

PALACKÝ UNIVERSITY OLOMOUC  
FACULTY OF ARTS

ALGORITHMIC TRADING STRATEGIES FOCUSED ON  
CRYPTOCURRENCIES

Bakalářská práce

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**Čestné prohlášení:**

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## Resumé

This work treats algorithmic trading and its application on the cryptocurrencies. Algorithmic trading is referring to the generation of buy and sell signals or orders by a computer algorithm and the management of these orders, without human intervention. Both cryptocurrencies and algorithmic trading part of the recent advancement in financial markets. A few trading strategies based on technical indicators are backtested in this study. The process of backtesting consist of evaluating the performance of algorithms on historical data. It is also usefull for improving these strategies. The strategies are then compared to a classic buy and hold strategy. The strategies appear to be less risky than holding one position over a long period of time. The strategies provide consistent results especially with the LTC/USD pair, for the BTC/USD even though most strategies were profitable, one of them was underperforming.

Tato práce pojednává o algoritmicke obchodování a jeho aplikaci na krypto-měnách. Algoritmicke obchodování slouží ke generování kupních a prodejních signálů nebo pomocí počítačových algoritmů a řízení těchto příkazů bez zásahu člověka. Jak krypto-měny, tak algoritmicke obchodování jsou součástí nedávného vývoje na finančních trzích. V této studii je zpětně testováno několik obchodních strategií založených na technických ukazatelích. Proces zpětného testování neboli backtesting spočívá v hodnocení výkonnosti algoritmů na historických datech. Tento process je taky užitečný pro zlepšení těchto strategií. Strategie jsou poté porovnány s klasickou strategií nákupu a držení. Strategie se zdají být méně riskantní než držet jednu pozici po dlouhou dobu. Strategie poskytují konzistentní výsledky, zejména s párem LTC / USD, pro BTC/USD, i když většina strategií byla zisková, jedna z nich byla nedostatečně výkonná.

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## **Introduction:**

In this bachelor thesis I am going to demonstrate the possibility of backtesting various algorithmic strategies for trading BTC/USD and LTC/USD. I will automate the process of backtesting in a simple and available software, the microsoft excel. The algorithms are based on popular technical indicators. I chosed this topic because I was introduced to regular trading last year in Sourh Korea during my Freemover student Exchange program. I appreciated this activity, but I wanted to extend my knowledge of trading in general and especially the domain of automated trading via different algorithmic computing techniques. This domain (I will use “Algorithmic trading” in the rest of the document) has been known now around for a couple of years and it is a common tool employed by professionals and offered by brokers (a broker is a company offering trading services to customers). (S. K. Rao, 2006).

In the extremely competitive financial markets, many new algorithms are being developed in the pursue of finding the best investement opportunities, genrating the highest possible gains with the lowest possible risks. This task reveal itself quite difficult especially in the long term. Some algorithms can become obsolete because of the adaptation and evolution of markets, others might be effective only in particular conditions. Lately, cryptocurrencies emerged as a subject of high interest in the field of finance. They have attracted the attention of business and investors around all the world. The cryptocurrency market is higly volatile. I will provide results of backtested strategies for the respective historical data. The performance of the chosen algorithmic trading strategies computed in excel (in terms of total revenues/losses, average buy and sell price, total of buy and sell orders) will be compared in the respective time-period and overall and the buy and hold strategy will be used as a universal benchmark.

# **THEORETICAL PART**

## **1 Definitions**

### **1.1 Financial market**

A financial market is a market in which people trade financial securities and derivatives such as futures and options at low transaction costs. Securities include stocks and bonds, and precious metals. The most known financial markets are New York Stock Exchange, the Nasdaq or the Tokyo stock exchange. In the technology domain, the most important financial market is Nasdaq (National Association of Securities Dealers Automated Quotations), which gathers the largest companies like Google, Apple, Facebook, Amazon (group also called GAFA). Unlike others financial market, the Nasdaq includes all inscribed companies to calculate its index (a reference value indicating the health of the market and which is progressively increasing, with times of minor pullbacks).

The financial markets experienced a large expansion in the recent years, as well in their growing indexes as in the transactions volume. This is due to the technological innovations, economic development, and globalization. (Karin Knorr Cetina and Urs Bruegger,2002).

Many people started their trading activities in the Over the Counter Market (OTC). The OTC differs from the classical financial markets (as the Nasdaq named above) on two points:

- Assets are exchanged. An asset can be a security but also includes currencies and commodities, It is possible to trade financial derivatives (futures, options, forwards contracts etc.) as well.
- The ways those assets are exchanged. There is no marketplace with centrally fixed prices, instead the trades are negotiated and executed online or via phones, by the market participants who are companies, individuals, corporations and market makers – brokers.



We will distinguish the buy and hold strategy from trading as two ways of achieving gains.

## 1.2 Trading

Three actions are naturally associated to trading – buy, sell and hold. One will hope to make profit by making the right decisions, - buying a promising asset, whose price should rise in the near future, or selling one, because of an expected decrease. He can also keep the asset expecting a long-term value.

But apart from these actions, other ways of trading are made available thanks to financial derivatives. Strangely enough, generating profits with those financial derivatives is not tied to the raise, decrease or still price of assets : when the price of an asset does not move (or at least not too much) it is possible to make profits/losses.

It's interesting to go a bit deeper in the mechanics of those financial derivatives, to illustrate the complexity of the trading world.

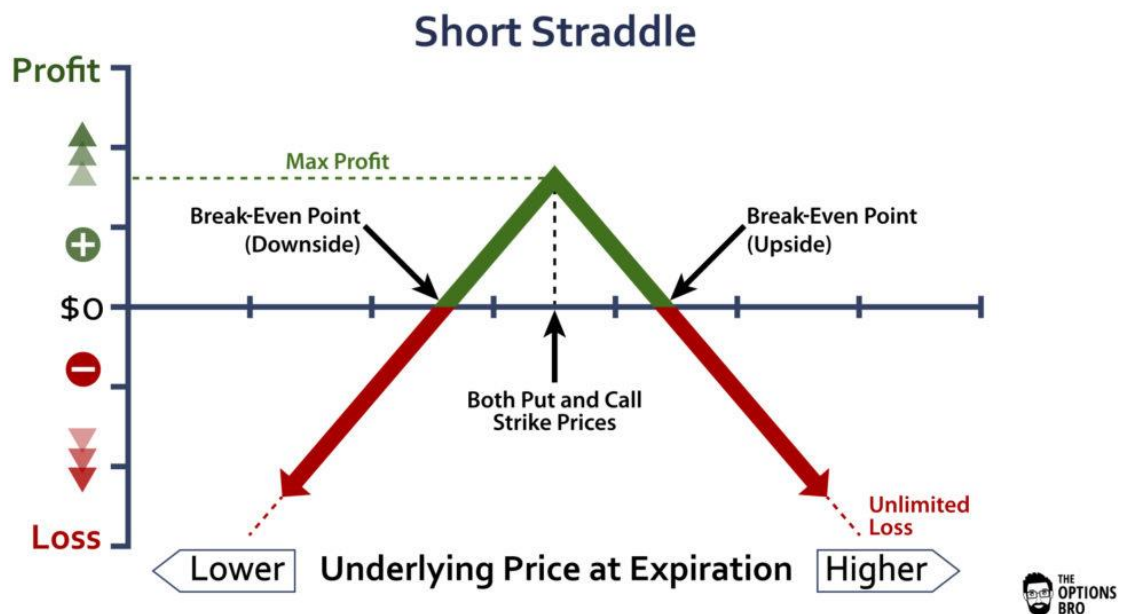


Figure 1 : Short strangle

Let us take for example the options. An option is a financial derivative allowing one to bet on the future price of an asset.

