HFT trading? HFT makes it possible to monitor some strategies more effectively. The disadvantage is that the cost of acquiring and operating HFT technology is relatively high. While speculating on the decline in Japanese

stocks over the six-month horizon is a relatively inexpensive matter, being a high-frequency market maker requires considerable resources. Especially if traders do not want to underestimate market conditions and try to eliminate risks (such as regular algorithm calibration, backup systems, a constant monitoring of algorithm behavior on the market is advised.) (N. Yusupov. 2017)

Although algorithmic trading represents a challenging opportunity for research and creation of new strategies even when working with right data 0 and with a sufficient computer system HFT has a occasional crash potential. It was on May 6, 2010 when the Dow Jones Industrial Average (is an indicator of stock market prices; based on the share values of 30 blue-chip stocks listed on the New York Stock Exchange) dropped about 1 trillion USD of market value including individual stocks in several minutes. To avoid such problems the whole system implementing algorithmic trading strategy has to be carefully back-tested. As for HFT and Ultra high-frequency trading, it will not be employed into this strategy testing research. Back-testing refers to a specific type of testing on historical data that defines the performance of the applied strategy. Although back-testing does not guarantee trader to foresee if the strategy will be beneficial in future conditions. It's main benefit dwells in discovering and in understanding the vulnerabilities of a strategy. It is a simulation of a clash with real-market conditions of the past. The trader who designed the strategy is capable to "learn from history" where in reality the faults were never made so trader did not lose any capital. The process of back-testing is extremely important aspect in any algorithmic strategy formation. Because without back-testing it would be impossible to know which combination of parameters would give the highest profit for a specified strategy. (Treleaven, Philip, Galas, 2013)

3.1 Advantages

Algorithmic trading has become very popular for traders in past few years. This is due to the advantages that algorithmic trading has to offer. The most interesting valuables would be technical reliability, speed and back-testing.

a) Speed

The main advantage of all is obviously speed, because algorithms are developed in the past and are executed automatically. The speed at which trades are executed is measured in fractions of a second even a milliseconds, much faster than a human trader can comprehend. Trading algorithms has a possibility to examine the market and perform trades on multiple indicators at a speed that is impossibe for a human trader. The fast excution of trade creates more opportunities and even for better prices. (Nasdaq.com, Advantages of Algorithmic Trading)

b) Technical reliability

Next advantage to algorithmic trading is accuracy, that is, removing human mistakes and emotions from the markert. Under the market's extreme pressure and vast variety of scenarios, it is easy for a human trader to make a mistake, associated with buying or selling a wrong asset. Before algorithmic tradins is initiated, a computer double checks to make sure the correct order is placed. Eliminating human emotions from the trade is very a helpful ability. The trades are controled with set of predefined criteria making trades more efficient. Greed, fear, uncertainty are the emotions leading to irrational decisions, which can create unnecessary loss of profit. (Gsell, Markus and Gomber, Peter. 2009)

c) Back-testing.

This advantage of algorithmic trading lies in the ability to backtest. Back-testing allows to traders to be able to recognize, which trading strategy is appropriate for the future execution of trades. Algorithmic trading allows designed to remove any flaws of a trading system before it is run on the live market. (Nasdaq.com, Advantages of Algorithmic Trading)

d) Reduciton of transaction costs

Last, but not least advantage of automated trading is the reduced transaction costs. Traders do not have to spend a lot of time monitoring the markets, as trades can be executed without

continuous supervision. The time invested in trading is considerably lower, which can reduce the transaction costs, due to the constant monitoring of the market. (K. Kunz. J. Martin, 2013)

3.2 Disadvantages

Although trading with algorithms has many possibilities and advantages as is often a habit, there are a few downsides as well. One of the disadvatages of algorithmic trading are high expenditures. Market brokers that are supporting the execution automated trades create unnecessary high expenditures.Traders are obliger to open their accounts with large amount of capital, which naturally in most cases individuals do not posses. This complication is step by step changing for the better as every as more brokers add the FIX protocol into their systems. Financial Information exchange protocol has revolutionised the trading environment, providing fundamental standards-based way to execute trades and also supporting equities trading in the pre-trade and trade environment. (Dhanjit Das, 2016)

The technology included in automated trading makes the hole process look easy. In reality, automated trading is a very sophisticated method for trading, however, it is not yet flawless. In the case if the internet connection has been interrupted the market would not be able to accept programmed order. Some complications can also appear in controling the automation. If the trade order is designed inaccurately, program is launched and trader is unable to control losses. Therefore they are needed to be tested properly in order to avoid loosing a profit. (K. Kunz. J. Martin, 2013)

What can be considered as a quality can also be proved as a weak point due to extreme velocity of the financial markets the professional algorithmic traders have to spend large sums of their capital to get access to legitimate historical data and to correctly develop strategies other additional cost is for a trader to have a powerful computer capable of high performance. The internet connection has to be extremely fast for the order to be placed before the price is changed by the market. Algorithmic trading requires to have a knowlege about programing in specific program languages .This difficulty can create disorder in

applying theoretically developed strategy on live market conditions. (Nasdaq.com, Disadvantages of Algorithmic Trading)

PRACTICAL PART

4 Chart indicators:

Technical indicators use the application of mathematical formulas to price time series data they are the crucial tools of technical analysts to foresee future price trends and action. They can be used to measure volatility and define the interrelationship between price and volume data and also to clarify the price trend. They provide a means to grasp the market behavior of the past and use that information to predict future prices. Technical market indicators can be classified into 4 groups: trend, momentum, volatility based indicators and volume.

In this chapter will describe technical chart indicators, for later application of strategies and calculation process CMF, EMA and Stochastic Oscillator are going to be used.

Trend

Trend traders are trying to isolate and profit from trends. There are several ways to do this.

