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**DESIGN AND SIMULATION OF STRATEGIES
FOR MARKET TRADING**

NÁVRH A SIMULACE STRATEGIÍ PRO OBCHODOVÁNÍ NA TRZÍCH

MASTER'S THESIS

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Assignment:

1. Study existing trading strategies and approaches for various financial instruments (including cryptocurrencies). Analyze the claimed results of the studied strategies and their assumptions.
2. Study existing simulation tools suitable for testing trading strategies and compare them.
3. Analyze the backlog of chosen financial instruments (including cryptocurrencies) and analyze observed events.
4. Implement a simulation tool for a comparison of various trading strategies and test it with at least 3 existing strategies.
5. Propose at least one novel trading strategy and test it on your simulation tool.
6. Evaluate your strategy and compare it with other supported strategies in your simulation tool.
7. Discuss further improvements and limitations of the practical deployment.

Literature:

- Bankless: "How to make money trading stablecoins", <https://newsletter.banklesshq.com/p/how-to-make-money-trading-stablecoins>
- HodlBlog: "When Does Portfolio Rebalancing Improve Returns?", <https://www.hodlbot.io/blog/when-does-portfolio-rebalancing-improve-returns>
- The Shrimpy Team: "What is Portfolio Rebalancing?", <https://blog.shrimpy.io/blog/portfolio-rebalancing-for-cryptocurrency>
- Holderlab.io: "Rebalancing Strategy For Your Crypto Portfolio", <https://medium.com/coinmonks/rebalancing-strategy-for-your-crypto-portfolio-590397f2282b>
- The Shrimpy Team: "Crypto Users who Diversify Perform Better", <https://hackernoon.com/crypto-users-who-diversify-perform-better-new-research-ebf775d348dd>
- The Shrimpy Team: "Portfolio Diversity: A Technical Analysis" <https://hackernoon.com/portfolio-diversity-a-technical-analysis-c2c49f4d3a77>

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Abstract

The objective of this study is to explore the world of trading by analyzing market behavior, identifying market participants, and examining various trading approaches. The study aims to not only investigate trading strategies but also analyze and simulate their performance. The outcome of this work is the development of a tool capable of comparing implemented methods and the author's own proposed strategies.

To achieve this goal, a Python simulation tool was implemented that uses data obtained from the Binance API. The analyzed and simulated strategies include Lump Sum (LS), Dollar Cost Averaging (DCA), and Rebalancing. Additionally, a novel strategy called Momentum and Overheating Strategy (MOS) is introduced, which incorporates the Relative Strength Index (RSI) indicator. The core of this strategy involves combining multiple weighted functions to achieve synergy, leveraging not only RSI but also moving averages and derivatives.

The results consist of an empirical comparison of all the methods to determine their relative suitability under different conditions. MOS and rebalancing were found to be similarly profitable, outperforming the other examined methods.

Finally, hypotheses are presented to explain the profitability of MOS and suggest potential future enhancements that could be implemented.

Abstrakt

Cíl této práce je prostudovat svět obchodování. Analyzovat jak se trhy chovají, kdo nebo co se na nich nachází a jaké existují přístupy k obchodování. Strategie obchodování nejen probádat, ale také analyzovat a simulovat jejich chování. Výsledkem by měl být nástroj schopný srovnání naimplementovaných metod a vlastního návrhu autora.

Pro řešení byla využita implementace simulačního nástroje v Pythonu, který pracuje s daty staženými z Binance rozhraní. Strategie, které jsou analyzovány a simulovány jsou *Lump Sum* (LS), *Dollar Cost Averaging* (DCA) a *Rebalancing*. Práce představuje také vlastní strategii pojmenovanou *Momentum and Overheating Strategy* (MOS), která využívá indikátoru relativní síly (RSI). Srdcem této metody je skládání několika ohodnocených funkcí tak, aby vznikla synergie. Využívá se nejen RSI, ale také klouzavého průměru a derivace.

Výsledkem je empirické porovnání všech metod a zjištění která z metod je jak moc vhodná a za jakých podmínek. MOS a *Rebalancing* se ukázaly být přibližně stejně výnosné a ze zkoumaných metod nejlepší.

Na závěr jsou uvedeny hypotézy proč je MOS lukrativní a jaké vhodné vylepšení do budoucna by mělo smysl implementovat.

Keywords

trading, trends, technical analysis, DCA, rebalancing, lump sum, trading strategies, markets.

Klíčová slova

obchodování, trendy, technická analýza, DCA, rebalancing, lump sum, obchodní strategie, trhy.

Reference

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Rozšířený abstrakt

Opravdové zbohatnutí je možné pouze ve finančním sektoru a to díky složenému úroku. Právě také z tohoto důvodu je důležité aby člověk měl o tomto odvětví přehled. Spousta lidí šetří peníze ať už na důchod nebo jen do blízké budoucnosti na koupi jakéhokoli druhu majetku a z důvodu nedostatku informací investují do nevhodných instrumentů. Této chybě se chceme vyvarovat a proto se tato práce zaměřuje i na přiměřeně hluboký ale i široký výzkum obchodování na trzích. V posledních letech se navíc objevuje čím dál větší procento algoritmických obchodníků na trzích, což má za následek nelidské chování cen aktiv. Cíl této práce je analyzovat chování trhu, kdo se na nich nachází, jak se chovají a jaké jsou existující popsané přístupy a strategie obchodování. K tomuto cíli je třeba vytvořit, případně využít existující, simulační nástroj, který bude umět simulovat a porovnat různé postupy. Nakonec navrhne vlastní strategii a pokusíme se dosáhnout konkurenceschopných výsledků vůči metodám obecně známým.

V počáteční části práce se zabýváme širokým spektrem konceptů ve finančním sektoru. Jsou popsány různé způsoby analýzy trhu, vhodné i nevhodné investiční nástroje při určitých investičních cílech. Jsou uvedeny rozdílné způsoby obchodování a jaký je rozdíl například mezi investováním a denním obchodováním i s jejich předpoklady, výhodami a nevýhodami. Rizika, vhodnost a parametry investování pro investora jsou adresovány na konci první části.

