Department of Business and Management

Blockchain and Cryptocurrencies

Algorithmic Trading Systems in Blockchain Era

SUPERVISOR

Prof. Massimo Bernaschi

CANDIDATE

Filippo Luci

ACADEMIC YEAR 2021/2022

Index

Abstract: With the recent technological progress it's possible not only to buy and sell shares online in a very short time but to interface with the Application Program Interfaces (API) of various brokers to receive historical and real-time data. Connectivity and data analysis made it possible to algorithmically mechanize the technical analysis and trading processes that were previously carried out manually, thus forming the field of algorithmic trading. This class of algorithms has evolved rapidly both by developing High Frequency Trading (HFT) and arbitrage strategies. Even more recent examples include sophisticated mathematical and statistical calculations to predict the future price of stocks or any other financial asset. The same system that worked for stocks and then for commodities may have the same ability to adapt to cryptocurrencies as well.

Introduction:

With the technological progress of the last decades, one of the sectors that has evolved the most is the financial sector - [1] [2]. Thanks to internet and digitalization, for example, people can buy and sell shares online through exchanges, intermediary platforms that allow the purchase and sale of shares, coins, bonds and other financial products. [3] A further category of interchangeable digital products arose around 2008 when a person or group of people known as Satoshi Nakamoto propose the Bitcoin network. Since then, the cryptocurrencies market has been booming, growing to a combined market capitalization of around $ 2 trillion - [4], in the past, automated trading technologies and algorithms were mainly applied to the stock, commodities and forex markets, today, given the ease of finding information on the blockchain and the cryptocurrency market, it is a legitimate question to ask whether methods may work in this case as well. This degree thesis focuses on the analysis and the possibility of implementing an automated trading system for the cryptocurrencies market.

Chapter 1: An introduction on Cryptocurrencies and Blockchain:

Cryptocurrencies and Blockchain:

Cryptocurrencies, often abbreviated to cryptocurrencies, are digital currencies designed to function as a medium of exchange across a computer network whose primary goal is to facilitate transactions via Internet. The ownership records of the individual coins are stored in a digital database called the Blockchain. Depending on the type and nature of the blockchain, a cryptocurrency can be backed by a permissionless blockchain, which means that no authorization is required to interact with it or permissioned where some permissions are needed to obtain access and interact with it. . A blockchain is a growing list of records, called blocks, that are securely linked together via cryptography. Each block contains a cryptographic hash of the previous block, a timestamp and transaction data. The timestamp proves that the transaction data existed when the block was published. As previously mentioned, the blockchain was born together with Bitcoin in 2009 thanks to Satoshi Nakamoto. [5]

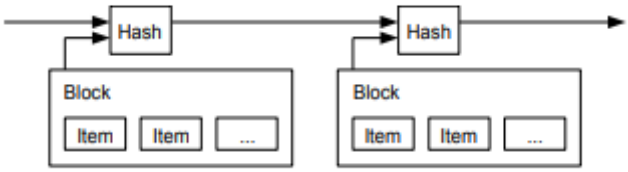

Figure 1 - Timestamp server - Satoshi Nakamoto

Other cases and different types of blockchain and cryptocurrency include Ethereum, Ripple, Solana, Dogecoin and others. Some types of cryptocurrency, unlike the ones mentioned above, are instead born with the value anchored to a traditional fiat currency, such as USDTether and USDCoin. Such cryptocurrencies are called stablecoins because they have a stable value of $ 1 and, due to their nature, they will be excluded from the analysis in this paper. On the commercial side, some of the key characteristics that are often used to determine the efficiency of a blockchain are scalability and transactions per second. Carrying out transactions on the blockchain has obvious benefits such as the speed of execution of the transaction and its low costs. When one of the two elements is missing, it can be disadvantageous to use the blockchain and cryptocurrencies to carry out transactions. [see 2017 bitcoin / ethereum cases]. Scalability is one of the most important problems in a blockchain, and it is also an often misused term. In computer systems, scalability refers to the system's ability to handle an increasing amount of work. In the blockchain among non-developers the term mainly refers to the amount of transactions per second the network can manage, or scale. In the case of Bitcoin, transactions per second (TPS) are about 7. Furthermore, these transactions must be sustainable in terms of fees. Past examples have shown how as the price of Bitcoin increases and therefore as the volume increases, transaction costs also increased uncontrollably, both in 2018 and between 2020 and 2022. The same problem occurred between 2020 and 2021 also with Ethereum. More recently cryptocurrencies were born with the aim of, in addition to serving as a platform for smart contracts, ensuringe adequate scalability, low transaction costs and high TPS. Solana's blockchain, for example, claims that its blockchain can carry out more than 50,000 transactions per second with average transaction costs of much less than one cent of $.

Figure 2 - Total Transaction Fees in USD - blockchain..com

Network congestion and Mempool Size:

Mempool or Memory pool is the repository of unconfirmed transactions. These transactions are waiting to be validated by the miners and included in the next block on the blockchain. A large mempool size indicates more network traffic which will result in a longer average confirmation time and higher priority rates. The size of the mempool is a good metric for estimating how long the congestion will last, while the Mempool's transaction count chart tells us how many transactions are causing the congestion. (See figure 3)

Network congestion occurs when the transaction load level no longer becomes sustainable for the network. Users pay commissions to miners for processing blockchain transactions. Miners receive a fixed amount of BTC per block mined. Although that number halves every four years, transaction fees are determined based on the state of the network (how congested it is) and the size of transactions. Bitcoin's block size is 1MB, which means miners can only process about 2000 transactions per mined block roughly every 10 minutes. If the number of transactions exceeds 2000 every 10 minutes, the network becomes congested and miners prioritize transactions with higher fees. In this paragraph it has been introduced how a sudden congestions of the network can lead to undesirable effects. Those effects should also be considered during both human and algorithmic trading operations. [7] Modern algorithmic trading systems in risk management should take into account such verifiable in the development of the trading systems. In this document this document, such assumptions were not taken into account. Any generic improvements will be discussed later in the final chapter. [6]