The “Short Strangle“ situation, showed on the schema (figure 1 above) can be explained like this: the spot price (the current price) is used as the reference for the strike price (the price at which the investor can buy the asset until or at the date of expiration) and an investor decide to short a put option and short a call option of an underlying asset at the same time. In this case when the underlying price of an asset at the time of maturity of the option is the same as the pre agreed Strike price, the investor who has short both option will not lose any money and keep the amount they received for shorting these options. However this position is extremely risky, especially for highly volatile markets. If there is a heavy increase or decrease in the underlying asset price, the investor may lose high amounts of money, therefore usually only trusted parties with large capital are allowed to short options (John C. Hull, 2012). The position is showed in figure 1.0. One of the most important factor to consider when trading is the time of opening and closing a positions. It means choising the side(position) of buyer or seller. Typically Contract for difference (CFD) are traded instead of trading directly the cryptocurrencies. CFD is a contract were both parties agree to pay the difference (negative or positive) after a position is closed.

### **1.3 Buy and hold**

If trading is very dynamic and active by nature, there are other strategies used by market participants, more interested in long-term investment. The most known is named „buy and hold“ strategy, and consist to take a buying decision on an asset (made on deep domain analysis or aligned with some business perspective of the company) and hold it a long amount of time (despite of short-term price movement). This is clearly a more passive strategy and not really in the scope of this work. With this strategy the investor can consider both, a CFD or directly buying a cryptocurrency.

## **2 Market analysis**

This chapter will present different ways to analyse the financial markets, in order to predict (or at least try) the future of assets value evolution.

### **2.1 Technical analysis strategy**

The technical analysis is entirely based on historical prices fluctuations. It is a very old strategy whose first real usages can be found in the 17th century Dutch financial markets. A great contributor to the diffusion of the many aspects of this strategy is Richard W. Schabacker, who has published several books on the subject.

It is now a popular trade method used by many traders sometimes referenced as „chartists“. Those fluctuations are used to calculate special values, called „indicators“. The calculus is usually based on volume, open prices, closed prices, high prices, low prices. More types of indicators exist, like trend indicators, momentum indicators (also named oscillators), or volume indicators. The formula defining those calculus will be presented in the chapter 4.

### **2.2 Fundamental analysis strategy**

Fundamental analysis of any asset is very different from technical analysis. It stand on analyzing economic factors that might affect the price of an asset. These factors are various macroeconomic factors as the interest rates, GDP, inflation, microeconomic factors as businesses revenues, the supply and demand, to name few examples. It can also be anything else as for instance political situation, media statements, intense lobbying by the industry or judicial challenges.

### **2.3 Pairs trading strategy**

Pairs trading is defined as a statistical arbitrage, where the prices of several financial instruments are moving together in the same direction. Habitually these instruments are related to each other or one is influencing another, as an example I can state the value of Canadian Dollar (CAD) which partially depends on the value of crude oil, as Canada is a large oil exporter. When the price of such instruments starts to diverge or create a spread, pairs trading imply selling the instrument which is currently increasing

its price compared to the other instrument. On the contrary, the second instrument is bought. Assuming history is repeating itself, the prices should move toward each other again, and thus the investor will obtain profit (Gatev, Evan Goetzmann, William N. Rouwenhorst, K. Geert, 2006).

## **2.4 Order anticipation strategy**

Order anticipation is a kind of strategy that aims to predict large orders creation. In doing so, traders can take advantage of other traders by trading ahead of them. Since large orders attract investors, the strategy consists in buying before these orders are realized and selling for a higher price afterwards. This is a basic way of how order anticipation strategies are designed to make profit, but the traders can also sell them directly to the large orderer when his order needs to trade on multiple platforms to fill itself.

## **3 Algorithmic trading**

This chapter will provide a brief explication of algorithmic trading. This new financial feature uses intensively mathematical models, computers and telecommunications networks to automate the buying, selling or holding decisions. Algorithmic trading created new challenges and also opportunities for the financial industry and its regulators.

The computer-based automation has improved trading by reducing human error, lowering costs and increasing its productivity.

Algorithmic trading has become a permanent and important part of the financial environment because it can save costs and permit bigger operating efficiency.

As wrote Andrei A. Kirilenko and Andrew W. Lo in the paper called Moore's Law versus Murphy's Law: Algorithmic Trading and Its Discontents 2013:

“Thanks to the twin forces of competition and innovation, the drive toward “faster, cheaper, and better” is as inexorable as it is profitable, and the financial industry is no stranger to such pressures.”

The common usage of computer algorithms for handling trading orders began 25 years ago (Chaboud, Alain P.Chiquoine, Benjamin Hjalmarsson, Erik Vega, 2014). Algorithmic trading (AT), also called automated trading, is referring to the generation of buy and sell signals or orders by a computer algorithm and the management of these orders, without human intervention. (Algorithmic trading: pros and cons) define AT more precisely : „Algorithmic trading can be defined as placing a buy or sell order of a defined quantity into a quantitative model that automatically generates the timing of orders and the size of orders based on goals specified by the parameters and constraints of the algorithm“.

According to (Terrence Hendershott, 2011), more than 73% of the traded volume is assigned to AT in the United States in 2009.

Over the last twenty years, algorithmic trading has been facilitated by three major trends in the financial sector.

The first is that the financial system has become more complex because of economic growth and globalization in the world. As a result, the number of market participants as well as the variety of financial transactions, the amounts involved and the distribution of risks increased.

The second trend is the development of "financial technology", quantitative models of financial markets that have been developed by the great scholar actors of the financial economy, such as Black, Cox, Fama, Lintner, Markowitz, Merton, Miller, Modigliani, Ross, Samuelson, Scholes, Sharpe and others. Based on them, modern quantitative financial analysis and also algorithmic trading are developed and improved.

The third is a huge improvement in computer technology, hardware, software, data availability and their interconnections as like as their electronic accessibility.

AT has advantages compared to regular trading. It can execute trades and process informations much faster than humans are able to do.

AT strategies are based on traditional market analysis strategies (presented in the previous chapter) coupled with quantitative models and computing facilities. Combining all thoses methods and approaches results in a huge variety of AT strategies. Additionally these different approaches can be combined together.

The first type of strategies is based entirely on technical analysis and traditional trading indicators as relative strength index, moving average, or the Fibonacci sequence.

(Huang, Boming Huan, Yuxiang Xu, Li Da Zheng, Lirong Zou, Zhuo, 2019). I am going to discuss trading indicators and explain more about strategies using them in the chapter 4.

### **3.1 AT and market analysis**

#### **3.1.1 Technical analysis**

AT brings added value by allowing more complex formulas for indicators and more data to crunch.

#### **3.1.2 Fundamental analysis**

AT doesn't bring a lot of value to those strategies, because of the complexity of the models and also the long-term orientation of fundamental analysis.

#### **3.1.3 Order anticipation**

In the case where a large order is not publicly displayed, algorithmic traders have ways to search for them. Pinging is one of them, in which traders send small orders to detect if they match another order, if they do, the algorithm knows about it and is designed to react and adapt its trading strategies.

Another way to find hidden orders is to predict them before they exist. This type of order anticipation is highly dependent on algorithms and analysis of data and statistics, it's similar to the basic algorithmic trade strategy but designed to target large orders.

#### **3.1.4 Arbitrage trading**

Many new brokers and other market players are present in the forex, and theoretically, not all exchange rates are exactly equal at some point of time. Trading robots can scan the market for the purpose of finding arbitrage opportunities. In general arbitrage trading is one of the 3 main types of trading, the other ones being speculation and hedging. Arbitrage consist of Such opportunities could take place for example when two brokers fix distinct prices on the same instrument at the same time, in this case it is enough to sell the instrument to one market maker and simultaneously buy it from the other.