V další části se zaměříme na existující strategie. Konkrétně to jsou například strategie Lump sum, Dollar cost averaging a Rebalancing. Tyto strategie jsou probírané více do hloubky, ale zmiňujeme i jiné přístupy pro uvedení do kontextu. Všechny z uvedených metod jsou známé a široce využívané mezi maloobchodníky, proto je dobré přinejmenším o nich vědět, že existují. Výše zmíněné strategie jsou nejnámější a proto jsme se zaměřili na ně. Je uvedeno několik empirických studií, které uvádí určité výsledky.

Vhodný nástroj na simulaci hledáme v následující kapitole. Nejdříve se zaměřujeme na simulační nástroje. Tyto nástroje jsou buď vhodné pro manuální simulaci případně mají jiná omezení. Pro analýzu na vlastním nástroji je nutné sehnat zdroj na stažení dat. Jako poskytovatele dat je vybráno rozhraní společnosti Binance a simulace probíhá ve vlastním nástroji implementovaném v jazyce Python. Je to vhodné i pro budoucí případné nasazení do provozu, protože rozhraní přímo burzy nabízí i otevírání a zavírání pozic.

Po důsledném průzkumu můžeme začít navrhopvat vlastní strategii i simulační nástroj. Pro strategii byl vybrán jako stěžejní *Relative strength index* (RSI) indikátor a váhování jak samotného RSI tak i jeho derivací a klouzavých průměrů. Tato strategie byla pojmenovaná *Momentum and overheating strategy* (MOS), podle principu nad kterým by měla fungovat. MOS se snaží vyhledávat hybnost na grafu a případně přehřátí, tedy přeprodání nebo překoupení aktiva. Po navržení simulačního nástroje včetně stahování dat a generování testovacích intervalů lze přistoupit k implementaci strategií. Jak bylo řečeno, simulované strategie byly *Lump sum*, *Dollar cost averaging* a *Rebalancing*. Dalšími přídatnými strategiemi bylo vylepšení DCA strategie a samotná originální strategie MOS.

Nakonec jsou uvedeny statistické výsledky simulací a porovnání strategií mezi sebou. Výsledky byly interpretovány a vznešeny názory ohledně jejich výkonu. V závěru jsou kriticky zhodnoceny i výsledky originální strategie MOS a jsou navrhnuty budoucí možnosti jejího vylepšení.

Design and Simulation of Strategies for Market Trading

Declaration

I hereby declare that this Bachelor's thesis was prepared as an original work by the author under the supervision of Ing. Ivan Homoliak. I have listed all the literary sources, publications and other sources, which were used during the preparation of this thesis.

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František Horázný
May 23, 2023

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Chapter 1

Introduction

The employment of algorithms in financial markets has grown in popularity in recent years [46]. It is referred to as automatic trading, algorithmic trading, or high-frequency trading. This approach includes the use of computer programs to perform transactions based on pre-determined criteria and circumstances. According to Wall Street data, algorithmic trading accounts for around 60–73 percent of all US equities trading [32]. One of the primary advantages of automated trading is the ability to execute trades at a significantly faster rate and with greater accuracy than human traders. This is especially effective in swift markets where manual decision-making is not always possible. Automatic trading also enables trade execution on a much larger scale, since the computer software can handle several deals at the same time. Automatic trades also assist in avoiding FOMO transactions, which are driven by human psychological factors. The backtest of trading techniques is an additional benefit of automated trading. This includes replicating a strategy’s implementation based on historical data to estimate its expected profitability. Traders can use simulation tools to assess the success of a strategy and make improvements before executing it on actual markets. DCA, technical analysis, arbitrage, and market creation are just a few of the trading strategies that may be used in automated trading. Each strategy has its own set of rules and criteria that determine when a transaction is performed.

Despite the numerous advantages of automated trading, it is critical to realize that it is not without risks. For example, an error in the computer program or a quick market move might result in huge losses. Before applying any technique, like any trading activity, it is critical to properly evaluate and understand the risks and benefits.

Overall, automated trading has the potential to be a beneficial tool for traders seeking rapid, precise transactions in financial markets. Traders might possibly increase their chances of success and optimize their earnings by using simulation tools and carefully selecting trading methods.

There are numerous strategies that can be used depending on the nature of the market (ranging or trending), the trading capital (\$1,000 or \$1,000,000), or the situation of the global economy (recession or prosperity).

1.1 Motivation

In our world, there are really only two ways how to get rich and it is establish a business or buy one. This requires a large investment of money and time, and the result is still uncertain. However, in markets, there is the possibility of buying just a portion of these businesses, making it easier to make a profit with any amount of time and money spent. It is possible to look at currencies, bonds, and other financial instruments as businesses. If their price rises, it is similar as when company is doing well and vice versa. However, the real game changer and the reason why it is so lucrative is compound interest. When working in a regular job, workers earn monthly wages and cannot come to their boss or owner with \$10,000 and ask for an increase in salary by 20%. But in trading the more you invest, the more you earn. That is why it is good to dive into at least investing and this thesis is trying to take advantage of the opportunity.

1.2 Organization

[chapter 2](#) provides an overview of the trading sector. It demonstrates the principles with which the trader should be familiar as well as those that will be used in later sections of this work. In [chapter 3](#), we introduce numerous frequently utilized trading strategy concepts, many of which have common roots. [chapter 4](#) discusses some of the most common trading tools, as well as some potential options for achieving algorithmic trading and validation. [chapter 5](#) goes into the design of the suggested strategy and the subsequent construction of a simulation tool. [chapter 6](#) focuses on modeling, optimizing, and evaluating various strategies. Examine the data used to test the techniques and explain why particular strategies were chosen. Each technique is fully studied, and ideas to explain their behavior are developed. Finally, in [chapter 7](#), the findings are summarized, a conclusion is reached, and recommendations for further research are suggested.