4.1 EMA

Exponencial Moving Average (EMA) is a indicator, that places a greater weight and significance on the most recent data points. EAM belongs to Moving Avege (MA) family along with Simple, Smoothed, Weighted Moving Avereges. Like all of it's family members, this technical indicator is used to produce sell and buy signals based on crossovers and divergences from the historical average. The EMA is also referred to as the exponentially weighted moving average. An exponentially weighted moving average reacts more essentially to recent price changes than a simple moving average (SMA), which applies a same weight to all monitored assets in the time period. The default stratery for MA is Simple moving average which is based on the arithmetic average of the prices. The calculation of exponencial moving average is as follows:

$$SMA = SUM(Close, N)/N$$

$$EMA = (Close \times P) + [EMA(prev) \times (1 - P)]$$

Firts equation represent standard calculation of MA basic strategy simple moving average, where SMA denotes simple moving average. N stands for the number of time periods and C represent close price SUM(C,N) signifies the sum of closes price in last N time periods. Second computation states EMA, which symbolizes exponential moving average. Inside the equation EMA (prev) denotes previous time period's exponential moving average value, C is the current period close price and period close price P stands for the percentage of using the close price value.

The source for theoretical description of EMA was posted by GitHub, titled "Indicators & Oscillators", (ÖZTÜRK, 2015) provides the equation for SMA and EMA. Link for GitHub can be found in references.

4.2   TEMA

TEMA, which is short for Triple Exponential Moving Average, a type of indicator created by Patrick G. Mulloy. As the name already implies, the support base of TEMA is exponential moving average.The TEMA is combined from a single, a double and a triple exponential moving average. This connection enhances price movements and the adjourn between the indicator. The quality of TEMA is the efficiency of smoothing price changes. The calculation for this indicator can be seen below.

$$\text{TEMA} = 3 \times \text{EMA1} - 3 \times \text{EMA2} + \text{EMA3}$$

The calculation process EMA1 denotes the exponential moving average of the close price, next EMA2 represents the exponential moving average of EMA1 and at last EMA3 is the exponential moving average of EMA2 in time periods The source for the informational content on TEMA indicator is GitHub, with the headline "Indicators & Oscillators" and the computation reference is to be to (ÖZTÜRK, 2015). Link for GitHub can be found in references.

Volume

Indicators based on volume contribute the intel about the number of shares or contracts traded on the financial market in a given period of time. For every seller, there is always a buyer and each transaction deal is a part of the total volume. There are very few types of indicators whose value is no based only on price. The volume is not the case of primary price based types of indicators, it depends on the selected time period. The traded amount of assets at any period of time can indicate as to whether the trend is going to persist or it might reverse. If the volume records an augmentation, it signifies an emerging trend and when a drop in volume is recorded, it refers to an end of the trend. The indicators of volume nature can be applied alone or in combined usage with other indicators. (TradingView.com, Volume)

The resource for this article has been posted by TradingView.com titled "Volume" and can be found in section "Technical Indicators". Link for TradingView.com is cited in references.

4.3 The ALD indicator

ALD is an indicatior created by Marc Chaikin and it stands for Accumulation Distribution Line. This indicator is depending on money flow volume.
Money flow volume defines the position of the close price regarding to the minimum and maximun price of the period mesaured with volume. The caltucation proceeds by taking into account the total sum of the money flow volume values. Following equations indicate the calcultion procces of the ADL indicator. Following equations indicate the calcultion procces of the ADL indicator.

$$\textbf{\textit{MFM}} = \frac{(\text{C} - \text{L}) - (H - C)}{(\text{H} - \text{L})}$$

$$MFV = MFM \times V$$

$$ADL = ADL\,(prev) + MFV$$

In firt equation, MFM indicates the money flow multiplier. The values C, L, H presented in numerator and denominator are close, low and high prices for ongoing time period. The next step is a calculation of the money flow volume (MFV). MFM is multiplied by V (volume), representing the present time period's volume. The final ALD equation is constructed from ADL and MFV representing the current period's ADL and money flow volume and then ADL(prev) indicates the previous period's ADL value. (ÖZTÜRK, 2015)

4.4   CMF

Another idicator, implemented on selected strategies is CMF. Developped by once already mentioned author Marc Chaikin, Chaikin Money Flow (CMF) is an indicator depending on Money Flow Volume specified in ADL indicator, earlier in Idicators section. The difference between these two indicators lies in their calculation. Accumulation Distribution Line is calculated by the running total of Money Flow Volume values, on contrary the calculation of ADL's relative CMF is that, the total Money Flow Volume values are divided by the volume total in a specified time period. The CMF is computed as follows.

$$MFM = \frac{(C-L) - (H-C)}{(H-L)}$$

$$MFV = MFM \times V$$

$$CMF = SUM(MFV, N)/SUM(V, N)$$

Where MFM represents the money flow multiplier, C indicates close price, H denotes highest price and L signifies lowest price all in the current time period. Next, the money flow volume (MFV) is calculated. MFV denotes the money flow volume and V is volume, both in the current time period. The third computation denotes the current time period's value of

CMF. The two SUM(V, N) and SUM(MFV, N) are standing for the sum of volume values and the sum of money flow volume in N time periods. In standard calculations value of N time period is 20, further use of this calculation than in this reseach work, N value is an aspect to change. (ÖZTÜRK, 2015)

Momentum

Momentum signifies the difference between two prices taken over a fixed interval. It could be explained as the distance covered over time. It is a form of smoothing price movement and same as a trend can serve to the same purpose. Although the momentum values are not as mellow as a moving average, larger momentum periods reduce the extremes. (Perry J. Kaufman. 2013)

4.5 The RSI indicator

The indicator itself is depending on Relative Strength (RS). In a selected time period RS is the ratio of average gain divided by average loss. As told, RSI is a momentum type of indicator, the speed and changes in price are refected by RSI. Its purpose lies also to identify the overbought/oversold levels of price. Values of RSI indicator are between 0 and 100 and these values are oscillating. Where 0 in denotes the price is oversold and 100 represents the price is overbought. A set of equations for calculating RSI indicator is following:

$$AG = \frac{[AG(prev)] \times 13 + G}{14}$$

$$AL = \frac{[AL(prev)] \times 13 + L}{14}$$

$$RS = \frac{\text{AG}}{\text{AL}}$$

$$RSI = 100 - \frac{100}{(1 + \text{RS})}$$

Equations contening AL, which signifies Average Loss and AG, which denotes Average Gain. Both of them are the present average gain and loss in N periods. AL(prev) and AG(prev) meaning Average Loss (prev) and Average Gain (prev) are the past period's average loss and gain. Possitive and negative difference between present and past period's close price is Gain and Loss. A period for standard calculation can be changed. (Perry J. Kaufman. 2013)