### **3.1.5 Trigger trading**

The Trigger trades is an algorithmic trading strategy that allows to quickly send orders from a computer to trade, buy or sell assets. This strategy is called the „trigger trades“ because the algorithms observe the market and once the condition set by the user occurs it triggers a series of orders (for example an order to purchase shares as soon as their value reaches 20 \$) (Yesha Yadav, 2015).

### **3.2 High frequency trading**

High Frequency Trading (HFT) principles lies in the massive execution of trades over a short period of time. "HFT firms typically trade hundreds or thousands of times per day, with a typical holding period measured in seconds or minutes“ (Jones, Charles M. 2013), the positions are for example not hold over night. Gains or losses generally represent only few pips. A pip is the acronym for "percentage in point" For example for the major currency pairs, like the USD/GBP, one pip is 0.0001 USD (or GBP). For the BTC/USD it offen represent 0,1 USD but it can be more or less depending on the broker. Recently the term ultra-high frequency trading appeared, which is even faster than HFT and can execute trades in milliseconds. The HFT and UHFT are used by market-makers to adapt their ask and bid prices as quickly as possible according to the newest market informations. (Charles M. Jones\*,2013) This prevent some losses, caused by slow reaction to price movements. The majority of research untill today shows that HFT is lowering trading costs and increasing liquidity. But there are also some disadvantages, for example the Market participants which do not have the capital to afford trading technology could be in disadvantage (Michael Chlistalla, 2011).

As the most used type of trading, hyper-frequency trading can be hard to differentiate from others since its main characteristics, necessary use of algorithms and securities changing hands in milliseconds, are also present in slightly slower (still in milliseconds) tradings.

Since real-time management of trades is not possible for hyper-frequency trading, traders have to rely entirely on their algorithms, whence their vital importance. To operate such rapid trades, equipment is also important to be able to analyse large volumes of data. Moreover, algorithms also have to process and analyse news rapidly by focusing on key

words, this can sometimes be risky as the faster the analysis is , the better the results. But faster algorithms analyse news, faster they are prone to errors.(Yesha Yadav 2015)

Some european countries desire to regulate HFT as it may have negative consequences on markets. This new subject is subject to furhter research.

With very short holding period, high-frequency trading has hard time when it comes to be highly and rapidly lucrative but it does provide traders with crucial advantages : if hyper-frequency trading can't make traders gain a lot of money rapidly it also can't make them loose money rapidly. Moreover, algorithms assure a cheaply exit on the trades and traders almost never have to assume high risks.

The job of a hyper-frequency trader is not the same as the usual one, as he has to anticipate and predict future changes on the next few seconds of the market and not over relatively long periods of time.

## **4 Cryptocurrencies**

Today there are many types of currencies. Many states have their own currencies. Means of payment and money have developed over time, from the commodity currency, passing through the metal currency, to the first bank notes. Thanks to the technologies the currency can circulate and be stored virtually, the majorities of the operations can be carried out on Internet, acutaly around 85% of the money supply is virtual. A new form of currency has appeared recently, the cryptocurrency. It has rapidly emerged in the past few years and has been the subject of much debate by the public and the media as well as speculation and criticism from investors and academics. First I will write about the history of cryptocurrencies then I will describe their fonctionning and the cryptography technology, afterwards I will try to discuss their advantages and disadvantage. I am also going to founnish some statistical data.

### **4.1 History and fonctionning**

Cryptocurrencies are a form of digital currency (Usman Cholan, 2017), that is based on the cryptography technology. This technology ensures the security of



payments and the issue of coins. The first cryptocurrency called Bitcoin was launched in January 2009. This cryptocurrency was created by an individual or a group called Satoshi Nakamoto, this name is just a pseudonym and the inventor or inventors are not known. Bitcoin remains today the number one of cryptocurrency in the world. The bitcoin can be divided by 100 million to get the smallest unit named Satoshi which are named after its creator. One of the first mention about an anonymous, distributed electronic cash system based on the cryptography technology is described in b-money which was published by Wei Dai in 1998. To perform a transaction between two bitcoin accounts, it is necessary to note the sender's and receiver's address and the amount traded. It is necessary to use a personal key that serves as a digital signature to confirm the possession of bitcoins. The receiver must check if there is not another transaction in progress (not validated) with the same shipping address in a register which contains all the previous transactions. This register is called the blockchain (Herrera-Joancomartí, Jordi, 2015).

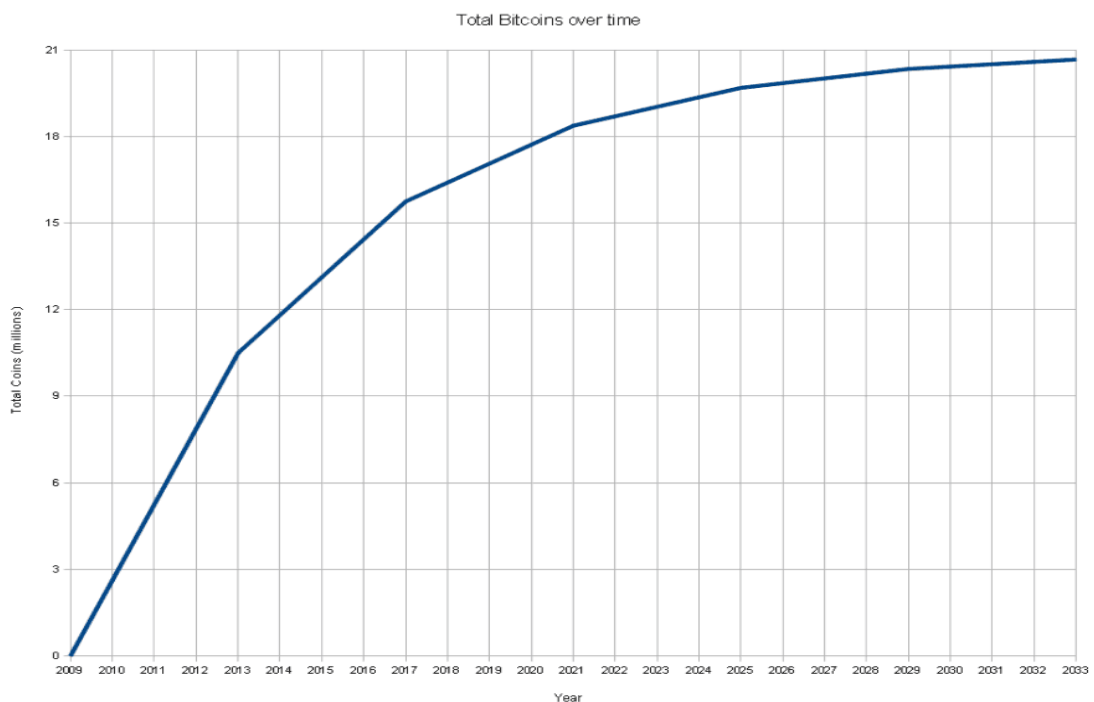


Figure 2 : Bitcoin supply

The creation of money supply was exactly defined at the initiation of Bitcoin. It has a limit (not infinite) of units that is reached in a specific time in the future and the evolution of the rate of creation of money supply is given by an algorithm (we see the speed of creation on the graph below). This limit is 21 million units, it will be reached in