Chapter 2

Basic concepts of financial sector

The trading industry may be sophisticated, full of terminology and symbols, and often overwhelming especially for those who are new to the industry. As a result, traders must have extensive knowledge of the underlying ideas driving the market. These concepts and principles can assist traders in developing profitable trading plans. Financial instruments, market analysis methodologies, trading psychology, and money management are some of the essential ideas that traders should be aware with. Financial instruments are assets that may be traded, including stocks, bonds, derivatives, and cryptocurrencies. To analyze the prospective performance of a financial instrument, market analysis techniques such as technical analysis and fundamental analysis are applied. The emotional and mental variables that might impact a trader's decision-making process are referred to as trading psychology. Money management is the process of determining objectives, reducing potential losses in a trade, and planning cash flow. This chapter will also go over different types of trading, including swing trading, day trading, scalping, and long-term investing.

2.1 Financial instruments

Financial instruments are assets that can be traded. These assets can take a variety of forms, including stocks, bonds, derivatives (futures, options) and currencies (including cryptocurrencies) [11].

Stocks represent ownership in a company and allow the holder to participate in the company's profits and decision-making process. **Bonds** are a form of debt that allows investors to lend money to a government or corporation in exchange for interest payments. **Derivatives** are financial instruments that derive their value from an underlying asset, such as a commodity or a currency. **Currencies**, such as the US dollar or the euro, are used as a medium of exchange to facilitate trade and commerce [12][41].

Financial instruments can be traded on financial markets, such as stock exchanges, forex markets¹ and other exchanges, and can be bought and sold by individuals, institutions, and governments. Understanding financial instruments is an important aspect of trading and investing.

¹Forex markets are those with FIAT currency pairs such as EUR/USD, etc.

2.2 Technical analysis

Technical analysis is a form of investment valuation that analyses past prices to **predict future price** action [34]. It operates from the assumption that past market data, such as price and volume, can be used to predict future price movements. Technical analysis employs models and trading rules based on price and volume transformations, such as the relative strength index, moving averages, regressions, inter-market, and intra-market price correlations. Technical analysts look for similar patterns that have formed in the past and will form trade ideas believing that the price could possibly act the same way as before [27]. Technical analysis focuses on market action, specifically volume and price, with charting tools used to optimize strategies. Commonly used technical indicators include moving averages, MACD signals, Fibonacci levels and pivot points.

2.2.1 Trends

Traders can identify a trend using various forms of technical analysis, such as trend lines, price action, and technical indicators. Trend lines are one of the simplest tools used to identify trends in financial instruments. Its example is shown in [Figure 2.1](#) Price action trading is another way to spot trends and involves analyzing the price movements of an asset over time. Technical indicators, such as moving averages, are also used to identify trends and can be combined with trend lines and price action trading for more accurate results.

2.2.2 Market phases

There are three phases of the market: bull market, bear market, and consolidation. A **bull market** is characterized by rising prices, often driven by optimism by investors. On the contrary, a **bear market** is characterized by falling prices, typically driven by investor pessimism. **Consolidation** refers to a period of stability or indecision during which the price of an asset does not show a clear trend. This is often referred to as a range and its example can be seen in [Figure 6.5](#). The terms bull market and bear market can also be used as adjectives: *bullish* and *bearish*. The bear or bull market generally denotes the overall market condition as recession or prosperity, but it can be used to describe much smaller scales such as days, hours, or even minutes. Examples of the bear market and the bull market are shown in [Figure 2.1](#).



Figure 2.1: On left side is uptrend with ascending trend line - bull market. On right is downtrend with descending trend line - bear market.

2.2.3 Patterns

Chart patterns are lines and shapes drawn onto price charts to help predict future price actions, such as breakouts and reversals. There are several types of chart patterns used in technical analysis. It includes continuation patterns, which denote a temporary interruption of an existing trend, and reversal patterns, which signal a change in the prevailing trend. Examples of common continuation patterns are ascending, descending, and symmetrical triangles, flags and pennants, while examples of common reversal patterns include head and shoulders, double top, double bottom, cup and handle, wedges and triangles. The outline of the said patterns can be seen in [Figure 2.2](#).