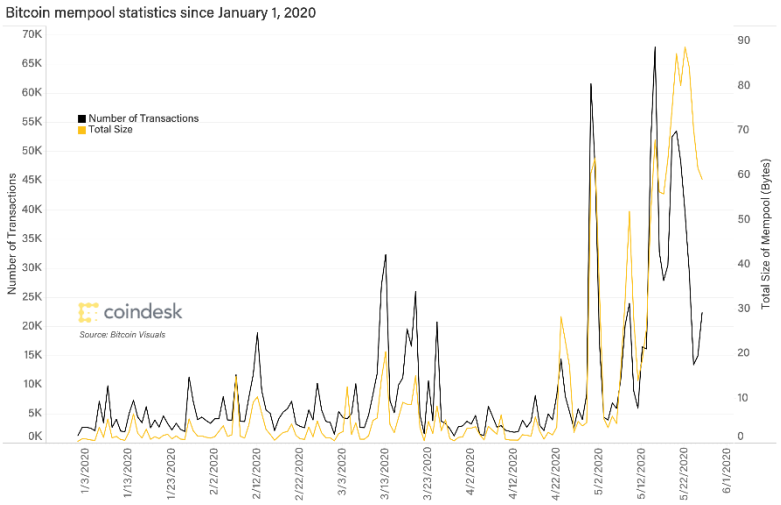

Figure 3 - Bitcoin Mempool statistics - coindesk.com

A few more details about Bitcoin and Ethereum:

Bitcoin:

Bitcoin is a decentralized, peer-to-peer cryptocurrency born thanks to a person or group of people known under the Satoshi Nakamoto pseudonym. Bitcoin, sometimes abbreviated as BTC, denoted with a capital B refers to the technology and network, while, if lowercase, it refers to the currency itself. For many experts, Bitcoin has taken hold more as a store of value than as a payment method due to its volatility. The concept of decentralization refers to the fact that, unlike what happens with legal tender Fiat currencies which are managed by a central bank, bitcoin is managed by a decentralized network of peers. The value is determined solely by the leverage of supply and demand; It uses a database system distributed between the nodes of the network that keep track of transactions by exploiting cryptography to manage functional aspects such as the generation of new coins and the attribution of ownership of bitcoins. The network allows the pseudo-anonymous possession and transfer of coins. The data necessary to use bitcoins can be saved on a personal computer or electronic devices such as smartphones. The bitcoin wallet has an address identified by an alphanumeric code that has between 26 and 35 characters between numbers and letters. It is the only data to be communicated in order to receive a payment that will enjoy a certain degree of anonymity, but will at the same time, be publicly and immutably visible on the blockchain forever. It is necessary to be very careful in transmitting the alphanumeric code as any errors do not allow the operation to be canceled and cause the loss of money. Another important aspect to take into consideration is the phenomenon called halving, that is the event in which the halving of bitcoin fees takes place. The process by which new bitcoins are created and transactions are validated and recorded on the blockchain is called mining. The maximum number of Bitcoins is 21 million and about 19 million have been mined so far (Sources coinmarketcap). Satoshi Nakamoto's protocol introduced the concept of digital scarcity by halving the reward obtained in mining every four until reaching the maximum supply of Bitcoin. This process is called Halving. [6] From a financial point of view, today, the sector has evolved surprisingly, reaching a market capitalization of around $ 2 trillion today

Ethereum:

Ethereum is a decentralized web 3.0 platform for peer-to-peer creation and publication of Smart Contracts created in a Turing-Complete programming language called Solidity. The cryptocurrency linked to it is called Ether. In order to run on the peer-to-peer network, Ethereum contracts "pay" for the use of its computational power through a unit of account, called Ether, which therefore acts as both cryptocurrency and fuel. In other words, unlike many other cryptocurrencies, Ethereum is not just a network for exchanging monetary value, but a network for running Ethereum-based contracts. These contracts can be safely used to perform a large number of operations: election systems, domain name registration, financial markets, crowdfunding platforms, intellectual property, etc. The platform was introduced by Vitalik Buterin and formalized together with Gavin Wood in 2014. However, the release of the first version took place in the middle of 2015. As with other cryptocurrencies, the validity of each Ether is guaranteed by a blockchain, which is an ever-growing list of records, called blocks, which are linked together and protected by encryption. By definition, the blockchain itself is resistant to data modification. It is an open, distributed, accounting ledger that records transactions between two parties in an efficient and permanently verifiable manner. Unlike Bitcoin, Ethereum operates using accounts and balances according to so-called state transitions, which are not based on unspent transaction outputs (UTXOs), but on the current balances (called states) of all accounts, as well as to some additional data. The information relating to the state is not stored in the blockchain, but is stored in its own Merkle tree, that is to say a binary tree in which each node is the father of two children and its hash is given recursively by the concatenation of the hashes of the two associated blocks.

Chapter II – Algorithmic Trading Infrastrucutre: How it work

AlgoTrading: A look into the past

While cryptocurrencies have only recently appeared, algorithmic trading has its roots in the past. Modern financial systems began to evolve around the 1970s when the New York Stock Exchange introduced the Designated Order Turnaround (DOT) system in the early 1970s. The system allowed for electronic routing of orders to the appropriate trading station. But already in the 70's there was a need to study what impact computers could have on trading. This necessity therefore gave rise to the Commodity Futures Trading Commission Act 1974. Ten years later, in 1984, the system adopted by the New York Stock Exchange evolved into SuperDOT. SuperDOT enabled the market to transmit the first automated orders in the securities sector. In 2000, 16 years later, SuperDOT was handling 90% of the NYSE's volume. Although SuperDOT has been decommissioned and replaced by modern technological systems, the volume of automated trading has continued to grow exponentially, accounting for around 75% of all trades in the United States in 2017. [9]

Although recent documents released by the Federal Reserve or FED, the central bank of the United States, highlight how algorithmic trading helps, especially in stock trading, to improve liquidity during normal market conditions, some types of algorithmic trading can exacerbate periods. volatility or causing unexpected market crashes such as the 2010 flash crash. Algorithmic trading strategies may involve using variable data such as price, date and daily volume along with technical indicators to evaluate buy / sell assumptions. stocks, commodities and forex.

In a market where the price of assets is volatile, it is necessary to know how to implement the right strategy at the right time. More complex strategies don't always translate into bigger profits. In the present work paper, the implementation of two different strategies with two different approaches will be discussed in greater detail: a first, slightly more complex, which keeps track of the Simple Moving Average (SMA) and a second, which simply invests part of the capital periodically. Just as, in the short term you can end up in false bull / bear runs, the same probability is exponentially reduced by increasing the time period in which the asset is held, investing one-off regardless of market conditions, in the long term, can prove to be the winning strategy.