2140. Bitcoin cash, another cryptocurrency will reach the same limit in the year 2050. This currency can be compared to the gold in term of supply, which is also limited. We also use the same term: mining for the exploitation of new resources, here the new bitcoin units. Mining is a process of calculations that solve and unblock access to new blocks (bitcoins), miners receive the units they find in exchange for calculations they perform with their machines. The Each cryptocurrency is a little different from the others, that concerns their prices, their total units, as well as their technical properties and characteristics as the transaction speed, the encoding of addresses, the security, the degree of anonymity etc. The factors that influence the prices of cryptocurrencies are especially: news and trends, often also false news. The number of transactions and the speed of circulation are also a decisive aspects. As an example we can name the official ban on cryptocurrencies in China ([bitcoinist.com](http://bitcoinist.com)), currently this country is trying to prevent access to foreign cryptocurrency trading platforms. For the false news we can take the example of South Korea ([www.forbes.com](http://www.forbes.com)), where the Ministry of Justice announced a plan to prohibit the trade of these currencies. There is a lot of news on the internet about this subject, but we must be able to identify the ones that are valid and those that have a real impact on cryptocurrencies prices. To predict future prices and profitability, traders say: "Buy the rumor and sell the news". Cryptocurrencies are decentralized, they are not controlled by governments, they are only subject to the laws of the market, for example the supply and demand, if demand increases the price also increase and vice versa. Technical analysis of price developments, including historical charts, also partly predict these prices.

In 2014 there was a new wave of cryptocurrency, notably Ethereum and Monero. Many other cryptocurrencies have been created so far and new ones will very probably continue to be created in the future.

## **4.2 Advantages**

This new form of money has many advantages over classical currencies. Among the main ones we consider the following: First it allows to make transactions quickly and easily, the duration of the transaction is about 10 minutes, this is beneficial especially

for international payments and for payments between different banks, where the transactions usually takes few days to complete. The cryptocurrencies can accelerate international trade, flows of goods and services. The system is transparent and traceable.

Then, as I have already said, cryptocurrencies are not controlled by the government of a particular country. The governments have no possibility to increase the money supply and therefore its users do not have to worry about the decisions on monetary policies of the state that can cause inflation of the currency. The "benevolence" of the state is not certain, one can take the example of the hyperinflation of the Zimbabwe dollar in 2008 where the central bank failed to calculate the rate of inflation, gave a false report on this rate. The government was using inflation as a tool to clear off political opponents (Jayson Coomer and Thomas Gstraunthaler). Money has always been regulated by the state in history, but recently economic agents are free to make choices about the used currency. Cryptocurrencies may represent a competition for the monopolies of classic currencies, which will have to try to hold their leader position in a larger currency market. This feature of the cryptocurrencies was already highlighted at the time when they did not exist by the renowned economist Milton Friedman (6). He mentioned several times that the federal bank system should replace the governors with a computer. A network that would not be controlled or managed by any authority. This predefined system would have an order and would be more reliable and predictable.

Cryptocurrencies offer greater privacy of payments. The information is a priori anonymous, but with a little effort and some computer skills it is often possible to trace users (Eli Ben-Sasson, Alessandro Chiesa, 2014). There are also cryptocurrencies as Zerocash trying to answer this problem by introducing the concept of a non-anonymous basecoin, which exist alongside with the zerocash. It is possible to proof the ownership of some coins without revealing the amount and identity (a zero-knowledge proof). The Basecoin can be converted to Zerocash anytime. It is more secure and it is impossible to find private information on its users. However, we will see that this may have negative effects. Payments by cryptocurrency remains in principle less anonymous than in cash, but more anonymous than by transfer or card. Unfortunately these currencies are not perfect, they also have some inconveniences. This apply also for the privacy of payments and it is mandatory to point out some negative attributes.

### 4.3 Disadvantages

Firstly the price of cryptocurrencies is unstable, investments in these currencies are accompanied by very high risks because the prices changes from one second to another, this effect apply for most currencies, but the fluctuations are usually much smaller. According to [www.investopedia.com](http://www.investopedia.com) bitcoin has a volatility ten times higher than the dollar. The volatility is shown using on the chart page XY. Cryptocurrencies have a great weakness which is the difficulty of making thrifts, they do not perform well in one of the three main functions of money, the storage of wealth. While many people who have invested in cryptocurrencies made a profit, many others have lost money. This is especially valid for people who have no decent knowledge of the economy and factors that influence the prices of cryptocurrencies.

Bitcoin has begun to play a growing role in illegal activities, mainly on the dark web. The dark web is a part of the World Wide Web, just like the deep web that forms most of the internet (90%), darkweb is just 6%. Bitcoin is actively used in the buying and selling of illegal goods and services on the dark web. This includes money laundering, cybercrime, illegal drugs and trade, the financing of terrorism (Gabriel Weimann), trafficking in human beings, child pornography, illegal software and documents such as passports, cards, identities, university degrees etc. About half of all bitcoin transactions involve illegal transactions either directly or indirectly on the dark web. In conclusion the cryptocurrencies facilitate and make accessible crimes and obscure desires.

Secondly, cryptocurrencies are also not totally secure against theft. There have been some incidents in the history of Bitcoin caused by problematic or malicious transactions. In the worst of these incidents, and the only one of its kind, someone created an illusion of an infinite possession of Bitcoin for almost 9 hours (10). It is mostly the public keys that can be vulnerable to computer attacks. Today's cryptocurrencies may stand in front of development challenges. With the quick technological development of recent years, the cryptocurrencies will also have to follow this direction and progress, otherwise there is a potential danger from other new technologies they will have instruments to attack and even destroy the current cryptography technology. In addition to software threats, there are also criminals who extort money (Bitcoins, Litecoins, etc.) by stealing laptops or other hardware from unsuspecting victims. In addition there are victims of

cybercriminals on gaming sites and also victims of prestigious companies and the financial and entertainment sectors (11). Other currencies like Dash, Monero, litecoin are starting to be popular on the dark web, Zcoin and Zcash may be ideal candidates for these activities.

Mining is accompanied by a massive electricity consumption. The consumed electricity represents additional costs and therefore they depreciate the value of cryptocurrencies. Even though renewable energy resources (solar, hydro, wind, etc.) start to form a large part of the electricity production, there are still nuclear power plants that reduce uranium reserves and pollute the earth. We see that cryptocurrencies have an impact on many aspects of life.

#### 4.4 Statistics

If we look at the extent of the cryptocurrency market we can see that at this moment (10.04.2019) the value of this market is 180 billion dollars which is more or less equivalent to the Algerian GDP. The Bitcoin counts for 51,2% and Litecoin for 2,96% of the total market capitalization. The market capital peaked over 800 billion USD in January 8th 2018. There are around 1600 cryptocurrencies and many more are in development. We can see the evolution of the total market value on the following graph: (coinmarketcap.com)



Figure 3 : Market capitalization of cryptocurrencies

|              | Total Value      | Value of one coin | Number of coins | Volume traded in the last 24hours |
|--------------|------------------|-------------------|-----------------|-----------------------------------|
| Bitcoin      | \$93 918 439 274 | \$5 324,55        | 17 655 610      | \$15 504 590 933                  |
| Ethereum     | \$18 728 058 767 | \$177,34          | 105 735 145     | \$7 856 924 879                   |
| Ripple       | \$14 827 516 669 | \$0,354792        | 41 970 748 022  | \$1 213 341 089                   |
| Bitcoin Cash | \$5 408 935 312  | \$305,22          | 17 738 421      | \$1 476 621 660                   |
| Litecoin     | \$5 416 155 738  | \$88,38           | 5 416 155 738   | \$2 765 900 677                   |

Table 1

Here are some statistics for the 5 largest cryptocurrencies (10.04.2019):

By the end of 2017 and the first month of 2018, bitcoin transaction fees have dramatically increased. It was a stimulus for Bitcoins owners to sell their assets. With rising fees at the end of 2017, companies have begun to withdraw from the network. Bitpay, which offers the transaction management service between users, has set up a minimum transaction amount of \$100 for a moment. The reaction from consumers was very negative and the firm decided to lower the minimum amount to \$ 5. Because of these problems the companies decided to stop to support the payments via cryptocurrencies. For example, a video game maker Valve stopped accepting payments from Bitcoin for its Steam platform in December 2017. Then, Stripe, a major credit card processor, also stopped accepting Bitcoin payments for its customers in January 2018, arguing that because to the very high fees there were fewer and fewer users in the payment network (Timothy B. Lee, 2018). As Bitcoin's transaction fees were on the rise, many companies started using other cryptocurrencies like Ethereum, Monero or Bitcoin Cash which resulted the increase of these cryptocurrencies.