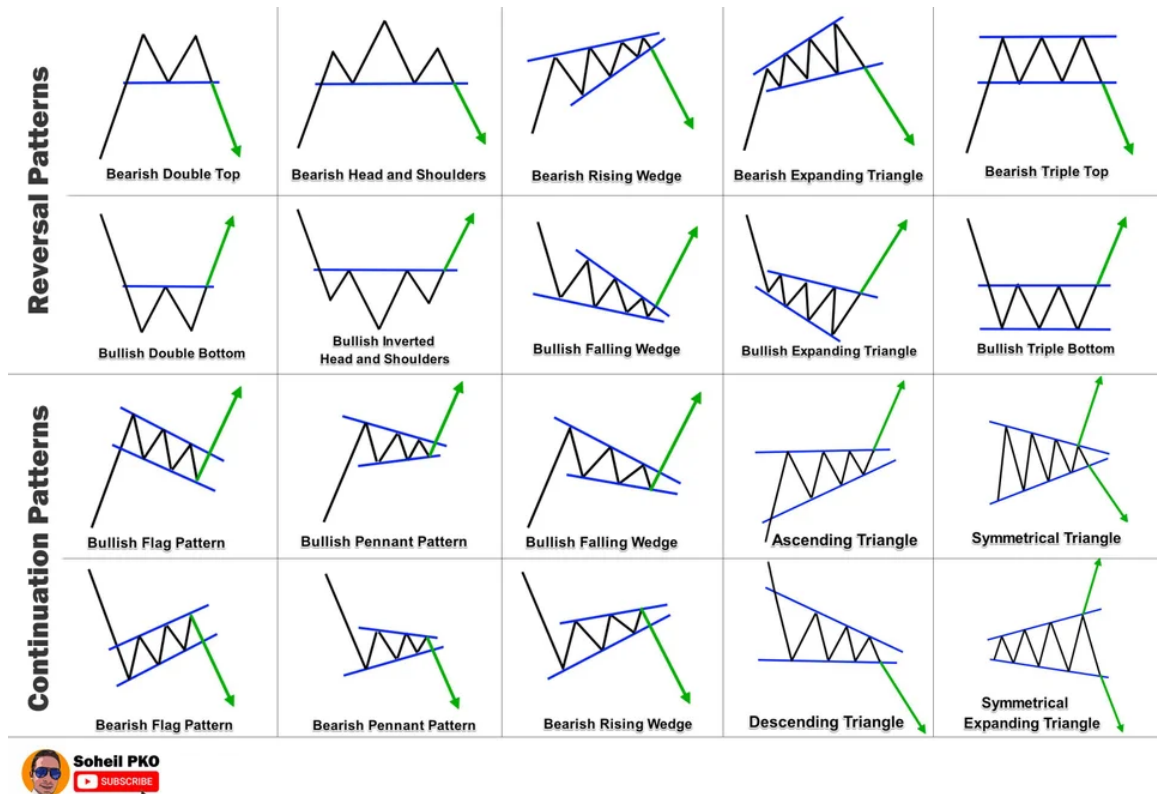


Figure 2.2: The picture showcases a multitude of crucial patterns [38].

2.2.4 Candlestick charts

The price movement is discrete, but data stream is so dense, that it is needed to aggregate these data. There are many ways to simplify and visualize them. In this thesis, we will always use a candlestick chart. It is a type of price graph used in technical analysis that displays the highest price, lowest price, open price, and closing price of a security for a specific period, as shown in [Figure 2.3](#). Candles are inserted one behind the other in the chart, where the x-axis indicates the time and the y-axis indicates the price. It is also most used graph type by traders [37]. Not only shape of graph, but also candlesticks themselves are useful for identifying potential trends and reversal patterns in the market due to their aggregating nature. One of the key features of candlestick charts is the appearance of the

candlesticks, which can provide insight into the underlying supply and demand dynamics of the market.

For example, if the price of an asset moves higher and is immediately sold off, resulting in a downward price movement, then the candlestick does not have body or even has the opposite direction to the previous candle. This may indicate that there is strong selling pressure in the market, and that the asset's price is likely to continue to decline in the near term. On the other hand, if the price of an asset moves higher and is met with strong buying demand, resulting in an upward price movement and strong full body of candlestick, this can be seen as a bullish event. This may indicate that there is strong buying pressure in the market, and that the asset's price is likely to continue to rise in the near term.

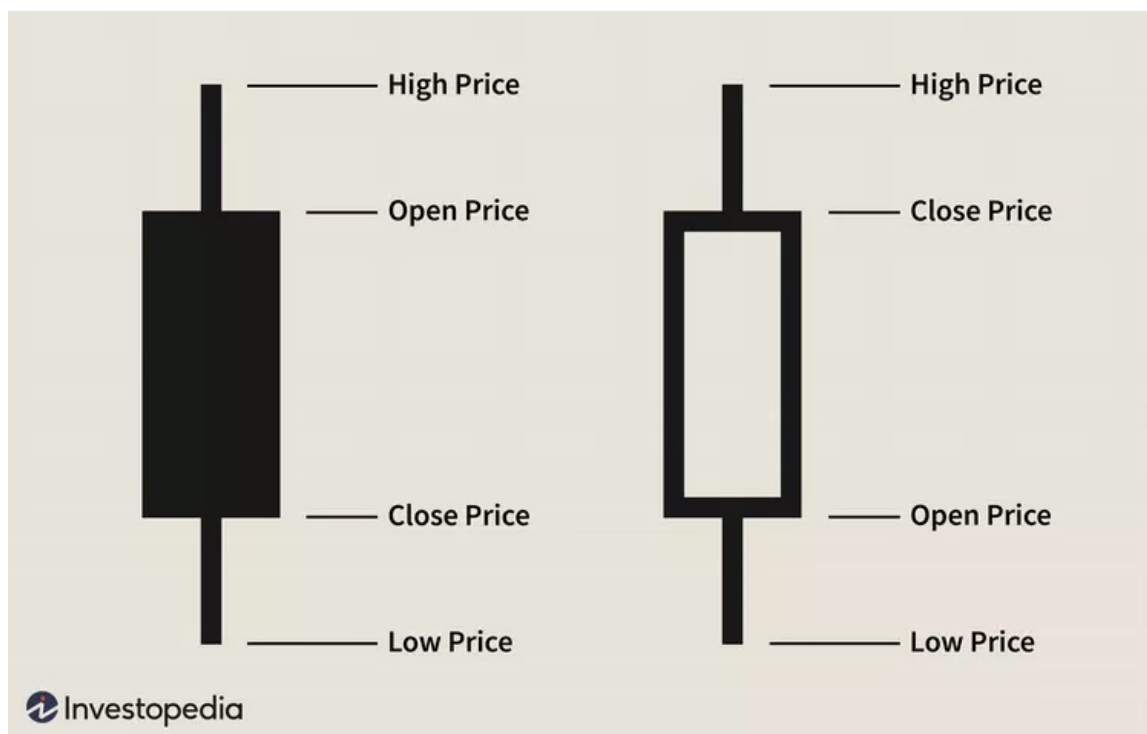


Figure 2.3: Example of candle and its description. Direction of price movement is distinguished by candle color [1].

2.3 Fundamental analysis

Fundamental analysis serves the same purpose as technical analysis, namely, to predict bullish or bearish price movements. Unlike technical analysis, fundamental analysis does not use graphs, but only market capitalization of underlying asset and any kind of news such as reports and filings of business, CPI data, FED interventions, and interest rate changes, overall market sentiment, laws changes, white papers, etc.

Some of the mentioned could be classified under **macroeconomics**, which is study of the part of economics concerned with large-scale or general economic factors and how they interact in economies [43][29]. It focuses on the performance of economies, such as changes in economic output, inflation, interest and foreign exchange rates, and the balance of payments. Macroeconomics is distinct from **microeconomics** which focuses on smaller

factors that affect choices made by individuals and companies, for example white papers, reports and filings, contracts and settlements, property and debts, etc. [42].