The following chapters introduce technical analysis and then illustrate some examples of implementation of a trading systems based on the Bitcoin and Ethereum series. [9] [10] [11] [12]

Algorithmic Trading today; the infrastructure:

The term algorithmic trading today is particularly generic, as it indicates multiple algorithmic classes each using different strategies and methods - [13]. Examples of strategies may include arbitrage, market making and high frequency trading. With technological progress there has been the possibility to explore new algorithmic trading methods, such as momentum or machine learning-based price forecasting approaches. Although each of these strategies may be different from each other, a design of the general technological infrastructure can be defined by the following image:

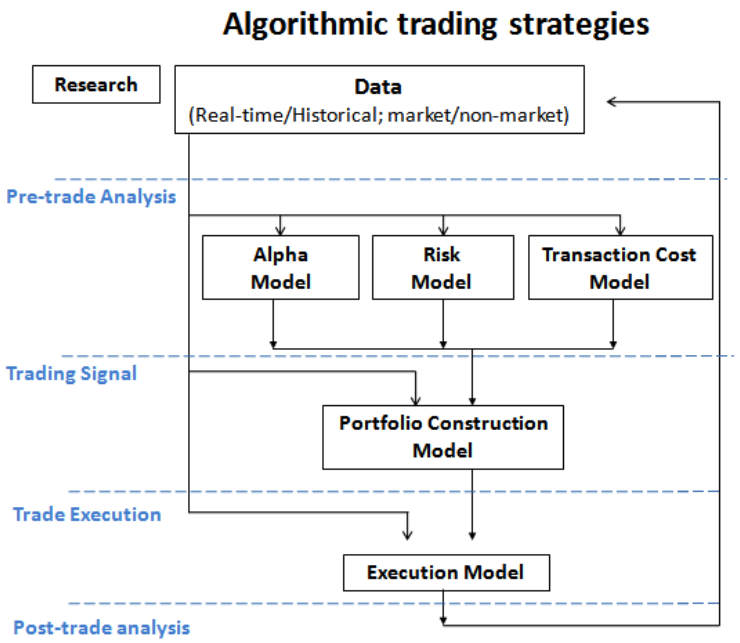

Figure 4 - Componenst of an Algorithmic trading system Dave Cliff, Dan Brown, Philip Treleaven. Technology Trends in the Financial Markets: A 2020 Vision

An algorithmic trading system can be divided into four parts: [14]

- A first part of research, origination of ideas and recovery of market or non-market data. (Non-market data may refer to momentum strategies based on news or social sentiments.)
- The pre-trade analysis includes three main components: the alpha model, designed to predict the future behavior of the financial instruments for which the trading algorithmic system is intended; the risk model, used to assess the levels of exposure / risk associated with the financial instruments being traded; and the transaction cost model, which calculates the (potential) costs associated with trading financial instruments, as illustrated in Figure 2.
- The third part called Trading Signal includes the portfolio construction model which takes as input the results of the alpha model, the risk model and the transaction cost model and optimally selects the best portfolio of financial instruments that should be taken into consideration.
- The final part, trade execution is where the model is adapted to the trading operations.

Tools and indicators for a trading systems:

As described in the previous paragraph, although each trading strategy can be completely different, the infrastructure remains, in general, the same and equal to the figure above.

Just as the infrastructure does not change, the tools and indicators used in algorithmic trading can be the same as those adopted by human traders. This paragraph introduces technical analysis and the Dow Theory and then illustrates the operation of the most common technical indicators such as the moving average, the bollinger bands and the MACD.

Technical analysis:

Technical analysis is the study of historical data with the aim of predicting the future price movement. Based on the historical price and volume, multiple technical indicators can be built which, generally, are plotted on a bar chart to predict future movement or market trend. Typical examples of technical indicators include a Simple Moving Average (SMA) which calculates the average of a selected range of prices, usually the closing prices and the exponential moving average (EMA). Another famous indicator is Bollinger Bands. Bollinger Bands' purpose is to provide a relative definition of the high and low prices of a market. Technical analysis, as seen, mainly takes into account past historical data to predict the future price, which makes it applicable to multiple sectors such as stocks, commodities, forex and cryptocurrencies.

Technical analysis is now mainly based on three premises:

- The market discounts everything: The prices projected by the stock exchanges reflect all the fundamental, political, economic factors ...
- The price moves within a trend: The market does not move randomly but in a trend.
- History repeats itself: The future could be a repetition of the past.

OHLCV and Data Sources

An Open-High-Low-Close-Volume chart is a type of chart typically used to illustrate movements in the price of stocks over time. The OHLC data refer to the price of a share or any other asset as well as cryptocurrencies and the Volume represents the number of entities traded during the time taken into consideration. The data sources used for data recovery is Yahoo Finance, which collects and processes data from CoinMarketCap.

Date	open	high	low	close	Volume
2019-01-06	1539.130005	1575.390015	1500.280029	1575.390015	8047100
2019-01-13	1629.510010	1659.420044	1629.510010	1640.560059	6883460
2019-01-20	1617.209961	1696.199951	1617.209961	1696.199951	5720140
2019-01-27	1632.170044	1670.569946	1632.170044	1670.569946	5169450
2019-02-03	1637.890015	1718.729980	1593.880005	1626.229980	7534160

Figure 5 - A dataframe in Pandas

Chapter III – Technical Analysis

Trading indicators:

By analyzing historical data such as price or volume it is possible to use the technical indicators introduced previously to predict the future movement of prices. For a better perception, the indicators as well as the OHLCV data are projected on graphs, generally candlesticks to better understand and observe the variation in values. Indicators are mainly used to analyze statistical trends and identify trading opportunities. Furthermore, technical indicators can be used on any stock with historical data such as stocks, futures, commodities and cryptocurrencies.

Moving Averages:

Moving averages fall within the class of trend indicators and are intended as an average defined on a number N of closing prices which is periodically updated by replacing the oldest data with the latest data in chronological order. The most commonly used moving averages are those at 25, 60 and 200 days. A rising moving average is a good strong market indicator while a falling moving average denotes a phase of weakness. A comparison of it with the price index, however, shows how the moving average changes direction well after the minimum or maximum of the prices of a share, making the signals generated "laggards".