## 5 Chart indicators:

In this chapter I will describe few technical chart indicators that are used in the strategies and which are build on the technical analysis

### 5.1 The Stochastic Oscillator

The stochastic oscillator is an indicator which measures the momentum, as it's name indicates, the indicator oscillate around a central point or channel. Typically the channel ranges from the values of 20 to 80. This indicator is calculated for each selected period of time (for each candlestick bar), for example it can be a minute, an hour, 4 hours or a day. (Moldovan, D. Mircea, M. Nitchi, Si). The limitation of this indicator is it's inability to identify market trends. For this purpose other indicators as various types of moving averages are employed. This oscilattor is used to identify overbought or overselled conditions. (P.Fernández-Blanco, D.Bodas-Sagi, F.Soltero, J.I.Hidalgo, 2008). The formula for calculating this indicator is:

$$K = 100 \times (C - L_n) / (H_n - L_n)$$

Where K is a value of the stochastic indicator, which is ranging from 0-100, because the value of  $H_n \geq C$  and both of these values are positive  $\rightarrow$

$$0 > (C - L_n) / (H_n - L_n) > 1$$

C is the closing price at the current candlestick/periods.

H is the Highest price of the last n candlesticks/periods.

L is the Lowest price of the last n candlesticks/periods.

I will use this indicator for generating buy and sell signals.

(MURAT ÖZTÜRK 2015)

D = 3day moving average of K

Which is the sum of values for the last 3 periods of K divided by 3.

## 5.2 On-Balance Volume

On-Balance Volume, or OBV, is a momentum indicator that continuously measures the flow of the total number of shares or contracts of a security or a whole market. If this flow tend to go up, it's probable that the price is about to increase.

## 5.3 MACD

The Moving Average Convergence Divergence (MACD) is a popular indicator created by Gerald Appel in the 1970. To calculate the MACD indicator it is required beforehand to compute two Exponential moving averages (EMA).The simple moving average(SMA), also sometimes referred to as arithmetic moving average is the average price of the n previous periods. The general formula for a moving average is as follow(Ramazan Gencay, Thanasis Stengos, 1998):

$$MA = \left(\frac{1}{n}\right) \times \sum_{i=0}^{n-1} (C_{t-i})$$

Where MA represent moving average and  $C_t$  is the close price for each n periods. In contrast with the SMA, the EMA contribute more importance to recent prices. The closer the period is to the current price, the greater is it's weight in the EMA indicator. The EMA takes into account previous EMA values: Since I have limited access to historical data, I cannot compute this indicator unless I compute the first value of EMA with the value of SMA.

Here is the formula for EMA and MACD:

$$EMA_t = (Close - EMA_{t-1}) \times \left(\frac{2}{n+1}\right) + EMA_{t-1}$$

$$MACD = EMA_{12} - EMA_{26}$$

The MACD is calculated by substracting the longer EMA(close price, 26 periods) from the shorter EMA (close price,12periods). Unlike the stochastic oscillator, MACD takes into consideration more aspects as the momentum, the trend strength and direction as well as the inversion of trends. As the indicator emphasize the most current movements in prices it should follow closely the underlying security. Therefore the indications will not



be false too long. (Seyed Hadi Mir Yazdi and Ziba Habibi Lashkari 2013). This however might not always be true for high volatility markets as cryptocurrencies are. The indicator is also suitable for hourly, daily, weekly or monthly tick data. Its parameters can be adjusted to better fit in these different timeframes, or markets/assets.

#### **5.4 VWAP**

Volume Weighted Average Price (VWAP) is an indicator, that can be used as a guideline to help us get some information about the trade graph. It can be described as a line going through the graph similarly to a moving average and its value is derived from the price and volume of traded asset. It can be easily mistaken for moving average but in moving average the calculation of volume is not counted in. It tells us about the trend and the value of an asset.

Rising volume weighted average price and its value being above the real price of the instrument means the price is plausible to go up. Declining volume weighted average price and its value being under the real price of the asset means the price is plausible to go down. Many investors use this guide as an accessing tool to tell if they bought at the right time of the day. If the price they paid during the day is higher than the volume weighted average price, the investor had likely paid more than he could. If the price they paid during the day is lower than the volume weighted average price, the investor had made a right call and bought at the right time. Volume weighted average price can be calculated by the formula:

$$\text{VWAP} = \frac{\sum \text{Price} * \text{Volume}}{\sum \text{Volume}}$$

The calculation is done by summing up the amount of money traded and dividing it by total volume of trades. To calculate it yourself, you must take a period and add up high, low and close values and divide them by three. This value is the average price of the asset. If you divide the average price multiplied by volume by the total volume of the asset traded over a day you get the volume weighted average price.

Small investors and retail traders use volume weighted average price as a tool of confirmation for their trades. If the volume weighted average price is below the price they only look for long positions. If the price is above the volume weighted average price they only look for short positions.

It may seem that volume weighted average price is a great benchmark, but it is a one-day indicator that restarts at the beginning of each new day. Trying to count in more days would get us further from the true value of the volume weighted average price. Also considering strong uptrends, the price will rise for a few days without sinking below the volume weighted average price so to conclude, this indicator should not be used as the only assessment of the market. I am not going to use this indicators in my strategies since, typically it is used when trading on shorter periods but I wanted to provide an example of a volume based indicator.

## 5.5 RSI

The relative Strength Index (RSI) is a convenient for validation for entering a position. It can also be used effectively (Seyed Hadi Mir Yazdi, Ziba Habibi Lashkari, Izlin Binti Ismail 2015?). for recognizing divergences of the price movements relative to the indicator movements. The formula for computing this index which value is ranging between 0 and 100 is:

$$RSI = 100 - [100 / (1 + (\text{Average loss} / \text{Average gain}))]$$

The average gain(AG) is the sum of positive changes in the close prices between two periods, for the last n periods. including the current one divided by N. In our backtest 14 periods are taken into account for the calculation. The average loss(AL) is the sum of negative movement in price over each period, divided by 14

$$AL = ([AL(\text{prev})] \times 13 + \text{Loss}) / 14$$

$$AG = ([AG(\text{prev})] \times 13 + \text{Gain}) / 14$$

In the equation above, Loss is the negative difference between current and previous period's close price, Gain is the positive difference.(MURAT ÖZTÜRK 2015)

Since these formulas require previous data for computing the RSI and I do not have access to all data for the backtested currencies, I will use the following formula to calculate the first value of RSI:

$$AL = \left(\frac{1}{n}\right) \times \sum_{i=0}^{n-1} (C_{t-i+1} - C_{t-i})$$

The employed period is n=14

$C_t$  is the current Close price

### 5.6 Rate of Change

Rate of Change, or ROC, is an indicator that compares the current close price and the close price n periods ago and in doing so as its names indicates, shows how fast the price changes in a specified period. The calculation of the indicator is as follows:

$$ROC = (Close - Close(\text{prev}, N)) / Close(\text{prev}, N) * 100$$

where N is the period, ROC is the rate of change value, Close is the current close price and Close(prev, N) is the close price N periods ago.