2.4 Trading psychology

Trading psychology is a critical aspect of successful trading that many novice traders often overlook. The ability to manage one's emotions, biases, and tendencies can significantly affect trading outcomes and the overall profitability of a trading strategy.

One of the most significant risks of trading psychology is the potential for a trader to fall into the trap of **gambling** [9]. This can happen when traders become overconfident and take unnecessary risks, or when they become so focused on the potential rewards that they disregard the risks involved. Gambling involves taking risks without a proper understanding of the market or the underlying assets, and it is a significant obstacle to successful trading. Several characteristics distinguish gambling from trading. One of such characteristic is the **illusion of control**, where traders believe that they have more control over the outcome of their trades than they actually do. This illusion can lead traders to take risks that are not justified by market conditions or underlying fundamentals. Another characteristic of gambling is **social learning and reinforcement**, where traders are influenced by others in their community to take certain positions or make specific trades. This can lead to herd behavior and a lack of independent thinking, which can be detrimental to trading outcomes. **Preoccupation** is another hallmark of gambling behavior, where traders become fixated on the potential rewards of a trade and lose sight of the risks involved. This can lead to impulsive and irrational decision-making, which can ultimately lead to losses.

Another psychological factor that can affect trading results is **FOMO** - Fear of Missing Out [39]. This is a common trend in which traders feel compelled to take action, even when it is not justified by market conditions or their trading strategy. FOMO can lead to impulsive and irrational decision-making, which can be detrimental to trading outcomes.

Individuals with specific **personality traits** may be more prone to certain biases and tendencies that can impact their trading outcomes [3]. Empirical evidence suggests that **impulsivity** can lead to more trading activity, but it may not necessarily lead to unprofitable trades. **Overconfidence**, on the other hand, can lead to poor decision-making and unprofitable trades. **Representativeness and confirmation biases** can also affect trading results, as traders may be inclined to rely on stereotypes or generalizations rather than considering individual circumstances or market conditions. These biases can hinder efficient learning and lead to unprofitable trades.

Large corporations have also been known to take advantage of retail behavior to extract more money from traders. This can involve tactics such as high-frequency trading or front-running, which can be difficult for retail traders to compete against. To counteract these risks and biases, it is essential to have a well-defined trading strategy and rules that are consistently followed. This can help traders stay disciplined and avoid impulsive decision making. Automated trading systems can also be useful in minimizing some of these risks and biases by removing emotions and biases from the trading process. In conclusion, trading psychology is a critical aspect of successful trading that should not be overlooked. By understanding the risks and biases involved, traders can develop strategies that mitigate these factors and improve their chances of success.

2.5 Investment and trading approaches

There are many approaches to trading or investing depending on the investment horizon, acceptable risk, time input, and capital size. This section discusses these differences and categorizes them.

2.5.1 Investment horizon

The main difference is investment horizon and we could divide it into the following categories [17]:

- Investing.
- Position trading.
- Swing trading.
- Day trading.
- Scalping.

Investing

Investing is usually **long-term** buy and hold strategy often improved with some kind of recurring purchase. It consumes **less time to manage**, and it is possible to invest almost any amount of money due to the possibility to split orders over longer time frames. Investing is often a matter even for inexperienced traders. Those investors usually picks less risky but also less profitable assets. The goal of investment is to accumulate wealth for later use, such as housing car or a retirement. As stated above, main characteristic is length of investment horizon, which is in most cases more then a year or even decades. There is the possibility to sell investment sooner in case of unexpected behavior and progression of market.

Position trading

Its name comes from derivatives, where leverage and shorting is possible, and instead of buying or selling, it is an opening position. Position can be opened in both directions, so buying and selling terms are ambiguous. Position trading is category of opening **positions for months**. Due to its big overlap with swing trading and investing its not mentioned often. Leverage in position trading is possible, but generally only really small, less than 2x or none. Shorting is unusual for this long time periods.

Swing trading

Swing trading is taking advantage of rising and falling markets. In this approach it is much more usual to open shorts. Positions are held **from days to a few months**. This approach is suitable for moderately active traders. which doesn't mean full time traders doesn't open swing trades.

Day trading

Day trading got its name from **trading only during the day** and not having open positions at night. Day traders are taking advantage of the open hours of large markets and the high volatility and liquidity. Positions are generally leveraged. Short positions are common, but due to their mathematical nature and due to inflation, it is always more beneficial in the long term to open more long positions. Day trading requires a significant amount of knowledge and experience in technical analysis, chart patterns and risk management. It is also important to be informed about relevant news and events on markets.

Scalping

Scalping is subcategory of day trading. It is specific by **very short investment horizons** from seconds to a few minutes and taking advantage of high volume and price spikes. Scalpers trades important price levels or news that moves with price. In scalping it is not a surprise to use leverage over 50x. Scalp trade can be transformed into a swing trade by closing the majority part and letting a small portion of the position open.

In the rest of this thesis trader, trading, investor and investing will refer to any of the above categories if not further specified by attribute.

High-frequency trading

High-frequency trading refers to algorithmic trading characterized by high speed [6]. It is used mainly by hedge funds, investment banks, and institutions due to the need for a fast connection to exchange. The frequency of trades can be several times per second. This connection is difficult to achieve for retail traders. Fees paid per trade would also make it impossible for retail traders to be profitable. In reduced form, retail trades are able to operate algorithmic bots, but those are not considered high-frequency. Also advantage of big companies are capability of creating and servicing much more complex algorithms using data from different sources and markets. An example of high-frequency trading could be arbitrage trading, which takes advantage of buying and selling the same asset on different markets at different prices.