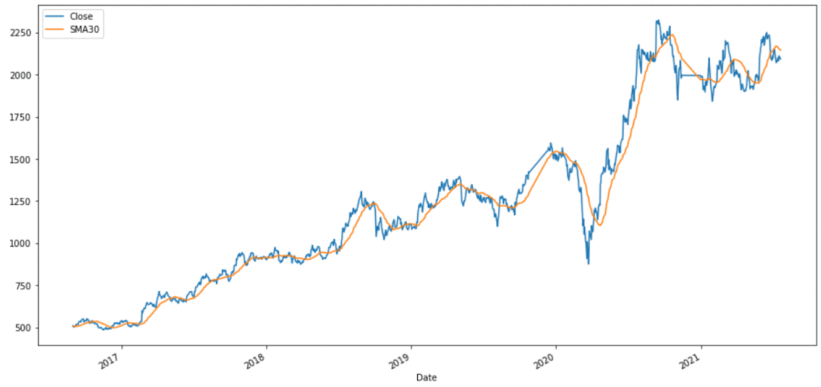

Figure 6 - Example of Moving Averages

Examples of moving averages (MA) can be the Simple Moving Average (SMA), which is calculated by adding the total of a data series and then dividing by the number of observations, or the Exponential Moving Averages (EMA).

Simple Moving Average:

Simple moving averages are calculated by adding the total of a series of data and then dividing by the number of observations, resulting in an arithmetic average. To make a moving average, the oldest price within the dataset is eliminated every day to introduce a more recent data into the series. Simple Moving Average is criticized as it assigns the same importance to every data regardless of its temporal location. The fact that the simple moving average changes direction well after the maximum or minimum of the prices of an index or a share makes the indicator lagging behind the trend in prices.

Exponential Moving Averages:

The Exponential Moving Averages are obtained by taking into consideration all the elements of the series with an exponentially decreasing weight up to infinitesimal values for the oldest values which, unlike the SMA, will remain included in the calculation.

Bollinger Bands:

Bollingers bands is a technical analysis tool defined by a set of trend lines drawn by two standard deviations (one positive and one negative) with respect to a Simple Moving Average (SMA) of the price of a stock. They were developed by John Bollinger and generate oversold or overbought signals.

There are three lines that make up the Bollinger bands: a simple moving average, an upper band and a lower band. The upper and lower bands are typically two positive and negative standard deviations from a 20-day simple moving average but can be changed. When the price approaches the upper band, it is a signal that the asset is overbought while if it approaches the lower band it is an oversold signal.

Figure 7 - Bollinger Bands computed via NumPy

The time span:

The choice of the time scale and the number of observations to be considered is fundamental. There are some typical values that can be considered standard according to the reference time window. For the very short term (intraday operations), the use of exponential moving averages between 5 and 9 days is widespread, for the short term at 25 - 30 days, for the medium term at 50 days and for the long term at 200 days. The more the average is short-term, the more it approaches prices and therefore many fluctuations and reversals will manifest. Conversely, a long-term moving average may have fewer fluctuations but at the same time it may send out signals later than the short one.

Trading strategies and applications on BTC / USD - ETH / USD:

As described in the previous chapter, trading strategies will be used relying on the generation of buy and sell signals via the moving averages and Bollinger bands on Bitcoin / U.S. Assets. Dollar and Ethereum / U.S. Dollar. A third strategy applied is Dollar-Cost Averaging (DCA) which will be discussed in the next paragraphs.

Chapter IV – Algorithmic trading strategies in action

Simple Moving Average Crossover:

The Simple Moving Average (SMA) Crossover occurs when, by plotting two moving averages, the traces of these averages cross. It does not foresee the future direction but it shows the trends. To apply the strategy it is therefore necessary to have a faster moving average, which is in the short term usually for a period of 5, 10 or 25 days, and a slower one which is in the medium or long term, usually for a period between 50,100 or 200 days). When the short-term moving average crosses above the long-term moving average it is a buy signal. On the other hand, when the short-term moving average is below the long-term one it is a sell signal as the trend is moving down. As illustrated in paragraph X, the choice of the time horizon of the moving averages is an important factor. From the experiments, in fact, it can be seen that the same strategy applied on Bitcoin offers different returns as the moving averages vary.

The SMA Crossover strategy applied to Bitcoin and Ethereum:

Bitcoin:

The SMA Crossover strategy was applied by taking historical data of the BTC / USD - ETH / USD exchange rate for the period between the beginning of 2019 and the end of 2021 with an initial capital set at $ 10,000. Although for part of the time (January 2019 to August 2020) there were no particular price changes, there was an impressive bull market phase that lasted for the entire second half of the analysis period. This second phase was characterized by two cycles, the first which took BTC from around $ 20k to $ 60k and the second which started from around $ 30k up to around $ 69k. The SMA Crossover strategy during this turbulent time resulted an effective job with a limited number of trades. (18 in total). As the results of the graph show, the strategy achieved a return of 95% per annum for both years under consideration. For the first half of the time, it can be seen that the largest losses and the largest number of failed trades were concentrated, where the algorithm bought above $ 10,000 and sold below $ 10,000. It is precisely in this phase that the largest drawdown of almost -38% occurs. This may show defects in the algorithm in the decreasing phases of the market that would require more in-depth analysis. The Equity peak, always following the figure below, occurred at the beginning of the second bull run cycle of the market and not at the end of the second. This could be an alarm bell that signals that the algorithm is unable to exploit and adapt to rapid and massive changes in market prices.