Oscillators

Oscillators are very much connected with momentum based indicators, thy are common type of technical indicator. For example, Perry J. Kaufman (2013) states an oscillator may have a low of -100 and a high of +100 where -100 represents oversold conditions and +100 represents overbought conditions. The standard momentum computation is transformed a into the normalized shape with a maximum value of +100 and a minimum value of −100, divide the momentum calculation by its maximum value over the identical rolling time period.

4.6   The Stochastic Oscillator

The last indicator implemented into the selected strategy is Stochastic Oscillator. An indicator, such as the Stochastic Oscillator, is measuring, which is computed for each candlestick bar (meaning time perionds) they are devided into a minute, an hour, four hours, or a day.

For calcuating the stochastic oscillator the formula is.

$$K = 100 \times (C - Ln)/(Hn - Ln)$$

Having K as a value of the stochastic indicator, which is moving from 0-100, for the value of $Hn \geq C$ and at the same time these values are positive so values are positive. C is the closing price at the current candlestick/period. L is the Lowest price of the las n candlesticks/periods. H is the Highest price of the last n candlesticks/periods. This indicator will be later used for generating buy and sell signals. (Moldovan, D. Mircea, M. Nitchi, Si).

4.7 Chaikin Oscillator

Chaikin Oscillator is an indicator also based on ALD indicator. Chaikin Oscillator as well as ADL were developed by the same designer.

It is solved that, the longer period exponential moving average of ADL values are subtracted from the shorter period exponential moving average ADL values all done in specified time period. Chaikin Oscillator is a kind of indicator, which has teh ability to display the momentum of ADL values, naturally shows the selling/buying pressure of decreasing/increasing ADL values. The calculation for Chaikin Oscillator indicator can be found below.

$$\textbf{\textit{Chaikin Oscillator}} = EMA \times (N1 period\ of\ ADL) - EMA \times (N2 period\ of\ ADL)$$

Identifying Chaikin Oscillator's value with EMA(ADL, N1period) and EMA(ADL, N2period) these are the exponential moving average of ADL indicator values in N periods. The standard setting computations define N time period as N1 = 3 and N2 = 10, the two values is a subject to change for possible further usage. (J. Chen, 2019)

Volatility

Volatility-based indicators are rare technical analysis tools that are looking at the adjustments in market prices over a specified period of time. The height of volatility is

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depending on whenever the price changes are fast or slow. As slower as the price changes are, the lower the volatility is. The faster price changement, the higher the volatility. The way how are volatility-based indicators mesured and cumputed is based on historical prices and can be used to identify a trend. The overbouught market signals that the price is illegitimatly high or in the case, when the market is oversold the price on the other hand is illegitimatly low, pointing to possible reversal or stalling of the trend. The indicators of this type are regularly used in combination with additional signal generating circumstances. The base of using volatility rests in identifiction of trading opportunities.

Informations provided about Volatility-based indicators refer to "Technical Indicators" section, posted by TradingView.com in subsection "Volatility"

4.8 ATR

Average True Range (ATR) is an indicator designed by J. Welles Wilder. This indicator is based upon True Range (TR). TR is an instrument for measurement the volatility of the price. Therefore the TR decreases or increases directly proportional to the market activity. The set of tree equations define the maximum of TR and the following computation belongs to ATR indicator.

$$TR = MAX \begin{cases} ABS(H - L) \\ ABS(H - C(prev)) \\ ABS(C(prev) - L) \end{cases}$$

$$ATR = \frac{(n - 1) \times \text{ATR(prev)} + \text{TR}}{n}$$

The first step is a calculation of TR value, where MAX denotes absolute value, H stands for the highest price, L represents the lowest price and C(prev) signifies the previous period's close price. Next step, the computation of Average True Range. TR in the equation is TR value detected in previous computing. IN standard calculations n is expressed by value 14, thus it is an aspect to change for further usage.

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The source for the informational content on TR is Linnsoft.com, more specifically it is to be found in the section called "True Range (TR)". The equation for True Range (TR) was also provided by Linnsoft.com and the ATR computation reference is to be to Ta-guru.com, which can be found in fourth part "Technical Analysis", subsection "Average True Range (ATR)".

4.9   Bollinger Bands

This type of indicator is called Bollinger Bands and it is named after it's inventor John Bollinger. It is construted of 3 bands (Middle Band, Upper Band, Lower Band), a key of these bands is moving average. Middle Band is a moving average of price in a specified period, Upper and Lower Bands are two rading bands placed above and below this moving average.

Essential is computing the lower and upper bolinger bans, which is stading on deviation of the price in the specified time period of the moving average.

Price volatility alters whether the lower and upper bands are widen or narrow. Following equation demonstrates calculation of Bollinger Bands.

$$SD = \frac{\sqrt{\sum (x_i + \mu)^n}}{N}$$

$$\mathbf{MiddleBand} = \text{SMA(CloseN)}$$

$$\mathbf{UpperBand} = \text{SMA(CloseN)} + \text{SD(CloseN)} \times 2$$

$$\mathbf{LowerBand} = \text{SMA(CloseN)} - \text{SD(CloseN)} \times 2$$

First step to get Bolinger bands vallues, SD must be computed. SD signifies the standard deviation, In the numerator, x stands for data point and μ indicates the average of data points. In the denominator N means the number of points.