2.5.2 Risk tolerance

Another relevant factor of investing is risk tolerance. Every trader want different risk, because more risk means more potential gains and losses. Generally the older trader is or the more capital is he trading with, the less risk he tolerates. Some assets can be risk-free, but there is a very high probability or even guarantee that they will not even cover inflation. It is suitable for saving for later use, such as buying a new car or building a house, or just to store money. It does not consume much time and it is possible to invest almost any amount of money. For example, building savings, savings accounts, and state bonds could be considered risk-free with pre-known evaluation. Higher-risk and potentially higher-reward assets are, for example, commodities, or exchange-traded funds (ETF). It needs to be said, that there is big risk difference in between different ETFs. These assets require more investigation and time to evaluate its possible performance. The most risky assets are derivatives, such as leveraged futures and options, and volatile markets, such

as cryptocurrencies and small market cap stocks. Trading these assets is the most time-consuming, as the trader needs to find a suitable asset, analyze it, set alerts, and be ready to intervene. Depending on what trading strategy is used, it is possible to reduce the time needed in front of the charts.

2.5.3 Time consumption

As already outlined in previous section, time consumption and risk are closely related. Many people who want to start trading have their jobs and do not have time to watch their portfolio every day. Therefore, it is important to think twice about how and where to invest money. The most time consuming is learning to trade, but it is a one-time investment. So it is good to have at least basic knowledge of financial instruments and what are we expecting as outcome. Long-term investing is the least time consuming approach as investor doesn't necessarily need to check portfolio every day. Suitable strategies are easy to understand and implement. For example DCA strategy is fully algorithmizable and many brokers offers recurring purchase automatically. It is less time-consuming, less risky, and has lower potential gains. Contrarily day trading is the domain of full-time traders as the trader needs to do research about instrument, then open position and close position. Also day trading requires much more initial knowledge to be profitable. In general, the more time and risk is input, the more profits. The question is, why aren't experienced day traders easily millionaires or billionaires? There are many reasons including manipulated market, inexperience, and less education. But why cant a trader be billionaire even if he is proved to be profitable? In theory, with compound interest and leverage, it should be possible to make infinite money. The reason why it is not possible is liquidity.

2.5.4 Capital size and liquidity

Liquidity refers to the degree to which an asset can be quickly bought or sold in the market at a price reflecting its real value [22][20]. Liquid assets are those that can be bought or sold quickly without having a significant impact on their traded price. Liquidity is characterized by a **solid order book, tight spread, and high trading volume**. **Order book** is book of offers to sell or to buy, they never overlap because they would match and execute trade and wouldn't appear in order book anymore. **Spread** is difference between highest bid (seller) and lowest ask (buyer) price. An example of spread, order book, and bid and ask prices can be seen in [Figure 2.4](#). High trading volume creates a denser order book, so the spread tightens. These orders wait for a trader willing to accept the loss due to the spread and will perform the market order. The exchange will match the best price offered in the order book with the market order and perform a trade. As can be seen, traders, especially those who trade frequently, will seek to trade liquid assets due to lesser draw-down caused by the high spread.

Examples of liquid and illiquid assets could be cash and a used car. If we want to sell dollars for Japanese yen, then we can go to almost any bank, and that bank will not have any problem selling Japanese yen without any impact on its price. On the other hand if we want to sell used car for objectively fair price we would need to advertise it and wait for a buyer for unknown time span. There is also the possibility going to car dealership and sell them the car for a reasonable price and they will be offering that car instead of us. This car dealership could be example of what we call in trading market makers. **Market makers** takes on the risk that the price will change over time in return for fee in the form of better price for them. These market makers are in all kinds of markets, not only illiquid but also

liquid. Liquidity is always finite even for the most liquid assets and its limits could be seen as its market capitalization [14]. Trying to buy a stock with more money than the market capitalization of that stock company would result in buying the whole company for more money than necessary. This is obviously a problem only for really wealthy individuals, but it can affect common retail traders too if investing with large capital or in short period of time. Due to the finality of the order book and the possibility to overwhelm market makers, it is necessary to wait for restoration of order book. There are several reasons why is this important.

Market manipulations

The first is for those with less funds. These traders should be aware of illiquid markets and leveraged markets, where there is the possibility to experience market manipulations. These manipulations are often used against traders with open orders to automatically stop position when in a specific loss. Lets call these orders **stop losses**. For example, a manipulator will buy a large amount of asset, and that action will move the price higher. That price shift can trigger stop losses of other traders who shorted lower and they will immediately be forced to buy higher. This action is illustrated on [Figure 2.4](#). It will cause the price to go even higher and may result in **cascading liquidations**. These stop losses can be filled by the one who caused the price to go higher and so makes him profit. This phenomenon is often used for market manipulation from those with a large amount of funds and can be used in stop-hunting strategy ([section 3.5](#)). Generally, the shorter the time period and the smaller the volume, the easier it is to manipulate the price. These manipulations are happening all the time and are visible on smaller time frames. They are the driving force of trading algorithms and exchanges with inside information on stop losses and liquidations.

Lack of offer

The second reason why it is important is for those with larger funds. As has been already said, liquidity is always finite and supply determines demand. In any market there is a limit to the invested funds during the time interval without affecting the price. This limit is not very high even for the most liquid markets. The most liquid markets are also very slowly moving in terms of percentages and so traders usually leverage their positions to gain more profits. Opening position itself can result in shifting the price in desired direction, but also leaving gap in order book and extending spread. The larger order, the larger price shift and the worse entry price as it would be average of orders taken out from order book. The illustration of what the order book looks like before and after buying a significant amount of an asset is in [Figure 2.4](#).

Immediate closing of position would then be in loss. This move can be seen as manipulation explained above, and results in price getting even higher, but if no new buyers would show up and trader would expect price to go even higher and so would not sell, then it could contrary trigger new sellers and move price even much lower under entry point. With small position this would not be a problem as order book could easily hold and restore fast.