| I     | J      | K    | L    | M        | N        | O        | P        | Q      | R          | S           | T         | U          | V | W | X | Y | Z | AA | AB |
|-------|--------|------|------|----------|----------|----------|----------|--------|------------|-------------|-----------|------------|---|---|---|---|---|----|----|
| close | CHANGE | GAIN | LOSS | AVE GAIN | AVE LOSS | RS       | RSI 14   |        |            |             |           |            |   |   |   |   |   |    |    |
| 17878 |        |      |      |          |          |          |          |        |            |             |           |            |   |   |   |   |   |    |    |
| 17476 |        |      |      |          |          |          |          |        |            |             |           |            |   |   |   |   |   |    |    |
| 17567 | 91     | 91   | 0    |          |          |          |          | 1.den  |            |             |           |            |   |   |   |   |   |    |    |
| 17444 | -123   | 0    | 123  |          |          |          |          | 2.den  |            |             |           |            |   |   |   |   |   |    |    |
| 17173 | -271   | 0    | 271  |          |          |          |          | 3.den  |            |             |           |            |   |   |   |   |   |    |    |
| 17709 | 536    | 536  | 0    |          |          |          |          | 4.den  |            |             |           |            |   |   |   |   |   |    |    |
| 17879 | 170    | 170  | 0    |          |          |          |          | 5.den  |            |             |           |            |   |   |   |   |   |    |    |
| 18673 | 794    | 794  | 0    |          |          |          |          | 6.den  |            |             |           |            |   |   |   |   |   |    |    |
| 19084 | 411    | 411  | 0    |          |          |          |          | 7.den  |            |             |           |            |   |   |   |   |   |    |    |
| 19084 | 0      | 0    | 0    |          |          |          |          | 8.den  |            |             |           |            |   |   |   |   |   |    |    |
| 18960 | -124   | 0    | 124  |          |          |          |          | 9.den  |            |             |           |            |   |   |   |   |   |    |    |
| 19450 | 490    | 490  | 0    |          |          |          |          | 10.den |            |             |           |            |   |   |   |   |   |    |    |
| 19656 | 206    | 206  | 0    |          |          |          |          | 11.den |            |             |           |            |   |   |   |   |   |    |    |
| 19242 | -414   | 0    | 414  |          |          |          |          | 10.den |            |             |           |            |   |   |   |   |   |    |    |
| 18731 | -511   | 0    | 511  |          |          |          |          | 13.den |            |             |           |            |   |   |   |   |   |    |    |
| 18786 | 55     | 55   | 0    | 196,6429 | 103,0714 | 1,907831 | 65,6101  | 14.den | buy signal | sell signal | buy price | sell price |   |   |   |   |   |    |    |
| 18331 | -455   | 0    | 455  | 182,5969 | 128,2092 | 1,424211 | 58,74947 |        |            |             |           |            |   |   |   |   |   |    |    |
| 18454 | 123    | 123  | 0    | 178,34   | 119,0514 | 1,498009 | 59,96811 |        |            |             |           |            |   |   |   |   |   |    |    |
| 18944 | 490    | 490  | 0    | 200,6014 | 110,5477 | 1,814614 | 64,47115 |        |            |             |           |            |   |   |   |   |   |    |    |
| 18580 | -364   | 0    | 364  | 186,2728 | 128,6514 | 1,447887 | 59,14844 |        |            |             |           |            |   |   |   |   |   |    |    |
| 18574 | -6     | 0    | 6    | 172,9676 | 119,8906 | 1,442711 | 59,06188 |        |            |             |           |            |   |   |   |   |   |    |    |
| 18749 | 175    | 175  | 0    | 173,1127 | 111,327  | 1,554993 | 60,86095 |        |            |             |           |            |   |   |   |   |   |    |    |
| 18725 | -24    | 0    | 24   | 160,7475 | 105,0894 | 1,529627 | 60,46848 |        |            |             |           |            |   |   |   |   |   |    |    |
| 18476 | -249   | 0    | 249  | 149,2656 | 115,3687 | 1,293813 | 56,40448 |        |            |             |           |            |   |   |   |   |   |    |    |
| 17423 | -1053  | 0    | 1053 | 138,6038 | 182,3424 | 0,760129 | 43,18599 |        |            |             |           |            |   |   |   |   |   |    |    |
| 17501 | 78     | 78   | 0    | 134,2749 | 169,3179 | 0,793034 | 44,22862 |        |            |             |           |            |   |   |   |   |   |    |    |
| 17474 | -27    | 0    | 27   | 124,6838 | 159,1523 | 0,783425 | 43,9281  |        |            |             |           |            |   |   |   |   |   |    |    |
| 17219 | -255   | 0    | 255  | 115,7779 | 165,9986 | 0,697463 | 41,08855 |        |            |             |           |            |   |   |   |   |   |    |    |
| 16535 | -684   | 0    | 684  | 107,508  | 202,9987 | 0,529599 | 34,62341 |        |            |             |           |            |   |   |   |   |   |    |    |
| 16203 | -332   | 0    | 332  | 99,82887 | 212,2131 | 0,470418 | 31,99213 |        |            |             |           |            |   |   |   |   |   |    |    |
| 17195 | 992    | 992  | 0    | 163,5554 | 197,055  | 0,829999 | 45,35515 |        |            |             |           |            |   |   |   |   |   |    |    |

Figure 4: Calculation in the Excel Work\_sheet

## 6 Methodology

The historical data is taken from ava metatrader platform. Metaquotes Software Corp is the provider of the data used in this research. The time period is 4hours long, and for every scheduled time period there are 5 input. Open, low, high and Close price and volume are all available. Where open price reffers to earliest data in 4 hours range and close price reffers to latest data in these 4 hours period. Low represent the lowest and high

the highest price throughout the period. These data are manipulated to obtain the value of indicators which then serve as signals for buying and selling. A total of 2048 records from 21.12.2017 to 11.04.2019 are available for the LTC/USD and 2847 records from 21.12.2017 to 11.04.2019 for LTC/USD pair. The algorithms are possibly created by traders, who are developing them by testing their performance on historical data. This process is called the backtesting. (Ernest P.CHAN, 2017).

In this research I will backtest some of these algorithms on Cryptocurrencies, first on BTC/USD, then LTC/USD. These simulations are done not only to evaluate the potential of the strategies, but mostly to correct and improve them (Treleaven, Philip Galas, Michal Lalchand, Vidhi, 2013). We have to note that positive results of backtesting these strategies do not guarantee any profits in the present market real conditions. This is true especially when applying these strategies only to one time period and one asset pair, because all the data from this period and pair could have been processed to form a perfect AT strategy. Moreover transaction costs are overlooked, in real market time and conditions the marketmakers want their part of the cake. The spread of ask and bid prices may vary but generally is not bigger than a few pips. To recall a pip is the acronym for „percentage in point“. The quantities traded in the backtest are always equal to one lot (10 BTC) and one mini lot (100 LTC), this means  
Here are the btc/usd (graph1.0) and LTC/USD (graph 1.1) exchange rates over the backtested periods:

As past data is needed to evaluate the values of indicators, the generation of buy and sell signals will only start at the first period for which the value of an indicator is calculated.