Where in 3 bands equations SMA(CloseN) denotes the simple moving average of close prices in N time periods and SD(CloseN) denotes the standard deviation of close prices in N time periods. The results would give the middle, lower and upper Bollinger bands values. (J. Bollinger. 2001)

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5 Methodology

In this paper will be used on some of these algoritms using the back-testing process, firstly on currency pair EUR/USD and then USD/JPY. The historical data used for the research has been provided by GKFX trading plaform. Established in 2010, GKFX platform was accepted very well by traders and by every year, the company continues to be among the most awarded and popular trading platform in the world. For exemple, GKFX has gained award for Best Forex Platform at the ADVFN International Financial Awards 2017. A four hour long time period is stated for every carefully planned time period there are 5 input, data avaible for the paper are Open, High, Low, Close price and Volume. The data are modified to get the value of indicators which are later generated as buying and selling signals. The total number of records is 2071, that is from 08.12.2017 to 11.04.2019 are available for the jpy/usd and 2071 records from 08.12.2017 to 11.04.2019 for eur/usd pair as well. It is important to note that backtested strategies with positive results do not guarantee any porfits in live market conditions.

Stochastic Oscillator

Calculating K, the value of Stochastic Oscillator is finding the lowest low price and highest high price for last 14 time periods. C in the computation denotes close price minus Ln, which is lowest low price, then divided by the result of Hn which signifies the highest high price minus Ln. All being multiplied by 100 at the end.

The first set of figures shows the the calculation process of Stochastic Oscillator applied on EUR/USD, USD/JPY, without alternate buy and sell signals.

Figure 5.0: Calculation process of Stochastic Oscillator on EUR/USD data – incorrect alternation

5.1: Calculation process of Stochastic Oscillator on USD/JPY data – incorrect alternation

The second set of figures shows the calculation process of Stochastic Oscillator applied on EUR/USD, USD/JPY historical data after applying correct strategy

Figure 5.2: Calculation process of Stochastic Oscillator on EUR/USD data – correct alternation

5.3: Calculation process of Stochastic Oscillator on USD/JPY data – correct alternation

EMA

Finding out the EMA value, where the close price is subtracted by previous exponential moving average multiplied by 2 and divided by n + 1, where in this case n signifies 10 time periods, in the end, attributed one more time by EMA(prev). Figures for the calculation process of EMA applied on EUR/USD, USD/JPY historical data is as follows:

Figure 5.3 Calculation process of EMA on EUR/USD data

Figure 5.4: Calculation process of EMA on USD/JPY data

CFM

CMF calculation begins by finding out the money flow multiplier where the value of MFM equals to close price minus low price then high price minus close price, the results are subtracted between each other and divided by high price minus low price. Next, the money flow volume must be computed. MFV value is defined by multiplication of the money flow volume and volume. Final computing step is the value of CMF, where the SUM of the money flow volume in N period is divided by SUM of volume in N period. The value of N has been defined as 21, other usage than this particular value is an aspect to change. Figures below describe the calculation process of CMF applied on EUR/USD, USD/JPY historical data.