Time and profit pay-off ratio

On average, investing long enough and with divergent portfolio investor should be able to achieve profit equal to inflation. Some assets would fall or even go bankrupt, and some assets would increase in price. Skill, good strategy, and fundamental analysis can help you

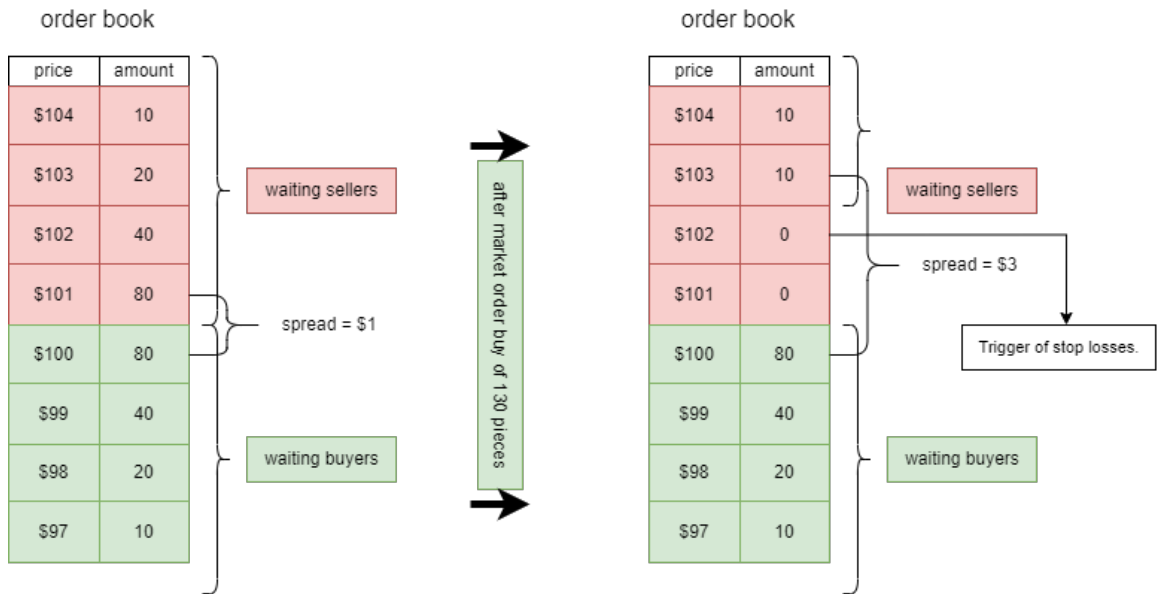


Figure 2.4: The illustration how order-book could look like, what is spread and what effect does the immediate purchase of 130 pieces of the asset have on order-book. In this specific example the average position entry would be $\frac{80 \cdot 101 + 40 \cdot 102 + 10 \cdot 103}{130} = \$101,46$. The triggered stop losses would do the same as the example to order-book again with different amounts.

achieve even better results and choose the right investment. Using complex strategy and performing fundamental analysis costs time Profit will always be percentage, and that is why capital size matters too. If the investor spends 1 hour a day managing investments and it will help him gain another 10 % annual profit, then his capital size would need to be 15x his monthly income to pay for his time accordingly. The payoff formula between time spent, capital size, monthly income, and annual profit gain (annual profit minus inflation) is as follows.

$$G \cdot C > \frac{12 \cdot M \cdot T}{J}$$

where

- T - average hours a day devoted from regular job to investments analysis,
- J - regular working hours a day,
- C - capital size,
- M - monthly income from full-time job,
- G - annual portfolio profitability minus inflation.

Let example be a student with a part-time job trying to invest his savings. He works 4 hours a day and wage is \$500 monthly, he is managing his investments every day for 1 hour, he is trading with \$10,000. How much annual profit he has to gain so his time input would be more valuable than in his regular job?

$$10000G > \frac{12 \cdot 500 \cdot 1}{4}$$

$$G > \frac{1500}{10000}$$
$$G > 0,15$$

He would need to make 15% + inflation profit for his time to be same valuable as in his job, which is not an easy task.

This example shows that, to a certain level, it pays off to save money in a savings account or in a time-saving investment and work in a regular job. Note that this example does not count time needed for education and trading experience, which is significant part. Some sources mention that trader need at least **6 to 12 months** to get profitable [31]. At a certain point, it is possible to earn more through investing and trading than through a job. It is important to remember the impact of inflation and that man's time also has a value. Of course, there are many amateur traders in the market because it is a hobby for them, and in such cases, it is obviously possible to accept certain losses, whether in terms of time or even money. It is also important to note that trading can be addictive, especially 24/7 trading like cryptocurrency or forex, and can be considered as gambling.

Chapter 3

Trading and investment strategies

After selecting a trading approach, it is equally important to choose a suitable trading strategy. Trading strategy is set of mostly strict rules about buying, selling, finding opportunities, managing risk, and cash-flow. Thanks to these rules, the performance of a strategy can be analyzed, enabling an assessment of its profitability and potential based on historical data. In this chapter, we introduce several widely used concepts in trading strategies, many of which share common foundations. Some strategies are well-suited for long-term investments, others for risk mitigation, and some for scalping or identifying position entries. It is worth noting that these strategies can be combined to further enhance trading outcomes.

3.1 Lump sum and Buy and hold strategy

These strategies are the easiest and most straightforward. The idea behind them is to buy at one time for all designated money. In relation to bitcoin, it is often referred to as **HODL**. HODL is a term derive from a misspelling of „hold“, in the context of buying and holding bitcoin [18].

Managing these strategies is very time-saving and can be used as a baseline for comparing with other trading strategies. Because of the fact that timing market is not easy task and making mistakes in trading is common, this strategy may result in significant loss. Due to this fact, it is good to consider some kind of risk management and to use other strategies such as DCA or rebalancing. There could be some modifications to the strategies. Such as not necessarily buy at one point, but over investment horizon. Such approach is suggested in this study [4]. However, this approach is more similar to the DCA strategy than the Lump Sum. The difference between lump sum and buy and hold strategies are negligible. It is believed that lump sum strategy is typically used when an investor has a significant amount of cash available to invest (e.g. inheritance, sold investment, etc.) and wants to maximize the potential return on new investment. A buy and hold strategy is often used as a long-term investment strategy and is followed by strong believe in fundamentals of the underlying securities. Both Lump sum and Buy and hold are static algorithms. Static algorithms work without any dependence on the price of the asset. Another static algorithm is dollar cost averaging.