Firstly I exported historical data from Metaquotes Software Corp to csv format and then imported them to excel. The function „minimum“ was utilized in Excel to find the smallest low price (L) of the last 14 periods. Then the function „maximum“ was used to identify the biggest value for the high price (H) over 14 last periods. Afterwards each strategy exposed in the chapter 7 are computed the stochastic oscillator(K) can be computed.

We can further extend this strategy by averaging last 3 periods of K (D): The Excel worksheet can be found in the CD which is provided along with the paper and looks as follows.

The MACD computation stands on the EMA's. For calculating the MACD there are as already mentioned several steps. The SMAs for the 26th period is evaluated by averaging the last 12 and 26 periods. We will use this as the first value for the EMA, the next values are computed by multiplying the difference between close price minus the previous period EMA by respectively  $2/13$  or  $2/27$  and then adding this result to the previous EMA value again.

## **7 Chosen strategies**

In this part I will present the algorithmic trading strategies I used for backtesting. They stand on trading rules, which as already mentioned can produce only 2 outcomes, a buy or sell order.

### **7.1 First strategy**

This strategy is backtested on historical data with the knowledge of the last fourteen highest and lowest prices of each fourteen past days(periods). Therefore, if someone wanted to apply this strategy in real time he would need the acces to continually updated data of the passed days highest and lowest prices, as well as the closing prices for these days.

Firstly I've elaborated a strategy consisting of the following rule: when the stochastic oscillator indicator returns a value which is smaller than 20 ( $K_t < 20$ ), the excel function will generate a buy signal and at the same time when the value is bigger then 80 ( $K_t > 80$ ), a sell signal will be generated.

This algorithm resulted in a different number of buy and sell orders. This may be an undesired outcome of trading for investors who wish to close all their positions and retire their investments. At the end of the period the trader would have to close these positions or hold them with the consciousness of uncertain future price movements.

Therefore, to achieve the same amount of buy and sell signals a new rule was added. This rule is assuring the alternance of buy and sell signals by returning a blank if the preceding signal was identical (it can be a signal from the last 3 periods). The signals are occurring only when the K value crosses above or below the respective thresholds.

## 7.2 Second strategy

The next strategy is further altering the first one by taking into account the D value of the stochastic oscillator alongside with the K values. I had the same outcome as in the strategy one at first (inequality of buy and sell signals), but the rule was again adjusted. The exact triggers of the signal occurs when K is above 80(sell) or below 20(buy) and when D crosses these values. The cross can more precisely be described by forming a condition which are expressed:

Sell signal:

$$D_{t-1} < 80$$

$$D_t > 80$$

Buy signal:

$$D_{t-1} > 20$$

$$D_t < 20$$

## 7.3 Third strategy

The second strategy is similar with the previous ones, because the trading rules are the nearly the same but we use a different indicator. The Relative Strength Index is used as a signal value for evaluating whether to buy, sell or do nothing. When the value of this indicator crosses above the value of 70 a sell signal is generated and when RSI crosses below 30 a buy signal occurs. I used 14 periods to compute the first value of RSI

## 7.4 Fourth strategy

This strategy is based on the MACD indicator. When a 9day EMA of MACD line crosses below the MACD indicator a sell signal is generated, and when this 9day EMA crosses above MACD, a buy signal is generated.

## 7.5 Fifth strategy

Another simple rule for trading with the MACD lies in taking short positions when the value of MACD crosses below zero, and taking long positions when MACD crosses above zero.

# 8 Results

## 8.1 First strategy (Stochastic oscillator)

When backtesting the first version of strategy one I obtained different results for each crypto-currency pair. After adjusting the strategy to always close the current position (alternance of buy and sell signals) we obtained these results:

|         | Average buy | Average sell | buy sum  | sell sum | total buy | total sell | Profits/losses |
|---------|-------------|--------------|----------|----------|-----------|------------|----------------|
| LTC/USD | 62,3807143  | 62,23904762  | 2.619,99 | 2.614,04 | 42        | 42         | -5,95          |
| BTC/USD | 6.832,65625 | 6.885,0625   | 437.290  | 440.644  | 64        | 64         | 3.354          |

Table 2: 1st strategy

Unfortunately this strategy did not prove efficient with LTC/USD.

## 8.2 Second strategy (Stochastic oscillator – D+K)

This strategy was the most successful of all with the BTC/USD

|         | average<br>buy | average<br>sell | total<br>buy | total<br>sell | Sum of<br>buy | Sum of<br>sell | net<br>profit/loss |
|---------|----------------|-----------------|--------------|---------------|---------------|----------------|--------------------|
| BTC/USD | 7010,093       | 7196,348        | 42           | 42            | 294423,9      | 302246,6       | 7822,7             |
| LTC/USD | 63,47346       | 63,15962        | 26           | 26            | 1650,31       | 1642,15        | -8,16              |

Table 3: 2nd strategy

### 8.3 Third strategy (RSI)

The backtesting of the strategy 2, does not provide convincing results. The strategy is based only on one trading rule which itself is based on one indicator(RSI) The first backtest is made on the btc/usd 4h data from 21.12.2017 to 10.04.2019. The average buy price was just a bit under 50% of the average sell price, but there is only a total of 176 sell signals compared to 259 buy signals, this is due to the lack of a rule which would impose the alternation between buy and sell signals. For the ltc/usd the number of buy signals is higher as well, additionally the strategy does not generate a positive balance for the average price of long and short orders. The average More research and data is needed to determine wheter this basic interpretation of the RSI can produce any profits for the btc/usd and ltc/usd pair. Notice that there i some more sell order for each pair, there is a deficit and normály the positions should be closed (but unfortunately the data stopped before a buy signal could be produced). Therefore real profits would be much lower.

|         | Average buy  | Average sell | buy sum  | sell sum | total buy<br>orders | total<br>sell<br>orders | Profits/loss |
|---------|--------------|--------------|----------|----------|---------------------|-------------------------|--------------|
| LTC/USD | 72,08        | 73,38857143  | 432,48   | 513,72   | 6                   | 7                       | 81,24        |
| BTC/USD | 6.851,981818 | 6.884,266667 | 75.371,8 | 82.611,2 | 11                  | 12                      | 7 239        |

Table 4: 3rd strategy



This is the RSI index calculated for ltc/usd from the first record(26.02.2018) to the last (11.04.2019):

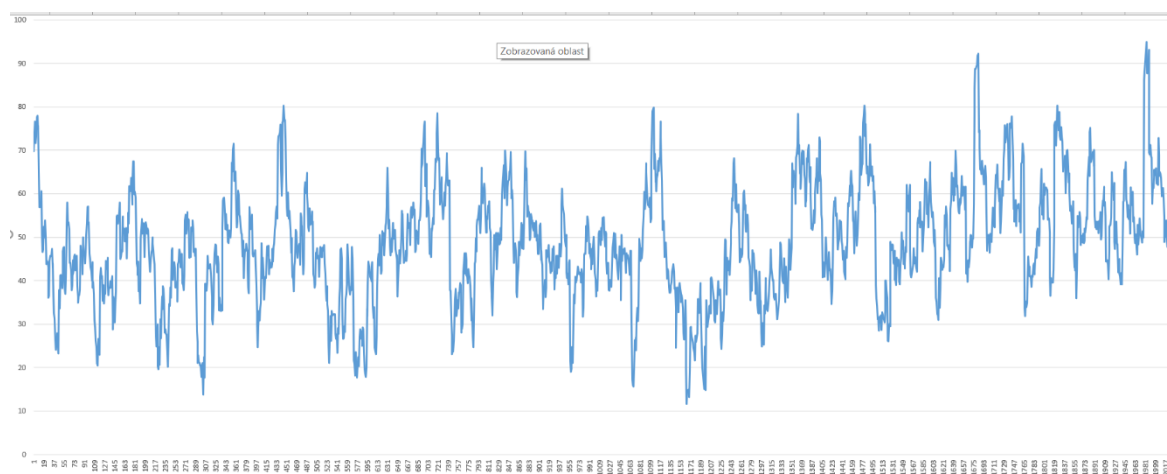


Figure 5 : Graph of RSI

#### 8.4 Fourth strategy (MACD)

The results of the last strategy are slightly positive for both currencies. The strategy is designed to have equal buy and sell orders, each opened position is closed, there is never more than one order at a time. Here are the results of the EMA(9) crossing over or above MACD

|         | average buy | average sell | total buy | total sell | Sum of buy | Sum of sell | net profit/loss |
|---------|-------------|--------------|-----------|------------|------------|-------------|-----------------|
| BTC/USD | 6.788,58657 | 6.798,55637  | 102       | 102        | 692.435,83 | 693.452,75  | 1.016,92        |
| LTC/USD | 60,2468493  | 60,7371233   | 73        | 73         | 4398,02    | 4433,81     | 35,79           |