Figure 5.5: Calculation process of CMF on EUR/USD data

	Date	Hour	Open	High	Low	Close	Volume		I	J		L	M (MFL)		O (MFV)		Q (21SUM V)	R (21SUM MFV)	T (CMF21)		V	W	X	Y
2	8.12.2017	8:00:00	1,17644	1,17671	1,17317	1,17361	15239					-0,00266	-0,75141		-11450,8									
3	8.12.2017	12:00:00	1,17359	1,17683	1,17294	1,17622	15596					0,00267	0,686375		10704,71									
4	8.12.2017	16:00:00	1,17628	1,17702	1,1746	1,17556	19686					-0,0005	-0,20661		-4067,36									
5	8.12.2017	20:00:00	1,17554	1,17733	1,1755	1,17702	7104					0,00121	0,661202		4697,18									
6	11.12.2017	0:00:00	1,17664	1,17773	1,17631	1,17762	6588					0,0012	0,84507		5567,324									
7	11.12.2017	4:00:00	1,1776	1,17837	1,17746	1,17796	4854					9E-05	0,098901		480,0659									
8	11.12.2017	8:00:00	1,17795	1,18	1,17746	1,17966	11346					0,00186	0,732283		8235,26									
9	11.12.2017	12:00:00	1,17964	1,18027	1,17761	1,17776	11926					-0,00236	-0,88722		-10581									
10	11.12.2017	16:00:00	1,17775	1,18112	1,17767	1,17911	15783					-0,00057	-0,16522		-2607,63									
11	11.12.2017	20:00:00	1,17911	1,17936	1,17634	1,17683	8095					-0,00204	-0,6755		-5468,15									
12	12.12.2017	0:00:00	1,17697	1,17791	1,17687	1,17687	5132					-0,00094	-0,82456		-4231,65									
13	12.12.2017	4:00:00	1,17686	1,17747	1,17639	1,17723	3307					0,0006	0,555556		1837,222									
14	12.12.2017	8:00:00	1,17724	1,17921	1,17693	1,17827	11719					0,0004	0,175439		2055,965									
15	12.12.2017	12:00:00	1,17829	1,17853	1,17491	1,17499	13380					-0,00346	-0,9558		-12788,6									
16	12.12.2017	16:00:00	1,175	1,17514	1,17168	1,17229	18839					-0,00224	-0,6474		-12066,9									
17	12.12.2017	20:00:00	1,17228	1,17481	1,17204	1,17407	9646					0,00129	0,465704		4492,181									
18	13.12.2017	0:00:00	1,17401	1,17475	1,17346	1,17424	4068					0,00027	0,209302		851,4419									
19	13.12.2017	4:00:00	1,17423	1,17615	1,17419	1,1754	4561					0,0046	0,234694		1070,439									
20	13.12.2017	8:00:00	1,17539	1,17621	1,17369	1,17486	8246					-0,00018	-0,07143		-589									
21	13.12.2017	12:00:00	1,17486	1,17702	1,17288	1,17569	14011		1,176263	3,28329E-07		0,00148	0,357488		5008,763					Sell/buy			sell	buy
22	13.12.2017	16:00:00	1,17569	1,17699	1,17469	1,17622	17121		1,176294	3,01022E-08		0,00076	0,330435		5657,374		-13193,1	208826	-0,06318		NEPRAVDA	NEPRAVDA		
23	13.12.2017	20:00:00	1,17623	1,18309	1,17621	1,18243	20809		1,176704	3,27871E-05		0,0556	0,80814		16816,58		15074,28	210708	0,071541		Buy	PRAVDA	NEPRAVDA	1,18...
24	14.12.2017	0:00:00	1,1824	1,18431	1,18208	1,18417	9106		1,177135	4,94983E-05		0,00195	0,874439		7962,646		12332,21	215921	0,057114		NEPRAVDA	NEPRAVDA		
25	14.12.2017	4:00:00	1,18417	1,18417	1,18251	1,18261	6013		1,177414	2,69984E-05		-0,00146	-0,87952		-5288,54		11111,03	205341	0,05411		NEPRAVDA	NEPRAVDA		
26	14.12.2017	8:00:00	1,1826	1,1857	1,18101	1,18183	14068		1,177625	1,76862E-05		-0,00105	-0,39033		-5491,23		922,6184	204250	0,004517		NEPRAVDA	NEPRAVDA		
27	14.12.2017	12:00:00	1,18186	1,18618	1,18115	1,182	19941		1,177827	1,74181E-05		-0,00333	-0,66203		-13201,5		-17846,2	211730	-0,08429		Sell	NEPRAVDA	PRAVDA	1,182
28	14.12.2017	16:00:00	1,18203	1,18261	1,177	1,17872	21040		1,17778	8,8454E-07		-0,00217	-0,38681		-8138,47		-26464,7	226817	-0,11668		NEPRAVDA	NEPRAVDA		
29	14.12.2017	20:00:00	1,17871	1,18006	1,17742	1,17766	13369		1,177775	1,31103E-08		-0,00216	-0,81818		-10938,3		-45638,3	236611	-0,19288		NEPRAVDA	NEPRAVDA		
30	15.12.2017	0:00:00	1,17765	1,17894	1,17638	1,1784	8362		1,177739	4,36921E-07		0,00148	0,578125		4834,281		-30223	238054	-0,12696		NEPRAVDA	NEPRAVDA		
31	15.12.2017	4:00:00	1,17839	1,17904	1,17777	1,17831	6267		1,177813	2,47009E-07		-0,0002	-0,15873		-994,762		-28610,2	230633	-0,12405		NEPRAVDA	NEPRAVDA		
32	15.12.2017	8:00:00	1,1783	1,17979	1,17786	1,17963	12708		1,177951	1,81904E-06		0,00161	0,834197		10600,97		-12541	228805	-0,05481		NEPRAVDA	NEPRAVDA		
33	15.12.2017	12:00:00	1,17961	1,18118	1,17902	1,17987	16807		1,178083	3,19337E-06		-0,00046	-0,21296		-3579,27		-11888,7	236381	-0,05029		NEPRAVDA	NEPRAVDA		
34	15.12.2017	16:00:00	1,17989	1,17996	1,17599	1,17646	21532		1,177993	2,34856E-06		-0,00303	-0,76322		-16433,7		-30159,6	249881	-0,1207		NEPRAVDA	NEPRAVDA		
35	15.12.2017	20:00:00	1,17645	1,1765	1,17474	1,17491	12161		1,177989	9,47716E-06		-0,00142	-0,80682		-9811,72		-42027,3	259694	-0,16183		NEPRAVDA	NEPRAVDA		
36	18.12.2017	0:00:00	1,1742	1,17565	1,17365	1,17559	9649		1,178154	6,57153E-06		0,00188	0,94		9070,06		-20168,6	258475	-0,07803		NEPRAVDA	NEPRAVDA		
37	18.12.2017	4:00:00	1,17558	1,17645	1,1755	1,17601	5350		1,178251	5,01984E-06		7E-05	0,073684		394,2105		-7707,55	249485	-0,03089		NEPRAVDA	NEPRAVDA		
38	18.12.2017	8:00:00	1,17602	1,17942	1,17602	1,17883	14042		1,17848	1,225E-07		0,00222	0,652941		9168,6		-3031,13	245189	-0,01236		NEPRAVDA	NEPRAVDA		
39	18.12.2017	12:00:00	1,17884	1,17987	1,17835	1,1793	14139		1,128675	3,90625E-07		0,00038	0,25		3534,75		-347,822	255163	-0,00136		NEPRAVDA	NEPRAVDA		