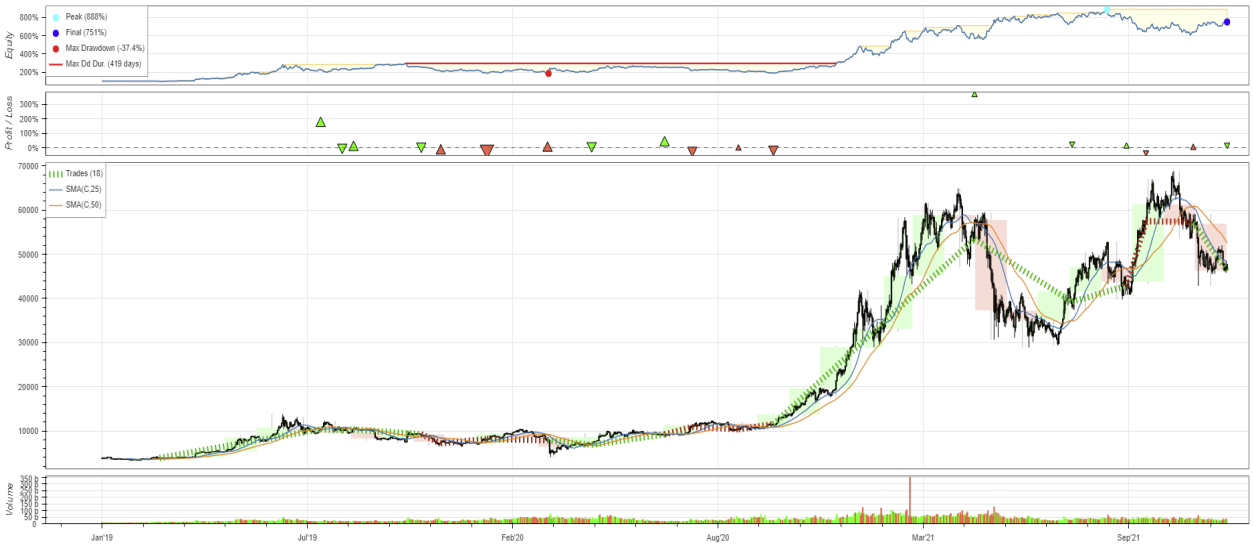

Figure 8 - Bitcoin SMA Crossover Strategy Results

Ethereum:

The SMA Crossover strategy applied to Ethereum uses the same concepts as the BTC / USD pair, thus taking the ETH / USD data for the period between the beginning of 2019 and the end of 2021 with an initial capital set at $ 10,000. Although for part of the time (January 2019 to August 2020) there were no particular price changes here too, there was an impressive bull market phase that lasted for the entire second half of the analysis period. This second phase was characterized by two cycles, the first which took ETH from nearly $ 200 to around $ 2000 followed by further growth which briefly pushed the price above $ 4000. Immediately after this growth, the stock fell to below $ 2000 and then resumed a run towards $ 4000 again. Ethereum, like Bitcoin, was also a very volatile asset in the analysis time taken into consideration. For the first half of the time the algorithm underperformed. It is in fact here that both the average and the max drawdown occur and, once again, the equity peak was recorded between the first and the second great growth. In total, the strategy, with its 25-day and 50-day SMA, achieved a return of 249% or 51% per annum. Once again, the algorithm was not able (it was built to) seize all the opportunities generated by the strong volatility of the securities in question. However, the algorithm seems to have a cautious approach, recording only 20 trades for the entire period in question with a 60% win rate. Here too, there is ample room for improvement which underlines that, however profitable the strategy may be, there is still room for improvement.

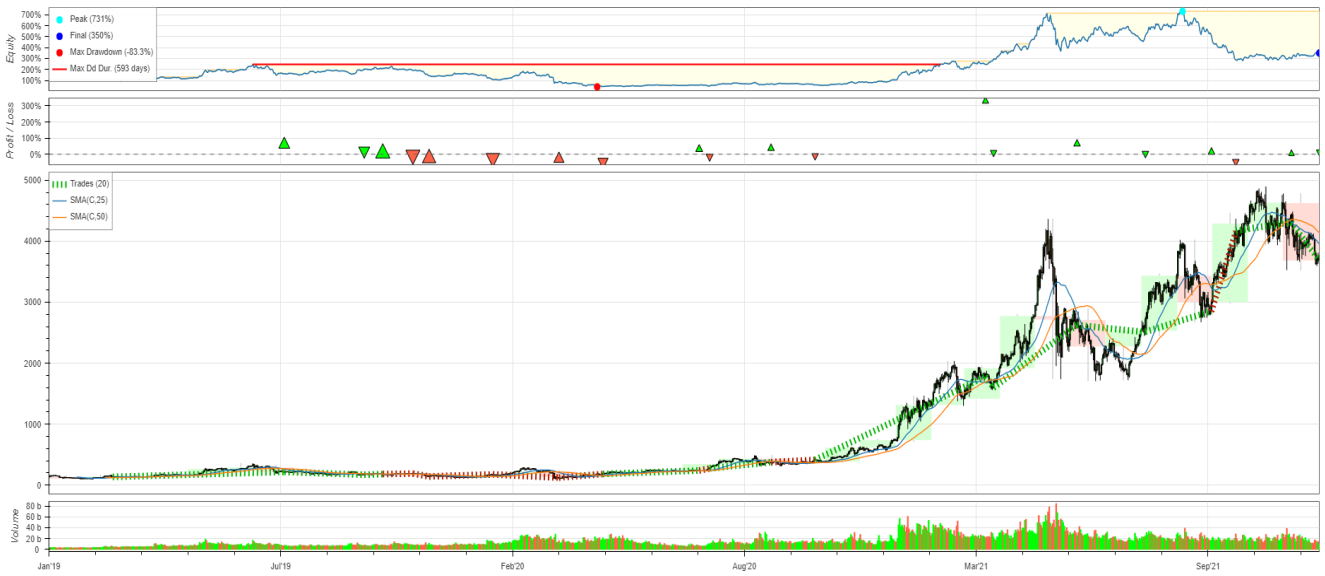

Figure 9 - Ethereum SMA Crossover strategy Results

Bollinger Bands:

Bitcoin:

The Bollinger Bands, as described in the previous paragraph, are a type of graphic indicator for technical analysis created by John Bollinger in the 1980s. Bollinger bands can be used to determine oversold and overbought levels and tracking breakouts. In addition, they are a commonly used tool for determining the entry and exit points for an operation. Due to their nature, therefore, Bollinger bands can be widely used in both trading and algorithmic trading of stocks, futures and cryptocurrencies. Bollinger Bands consist of three lines. The average band is usually calculated with a 20-day simple moving average. The upper band is calculated by taking the mean band and adding twice the daily standard deviation and the lower band is calculated by taking the mean band minus twice the daily standard deviation.

When the asset price breaks below the lower band, prices have perhaps fallen too much and could be subject to a rebound. Conversely, when the price breaks out of the upper band, the market may be overbought and should experience a retreat. The strategy in question was applied on BTC / USD and ETH / USD pairs with an initial total of $ 10,000 for the period 2019-2021. The median band, as previously reported, was set as a 20-day Simple Moving Average. The results obtained in this strategy too, at least for the BTC / USD pair were positive. The total return generated by the strategy is 591%. Although lower than a common buy and hold strategy (not discussed in this paper), it was once again very effective, especially in periods of high volatility and price increases, always characterized in the second analysis period. The greatest losses, in fact, were recorded again in the first half of the analysis where the volatility is lower. While it can be seen how, the bollinger bands strategy has better captured periods of high volatility than the previously discussed SMA Cross strategy. In addition, there is a missed opportunity to sell in the first high price spike.