Table 5: 4th strategy

#### 8.5 Fifth strategy

In this strategy there was one more sell signal for each crypto-currency-pair.

|         | average buy | average sell | total buy | total sell | Sum of buy | Sum of sell | net profit/loss |
|---------|-------------|--------------|-----------|------------|------------|-------------|-----------------|
| BTC/USD | 7180,742    | 6762,352     | 32        | 33         | 229783,7   | 223157,6    | -6626,12        |
| LTC/USD | 54,26042    | 63,57478     | 23        | 24         | 1302,25    | 1462,22     | 159,97          |

Table 6: fifth strategy

We can see the evolution of market prices below:

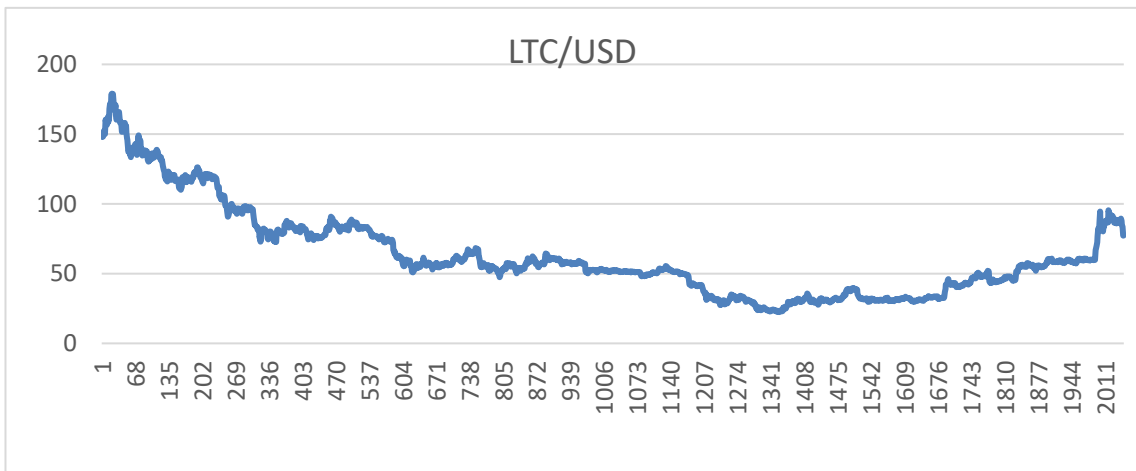


figure6: LTC/USD (02.05.2018-11.04.2019) price evolution

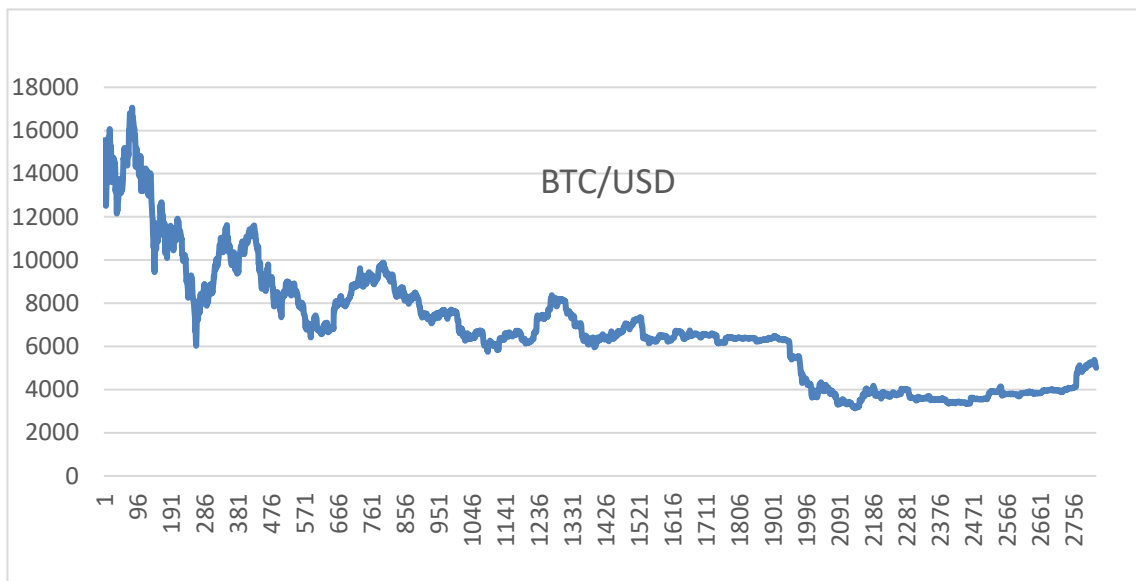


figure7: BTC/USD (21.12.2017-11.04.2019) price evolution

The trading strategies backtested in excel are rather simple, for implementing more complex rules and strategies including bearish and bullish divergences, more advanced software as Metaeditor, Python, Tradestation would serve as a better tools. If someone wanted to analyze a much longer period of time with shorter time frames it would also be less appropriate to use excel or even impossible. Obviously techniques used by HFT involve much more tooling with specific computer programming and networking

optimizations. Those techniques are developed by high profile computing companies, which are keeping in secret of the domain. This is far beyond the scope of my work. Furthermore, excel only serve as a signal generator and it does not itself submit trade orders to a server.

## **9 Conclusion**

It must be stressed that highly volatile cryptocurrency markets are more likely to be adapted to algorithmic trading because they may reduce risks thanks to their short term qualities. This could be true also for high frequency trading, because the trades are executed so fast that the price movements are often very small. Both cryptocurrencies and AT are new fields which still have much room for improvement. We cannot conclude that any of the strategies are profitable, mainly because of lack of data. But in comparison with the passive investment buy and hold strategy, the algorithmic strategies are not making drastic losses for the researched intervals as the results in the previous section showed. The best performing strategy made net profit 7 822,7 USD, but as we already said, when considering the number of transactions and the bid ask spread, the profit in real conditions would be significantly lower. At the beginning of our backtest, at 21december 2017 (8:00), the bitcoin was nearly at its peak for 15 287 USD. By the end of our backtest (10.04.2019), bitcoin was valued for 5 200USD. This represent a massive decrease of 66% in price. The standard deviation over the whole period was 3 522,32USD. For the litecoin the initial price was 146,93 USD and 87,74 at the end of the backtest, the lowest point was at The high volatility of cryptocurrencies makes the buy and hold strategy a very risky investment. If we consider the buy and hold strategy from the beginning of cryptocurrencies (bitcoin and litecoin respectively) creation we could of course acheive great profits with the right timing.

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