Figure 5.6: Calculation process of CMF on USD/JPY data

	Date	Hour	Open	High	Low	Close	Volume		I	J		L	M (MFL)		O (MFV)		Q (21SUM V)	R (21SUM MFV)	T (CMF21)		V	W	X	Y
2	8.12.2017	8:00:00	113,38	113,58	113,37	113,55	13693					0,155	0,74879		10253,2									
3	8.12.2017	12:00:00	113,55	113,56	113,22	113,33	13896					-0,121	-0,3507		-4873,7									
4	8.12.2017	16:00:00	113,33	113,58	113,12	113,51	21123					0,319	0,69499		14680,3									
5	8.12.2017	20:00:00	113,51	113,54	113,43	113,43	14235					-0,108	-1		-14235									
6	11.12.2017	0:00:00	113,52	113,68	113,45	113,61	24959					0,082	0,34746		8672,19									
7	11.12.2017	4:00:00	113,63	113,69	113,49	113,56	18041					-0,042	-0,2877		-5189,9									
8	11.12.2017	8:00:00	113,54	113,56	113,31	113,36	21983					-0,164	-0,6508		-14306									
9	11.12.2017	12:00:00	113,36	113,43	113,23	113,4	14050					0,132	0,67347		9462,24									
10	11.12.2017	16:00:00	113,4	113,44	113,27	113,43	16818					0,149	0,88166		14827,7									
11	11.12.2017	20:00:00	113,43	113,57	113,42	113,54	9258					0,1	0,67568		6255,41									
12	12.12.2017	0:00:00	113,53	113,57	113,43	113,44	9086					-0,115	-0,8519		-7739,9									
13	12.12.2017	4:00:00	113,45	113,51	113,43	113,44	11252					-0,045	-0,5696		-6409,4									
14	12.12.2017	8:00:00	113,45	113,49	113,36	113,44	14639					0,037	0,296		4333,14									
15	12.12.2017	12:00:00	113,44	113,53	113,41	113,48	11746					0,02	0,16667		1957,67									
16	12.12.2017	16:00:00	113,49	113,74	113,36	113,62	18425					0,129	0,34218		6304,58									
17	12.12.2017	20:00:00	113,62	113,63	113,48	113,53	14693					-0,047	-0,3032		-4455,3									
18	13.12.2017	0:00:00	113,5	113,57	113,41	113,48	14623					-0,02	-0,1266		-1851									
19	13.12.2017	4:00:00	113,48	113,5	113,12	113,31	15536					0,008	0,02094		325,361									
20	13.12.2017	8:00:00	113,31	113,44	113,3	113,39	10978					0,039	0,26531		2912,53									
21	13.12.2017	12:00:00	113,39	113,41	112,94	113,05	15716		113,444	0,15433		-0,256	-0,5447		-8560,2						Sell/buy			sell
22	13.12.2017	16:00:00	113,05	113,26	112,99	113,12	18842		113,422	0,09193		-0,017	-0,0632		-1190,8		11172,8	304750	0,03666		NEPRAVDA	NEPRAVDA		
23	13.12.2017	20:00:00	113,12	113,12	112,45	112,53	25235		113,382	0,73291		-0,52	-0,7738		-19527		-18608	309899	-0,06		Sell	NEPRAVDA	PRAVDA	112,5
24	14.12.2017	0:00:00	112,51	112,79	112,51	112,6	15129		113,337	0,54546		-0,104	-0,3824		-5784,6		-19518	321238	-0,0608		NEPRAVDA	NEPRAVDA		
25	14.12.2017	4:00:00	112,6	112,68	112,55	112,56	13041		113,293	0,53597		-0,104	-0,7761		-10121		-44320	315244	-0,1406		NEPRAVDA	NEPRAVDA		
26	14.12.2017	8:00:00	112,56	112,87	112,56	112,77	14574		113,251	0,23445		0,1	0,31847		4641,4		-25444	314050	-0,081		NEPRAVDA	NEPRAVDA		
27	14.12.2017	12:00:00	112,77	112,83	112,57	112,75	18214		113,212	0,21142		0,108	0,4252		7744,54		-26371	303665	-0,0868		NEPRAVDA	NEPRAVDA		
28	14.12.2017	16:00:00	112,75	112,79	112,23	112,35	18316		113,162	0,66016		-0,421	-0,9132		-16727		-37908	303838	-0,1248		NEPRAVDA	NEPRAVDA		
29	14.12.2017	20:00:00	112,35	112,42	112,06	112,38	20235		113,111	0,52831		0,296	0,82222		16637,7		-6964,2	300171	-0,0232		NEPRAVDA	NEPRAVDA		
30	15.12.2017	0:00:00	112,37	112,39	112,23	112,23	16319		113,051	0,67725		-0,163	-1		-16319		-32745	306356	-0,1069		NEPRAVDA	NEPRAVDA		
31	15.12.2017	4:00:00	112,23	112,38	112,1	112,24	15879		112,986	0,5519		0,002	0,00719		114,237		-47459	305857	-0,1552		NEPRAVDA	NEPRAVDA		
32	15.12.2017	8:00:00	112,24	112,27	112,02	112,14	15543		112,921	0,60357		-0,002	-0,0081		-126,37		-53841	312478	-0,1723		NEPRAVDA	NEPRAVDA		
33	15.12.2017	12:00:00	112,14	112,25	112,11	112,22	16399		112,86	0,41409		0,073	0,51049		8371,52		-37729	318935	-0,1183		NEPRAVDA	NEPRAVDA		

All Exel calculations are attached on CD to the research work.

Furthermore, often it happens that transaction costs are overlooked, in real market conditions. The quantities traded are always equal to one lot and one mini lot. The programed systems (algorithms) are created by the process of back-testing which consist of evaluating algorithms on historical data. Those who develop these algorithms are working with numerous types of simulations which includes necessary process of back-testing to evaluate and improve benefit of their algorithms. (Quantitative trading – Ernest P.CHAN). That means that positive feedback of back-testing these strategies does not secure profit on the

market in present time. Using strategy on one time period and one asset pair is not significant because the strategy can be altered to present excellent results. That is because financial market is like a gigantic wilderness, there is a certain uncertainty.

6 Chosen strategies

This division will describe algorithmic trading strategies and how they function. These strategies are based upon strictly defined trading rules, which can generate buy and sell signal.