Figure 10 - Bollinger Bands Bitcoin Trading Strategy Result

Ethereum:

The same strategy has seen much lower returns on the ETH / USD pair. The return obtained is significantly lower than that obtained with BTC / USD, equal to approximately 18.94% overall. Once again, part of the problem is due to the algorithmic inefficiency of performing when volatility is low, as in the first half of the graph (prior to the great price growth). Contrary to what was previously stated for the BTC / USD strategy, this time, for the second half characterized by greater price growth, a negative trade closure can be seen from the graph below when the last top of the graph is reached. The reasons for this loss can be many. First of all, what works for one asset doesn't necessarily work for a different asset. Furthermore, the Bollinger bands do not take into account an additional amount of data but only what is listed above. This could lead to a misinterpretation of the algorithm with false buy and sell signals which, inevitably, will lead to closing losing positions. A further defeat that could force us to review what was stated in the BTC / USD case, is that in this time the algorithm was unable to sell by fully exploiting its volatility as in the case of the second peak BTC / USD, as can been seen from the first peak at the top of prices.

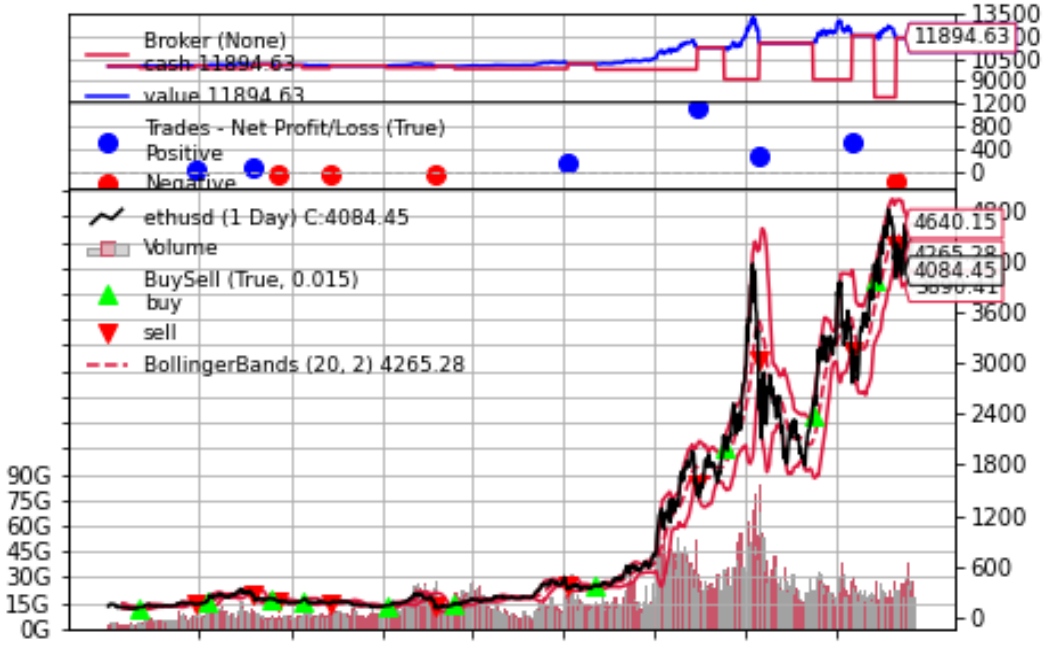

Figure 11 - Bollinger Bands Ethereum Trading Strategy Result

Dollar Cost Averaging:

Dollar Cost Averaging (DCA) is an investment strategy in which an investor divides the total amount to be invested in periodic purchases of a target asset in an attempt to reduce the impact of volatility on the overall purchase. Purchases take place regardless of the price of the asset and at regular intervals. Indeed, this strategy removes much of the detailed work of attempting to time the market to make stock purchases at the best prices. Dollar cost averaging is a tool that an investor can use to create savings and wealth over a long period. It is important to note that dollar cost averaging only works favorably if the asset increases in value over the time period in question. Average dollar cost improves the performance of an investment over time, but only if the investment increases in price. The strategy cannot protect the investor from the risk of a decline in market prices. The general idea of the strategy assumes that prices will always go up in the end. Using this strategy on a single stock without knowing the details of the company or the asset in general could be dangerous because the strategy could encourage an investor to continue to buy more stocks at a time when he should simply exit the position. The dollar cost average can also be better than buying the decline, because if you consistently invest a fixed amount, you'll have more exposure to declines when they occur rather than tracking a decline. Also, the fixed amount will mean that you will end up buying more shares when the price is lower than when it is higher. The primary benefit of dollar cost averaging is that it reduces the effects of investor psychology and market timing on their portfolio. By engaging in an average dollar cost approach, investors avoid the risk of making counterproductive decisions out of greed or fear, such as buying more when prices rise or selling in panic when prices fall. Instead, the dollar cost averaging forces investors to focus on contributing a certain amount of money each period while ignoring the price of each individual purchase. In the long run, however, investors using an average dollar cost strategy are betting that the simplicity of the strategy, coupled with the fact that it protects them from the temptation to buy high and sell low, will ultimately lead to better results than trying to time the market on every purchase.

Bitcoin Dollar Cost Averaging:

The BTC / USD strategy was used with an initial capital of $ 10,000 for the period 2019-1Q 2022 by investing an additional $ 500 periodically. Compared to the same strategy applied on Ethereum, this time, the algorithm took a more conservative approach. The total amount invested including one-off investments was $ 12,500 placing only 5 trades in the period under consideration. The return generated was 58% yearly or 350% in total.