6.1 First stategy

The first strategy will be based on the Stochastic indicator. The strategy is backtested on daily data from 01/01/2017 to 01/01/2019. It is necessary to evalute this strategy on a larger time seiries to obtain more significative results. For determinating the lowest(L) and higest prices(H) of the stochastic indicator at a selected day I will consider the 14 previous days, in other words n = 14. The buy signal is generated when the value of K < 20 and the sell singal is generated when K > 80. Graphical representations of exchange rates over the backtested periods for EUR/USD and USD/JPY can be found below:
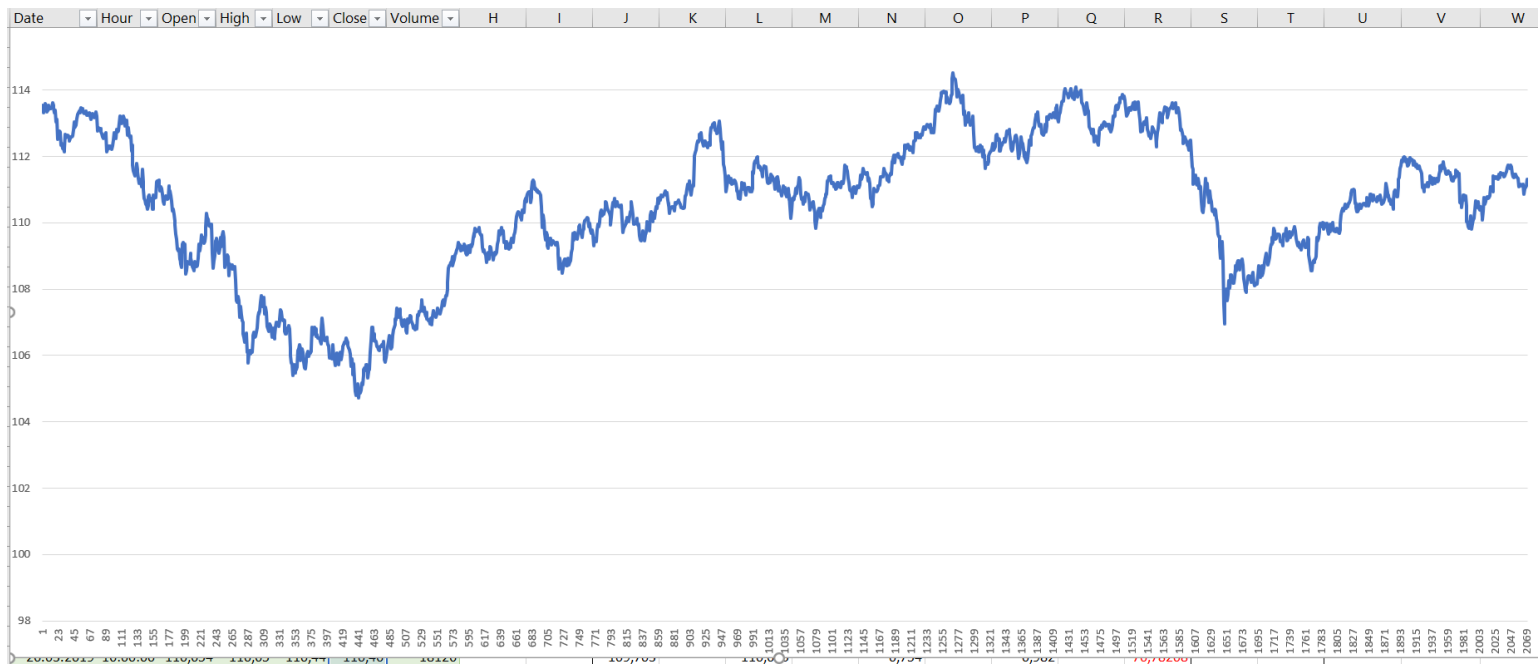
Figure 6.0: Exchange rate over the back-tested period for EUR/USD

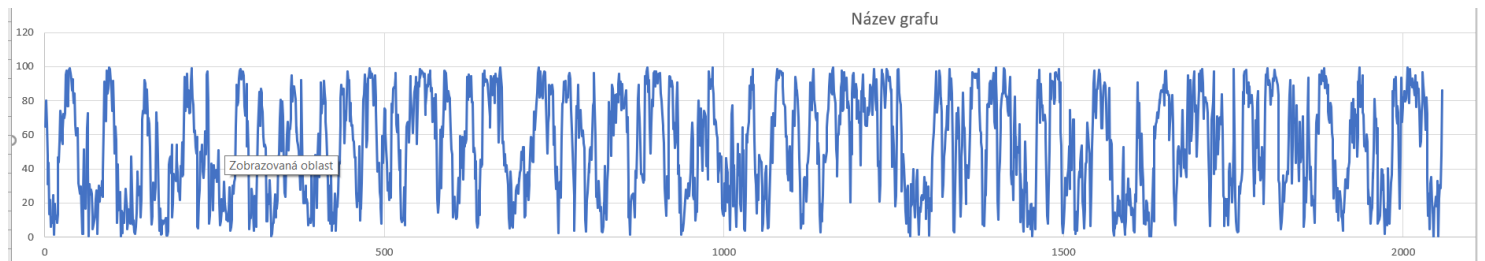The second, shows The Stochastic Oscillator

Figure 6.1: Stochastic Oscillator movement

6.2   Second stategy

This strategy is based on the CMF indicator. when the value of the indicator crosses above 0,05 a buy signal is generated, conversly when it crosses below – 0,05, a sell signal is made. The last 21 time periods are considered in this strategy. The strategy used in combination with CMF indicator on EUR/USD and JPY/USD pairs from 08.12 2017 to 11. 04. 2019

6.3 Third strategy

The last strategy is called Exponential Moving Average(EMA). This one is used by traders as a evaluation signal value buy, when EMA crosses above close price. In the case EMA crosses below close price, sell signal is generated. The date used for this stratery are also recorded from 08. 12. 2017 to the last 11. 04. 2019

7 Results

1) The Stochastic Oscillator

Applying the first algoritmic trading strategy on the data for EUR/USD, USD/JPY from 08.12.2017 to 11.04.2019 resulted in slightly higher average sell prices than buy prices.

This strategy has proven to be unfortunately insufficient. The buy and sell signals generated for this particular strategy in combination with The Stochastic Oscillator applied on historical data of both currency pairs EUR/USD, USD/JPY were not alternate. Another reason why the strategy was not successful is, that it was initiated only on one-time serie.

	usd/jpy	eur/usd
number of sell	504	403
number of buy	328	460
total sell	5853,632	475,5995
total buy	328	536,6046
average sell	55907,5	1,180148
average buy	36114,5	1,166532
profit/loss	19,79	0,013

Table 7.0: Results of Stochastic Oscillator after incorrect strategy employment EUR/USD, USD/JPY