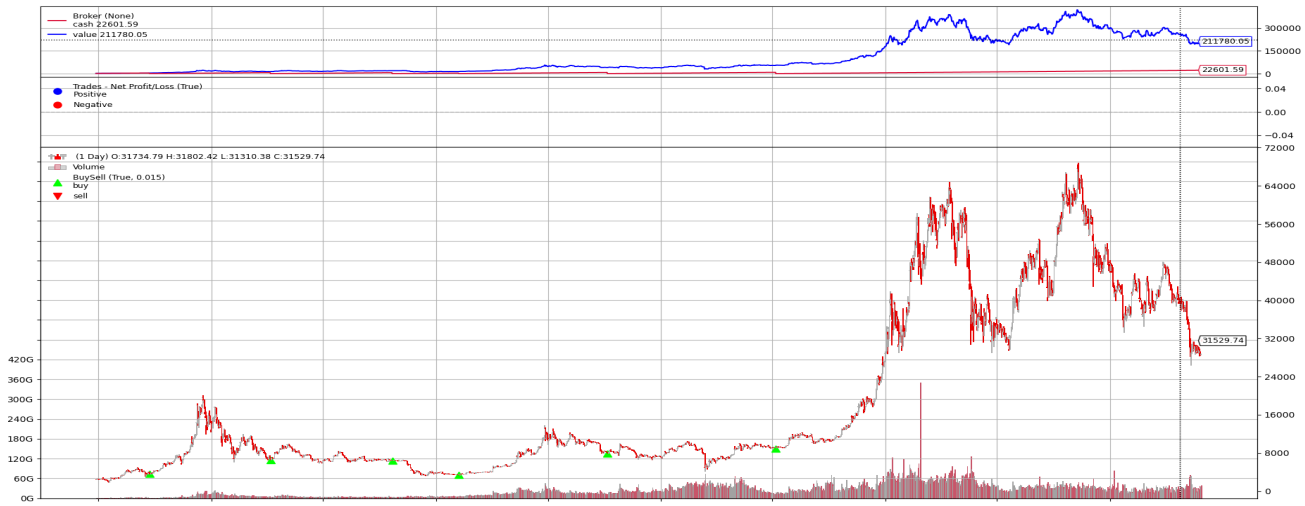

Figure 12 - Bitcoin Dollar Cost Averaging Trading Strategy Result

Ethereum Dollar Cost Averaging:

The ETH / USD strategy was used with an initial capital of $ 10,000 for the period 2019-2021 by investing an additional $ 500 per month. For the implementation of this strategy, the time taken into consideration extends to the first quarter of the year 2022. The total invested was therefore $ 28,000. Most of the trades visibly concentrated on the first part of the analysis period (the period before the first big peak) characterized by low volatility. The total return obtained was 48.55% per annum, resulting in a final gross profit of $ 50,000.

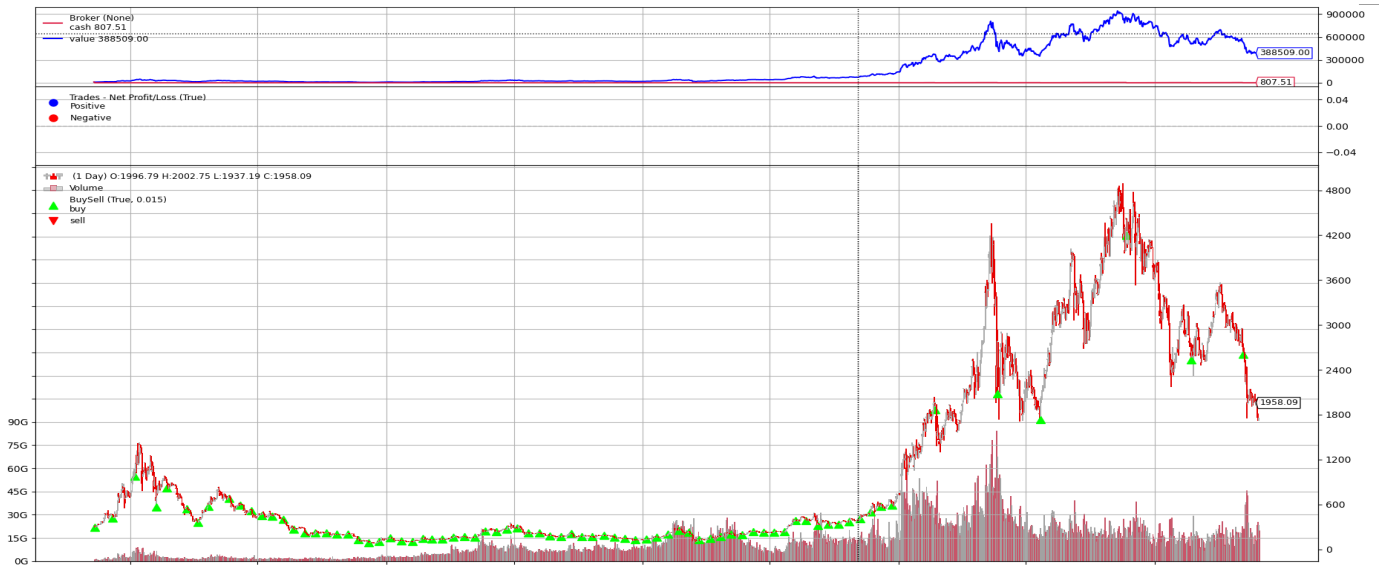

Figure 13 - Ethereum Dollar Cost Averaging Trading results

Conclusions:

The results obtained during the writing of this degree thesis were more positive than expected. The lack of a strategy with a negative return is not due to algorithmic infallibility or to the perfection of the applied strategies which, among other things, have ample room for improvement. The absence of a negative return is mainly due to the period under consideration, characterized by a bull phase of the market. In addition to a good choice of time and investment horizon, it is appropriate, as already discussed above, to apply the appropriate tools and technical indicators for the time horizon taken into consideration. In the backtesting phase, the results obtained with the time series may not reflect the performance that the algorithm could record in a live application on the market. The choice to analyze and test the algorithms during a bull market phase was made taking into consideration the curiosity of how, indeed, the algorithms behave in an optimal market phase. However, also taking into account how, even if not tested, the same returns may not be guaranteed during a bearish phase of the market, it is worth mentioning different algorithmic trading strategies commonly used even if not discussed in this paper. The trading algorithms discussed in the paper were characterized as Buy Long, acquiring and holding as much as necessary the cryptocurrencies in the portfolio. However, during a bearish phase, it is possible to transform the same algorithm by applying the Short Only strategy, actually going to bet in the falling prices when, through the generation of signals and alarms, the algorithm determines this phase of the market. A final consideration is the implementation of advanced trading techniques, including the use of Machine Learning [insert quote] and Artificial Intelligence. The use of ML & AI in finance is increasingly used [quote] and today, many hedge funds and investors are using techniques based on Machine Learning and Artificial Intelligence in algorithmic trading processes. Some of these techniques may include linear regression, clustering, and [insert]. While it is true that algorithmic funds such as Medallion by Renaissance Technologies have achieved exceptional returns over time, it is perhaps fair to mention that there are strategies and approaches that are very different from those discussed in this paper. An example is the use of fundamental analysis, a technique that consists in analyzing, in the case of the stock market, the accounting balance sheet and the balance sheet of a company rather than the fluctuation of prices as in technical analysis. Just like companies, blockchains and cryptocurrencies can also be the subject of fundamental analysis. Some of the factors that are taken into consideration are, in addition to the adoption and evaluation of the technology itself, are the analysis of the distribution of the coin (addresses with abundant quantities of this cryptoasset, called whales), studying the Mempools (The mempool is the place where all valid transactions are waiting to be confirmed by the Bitcoin network. A large mempool size indicates more network traffic which will result in a longer average confirmation time and higher priority rates. The size of the mempool is one good metric for estimating how long the congestion will last, while Mempool's transaction count chart tells us how many transactions are causing the congestion) or institution adoption. As for the results obtained, the strategy with the highest return was on Bitcoin using the Bollinger Bands, followed by the Dollar Cost Averaging again on Bitcoin and then the Simple Moving Average Crossover on Bitcoin. While it is true that the implementation of a more complex strategy has yielded more in the short and medium term, it is not certain that it will record the same returns in the long term. A comparison can be made by comparing James Simons, a mathematics professor and legendary investor using algorithms, and Warren Buffet, another legendary investor who bases his valuations on the fundamental aspects of companies by looking for the most undervalued and holding them for a long time. Simons's return on the Medallion fund year after year is higher than Warren Buffet's return, but the latter's skill has been to achieve an excellent return for more than 50 years at the same time. This could be a good example of the long-term potential -[16]. A final fundamental aspect, returning to the main aspects of the cryptocurrencies market is the possibility of arbitrage. As in traditional finance there are arbitrage opportunities for stocks, commodities and currencies traded on different global markets, this opportunity also exists for Bitcoin and other cryptocurrencies. Arbitrage consists of identifying the price differences between cryptocurrencies on the exchange. As cryptocurrencies are by nature a market open 365 days a year and 24 hours a day and being highly volatilized, they could offer a great deal of arbitrage opportunities compared to traditional markets.

The nature of the price discrepancy between the various exchanges could stem from the fact that the price of the assets in the centralized exchanges depends on the most recent bid-ask matched order on the exchange order book. In other words, the most recent price at which a trader buys or sells a digital asset on an exchange is considered to be the real-time price of that asset on the exchange. Another interesting aspect is in decentralized exchanges, where a different method is used to evaluate crypto assets known as an automated market maker system. This relies directly on crypto arbitrage traders to keep prices in line with those shown on other exchanges. - Some crypto arbitrage strategies can be: Cross-exchange arbitrage where a trader tries to generate profit by buying cryptocurrencies on an exchange and selling it on another exchange or decentralized arbitrage which, as just mentioned, is common in decentralized exchanges. If the prices of cryptocurrency pairs are significantly different from their spot prices on centralized exchanges, arbitrage traders can swoop in and perform cross-trading operations involving decentralized exchange and a centralized exchange. An interesting aspect is the reduction of risks in the portfolio as unlike day traders you do not need to predict the future price of an asset or enter into operations that could take hours or days before they start to generate profit. On the other hand, arbitrage trading is time sensitive, from seconds to a few minutes an algorithm should buy and sell the asset in question while also taking into account the transaction fees. To mitigate the risks of incurring losses due to high fees, a trader should choose to limit the activity to trading with competitive transaction fees – [17].

Bibliography:

[1]: James Manyika, Charles Roxburgh. The great transformer: The impact of the Internet on economic growth and prosperity. October 2011. McKinsey Global Institute.
[2] Andrea Pinna, Wiebe Ruttenberg. Distributed Ledger Technologies in securities post-trading. April 2016. European Central Banl.
[3]: Shukla, Ajay and Shukla, Ajay and Nerlekar, Shriram, Impact of Digitization Transformation on Financial Markets (February 15, 2019). MET Management Retrospect, Volume 3, Issue 1, 2019, Available at SSRN: https://ssrn.com/abstract=3342126 or http://dx.doi.org/10.2139/ssrn.3342126
[4]: CoinMarketCap – www.coinmarketcap.com
[5] – Satoski Nakamoto. Bitcoin Whitepaper.
[6] Cyril Grunspan, Ricardo Pérez-Marco. The mathematics of Bitcoin. EMS Newsletter, European Mathematical Society, 2020. ffhal-02486029f
[7] Sivaraman, Vibhaalakshmi and Venkatakrishnan, Shaileshh Bojja and Ruan, Kathy and Negi, Parimarjan and Yang, Lei and Mittal, Radhika and Alizadeh, Mohammad and Fanti, Giulia. High Throughput Cryptocurrency Routing in Payment Channel Networks. Arxiv 2018.
[8] Nishit Kumar Ghosh. A Quantitative Case Study on the Impact of Transaction Cost in High-Frequency Trading Models.2020
[9] Lajos Gergely Gyurkò. The evolution of algorithmic classes. Mathematical Institute, University of Oxford.
[10] Findings Regarding The Market Events of May 6, 2010. Federal Reserve. September 2010.
[11] : Algorithmic Trading in U.S. Capital Markets. Federal Reserve. August 2020.
[12]: Tom C.W. Lin. The New Investor. UCLA Law Review. 2013
[13]: Paolo Cremonesi, Chiara Francalanci, Alessandro Poli, Roberto Pagano, Luca Mazzoni, Alberto Maggioni, Medhi Elahi. Social Network based Short-Term Stock Trading System. Arxiv.
[14]: Dave Cliff, Dan Brown, Philip Treleaven. Technology Trends in the Financial Markets: A 2020 Vision. October 2010.
[15]: Technical Analysis. 2011. Cambridge University.
[16]: Gemma Acton, Nancy Hungerford. I admire Buffett the most but he wouldn’t approve of what we do: Winton’s Harding. CNBC. 2016
[17]: T. Crépelière, S. Zeisberger, "Arbitrage in the Market for Cryptocurrencies", SSRN Electron. J., 2020.

List of figures:

List of software and technologies used:

Python – https://www.python.org/
Pandas - https://pandas.pydata.org/
NumPy - https://numpy.org/
Backtesting.py - https://kernc.github.io/backtesting.py/
Backtrader - https://www.backtrader.com/