After trying and considering numerous trading strategies whose proven to be inefficient, The Stochastic Oscillator was almost dismissed from the research completely. The main issue lied in the alternation of buy and sell signals, For the last time, a completely new strategy was applied on the stochastic oscillator and unexcitingly has brought positive

results. The strategy reformed to generate buy and sell signals alternatively. In the case of EUR/USD a slight profit was made 1.114, but the buy and sell signals were not completely alternating. 46 buy signals were obtained and 47 sell signals. One additional sell signal was generated, that will influence profit, it will be even lower. The strategy has proven to be profitable considering the EUR/USD pair. The USD/JPY has proven to be much more efficient. The process finished with pretty much same altering of buy (51) and sell (52) signals. The process has generated a decent profit, which is 110. With one additional sell signal, the final profit will be a bit lower.

	usd/jpy	eur/usd
number of sell	52	47
number of buy	51	46
total sell	5853,632	55,1915
total buy	5742,67	54,0766
average sell	110,446	1,174286383
average buy	110,436	1,17557826
profit/loss	110	1,114

Table 7.1: Results of Stochastic Oscillator after correct strategy employment EUR/USD, USD/JPY

2) EMA

The second strategy after bactesting has brought persuasive results. The strategy for EUR/USD has brought loss of -0.014. After appllying the strategy, Sum of buy is 210.113 and Sum of sell is 210.099. One single indicator used for this strategy is EMA and on one trading rule. Back-testing was firstly run from 08. 12. 2017 to 11.04.2019. The strategy generated 179 buy signals and 179 sell signals. The frequency of buy and sell signals is alternating. For this strategy has carried out a successfull alternation of signals, although the strategy has not generated profit, it has prooven to be na working strategy. In the case of USD/JPY, the strategy received -3.32 loss of profit, which is slightly more than euro-dollar. For this strategy also generated on this pair the same number of sell and buy signals, which is 191. For more profitable returns, further research and more precisive data are necessary.

	usd/jpy	eur/usd
number of sell	191	179
number of buy	191	179
total sell	21101,48	210,099
total buy	21104,804	210,113
average sell	110,4789	1,17373
average buy	110,496357	1,17404
profit/loss	-3,32	-0,014

Table 7.2: Results of EMA after strategy employment EUR/USD, USD/JPY

3) CMF

The last strategy resulted positively for both currency pairs (EUR/USD, USD/JPY) The backtest has began 8th December 2017 at 8:00 am and ended 11th April 2019. For EUR/USD the strategy generated the same number of buy and sell signals, which is 120 with a total loss of -0.074. Although the strategy in the case of USD/JPY has gained a profit of 113. Considering that 108 sell signals were generated and only 107 buy signals, the strategy can be defined as profitable, although the frequency of buy and sell signal is not one hundred percent alternate, th final profit will be lower. In both cases this strategy has carried out a successfull alternation of signals.

	usd/jpy	eur/usd
number of sell	108	120
number of buy	107	120
total sell	11911,837	140,81021
total buy	11798,733	140,88477
average sell	110,294787	1,173418417
average buy	110,2685327	1,17403975
profit/loss	113,104	-0,014

Table 7.3: Results of CMF after strategy employment EUR/USD, USD/JPY

Conclusion

The bachelor thesis focused on FOREX financial market, mainly targeted on algorithmic trading strategies. In the end, it is important to point out that currencies have low volatility. The results quite precisely reflected the theoretical foundations of algorithmic trading. In most of the time, the usage of one single indicator on one single time period can prove quite inadequate due to the lack of a procedure and rule implemented in chosen strategy, which would impose the alternation between buy and sell signals. For this research Stochastic Oscillator, CMF indicator and ADL were implicated into selected strategies. The selected algorithmic strategies have not made crucial losses for a selected period of time, comparing with passive Buy & Hold. The strategy with pest performance is CMF strategy, applied on USD/JPY currency pair, with a profit of 113 US. The process of backtesting has initiated on 08.12.2017 and ended on 11.04.2019. At the beginning of the backtest the EUR/USD initial price was 1,8622 and at the end it was 1,12983. The backtest for USD/JPY began at the same time, from 08.12.2017 to 11.04.2019. Before the backtest initiation USD/JPY was at 113,485 and after the backtest ended it was at 111,683. The Buy & Hold strategy can prove to be a very treacherous investment, because of quite low volatility of currencies. The benefit of algorithmic trading lies in the ability to execute trades in a fraction of seconds, With always rotating currencies, where one can appreciate over another in second, with HFT would be possible for a trader to make a profit. Further implementation and usage of algorithmic trading strategies requires more research.

Summary

This study aimed to implement algorithmic trading strategies on the two most popular currency pairs EUR/USD, USD/JPY. The thesis also covers topics, FOREX exchange market, characteristics and relationship between EUR/USD and USD/JPY. and technical indicators. The historical data for selected currency pairs served as the base data for further computations. Exel has proven to be surprisingly sufficient, the research has shown the capability of Excel in backtesting algorithmic trading strategies. For professional traders,

Excel simply does not represent a perfect tool for testing strategies, but it is not counterproductive. There exist a various number of technical indicators, which are helping factors in determinating the financial market's movement. In conclusion, algorithmic trading requires a lot of enhanced knowledge in computer programs and design of algorithms. Exel is a publicly known platform with entrenched features more common to potential users.

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ACRONYMS

FX	FOREX exchange
NYSE	New York stock exchange
OTC	Over the counter market
NASDAQ	National association of securities dealers automated quotations
LSE	London stock exchange
USD	American dollar
GBP	British pound
JPY	Japanese yen
AUD	Austalian dollar
EUR	Euro
CHF	Swiss franc
CAD	Canadian dollar
NZD	New Zealand dollar
HFT	High frequency trading
FIX	Financial information exchange
MT5	Meta trader 5
CMF	Chaikin money flow
EMA	Exponencial moving average
MA	Moving average
SMA	Simple moving average
SUM	Sum
TEMA	Triple exponential moving average
ALD	Accumulation distribution line
MFM	Money flow multiplier
MFV	Money flow volume
RS	Relative strength
RSI	Relative strength index
AL	Average loss
AG	Average gain
ATR	Average true range
TR	True range
GPD	Gross domestic product
BoJ	Bank of Japan
FED	Federal reserve

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