3.2 Dollar cost averaging

Shortly **DCA** is one of the main approaches to enter position for retail investors. The algorithm is simple. Whole investment is divided into equal parts and invests them at regular intervals over a period of time. If the price is higher, then a smaller portion is bought and opposite when the price is low, a larger portion is bought as the same amount of money is invested [30]. DCA is static algorithm and despite its popularity its been proven, that DCA strategy in its common form isn't optimal. The optimal algorithm is introduced as the **balanced strategy** in study [4]. This strategy is very similar to DCA, but it takes advantage of bounded daily return model. By this strategy investment is divided into desired number of portions n . The upper bound is β and lower bound is $\frac{1}{\alpha}$. Calculation formula for first investment is:

$$\frac{\alpha \cdot (\beta - 1)}{n \cdot \alpha \cdot \beta - (n - 1) \cdot (\alpha + \beta) + (n + 2)}$$

The formula for the last investment is the following.

$$\frac{(\alpha - 1) \cdot \beta}{n \cdot \alpha \cdot \beta - (n - 1) \cdot (\alpha + \beta) + (n + 2)}$$

And the formula for every other investment in between is:

$$\frac{(\alpha - 1) \cdot (\beta - 1)}{n \cdot \alpha \cdot \beta - (n - 1) \cdot (\alpha + \beta) + (n + 2)}$$

The bounds α and β are circuit breakers [13] for given asset or can be estimated from historical asset price data for assets without circuit breakers as are for example cryptocurrencies.

The most valuable feature of DCA advocated by articles, firms, and the media is the reduction of risk. DCA strategy flattens its yield curve. As the world economy is based on inflation and all assets are rising in price over time, this DCA approach turned out not to be beneficial, because risky assets grow more rapidly then risk-less cash. In empirical analysis, both the buy and hold strategy and optimal rebalancing were shown to be more profitable than DCA [26]. It is important to note that the analysis was on long period of time. On shorter intervals, it would appear more often that buy and hold could be less profitable due to buying at local high.

Very clear results were achieved in the study by Merlone and Pilotto [30]. Stock markets and funds were more likely to be more profitable if the Lump Sum strategy was used instead of DCA. It was found that Lump Sum has greater dispersion than DCA and so higher risk of larger losses, but also higher chance of larger profits. As [Figure 3.1](#) shows, it is clear that LS has better results.

It is very important to mention, that monthly recurring purchase with money that were earned that month isn't DCA but buy and hold strategy. DCA operates with whole bundle of money that is divided and each of those parts are waiting to be invested. This phenomenon makes it so poorly performing, because of opportunity cost, which is missing opportunity to make profit.

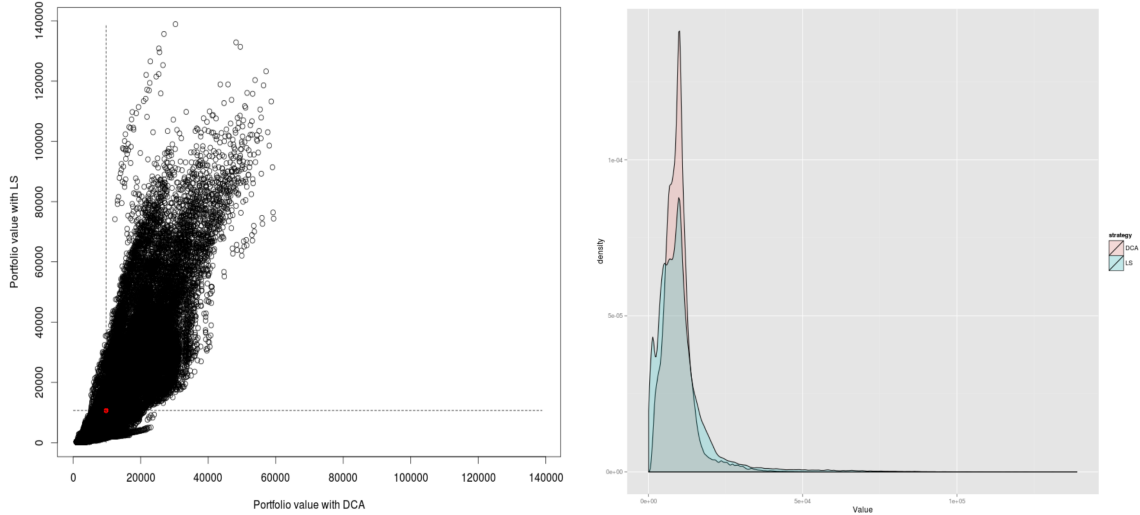


Figure 3.1: On the left is stock portfolio value and on the right is distribution of portfolio value with DCA and LS at the end of investment period [30]. Lump Sum worked a little worse on stock portfolio, but still clearly better than DCA.

3.3 Time weighted average price

Despite the inefficiency of DCA, part of it found its place with large institutional investors as TWAP. TWAP stands for „Time Weighted Average Price“. It is a trading algorithm used to execute large trades over a specific period of time while minimizing market impact. With TWAP it is possible to open large position even in illiquid market. The TWAP trading algorithm works by dividing a large order into smaller, evenly sized orders and executing each order over a specific time period. The time period is typically chosen on the basis of the volume of the market and the liquidity of the asset being traded. By executing orders in smaller increments over time, the algorithm aims to minimize the impact on the market and avoid sudden price movements that could result from executing a large order all at once [8]. Difference between TWAP and DCA is that DCA strategy assumes closing position after last portion was invested, contrary TWAP will keep the position open longer after it is fully filled.

3.4 Rebalancing

Rebalancing is an investment strategy that involves periodically adjusting the weights of assets in a portfolio to maintain a **target asset allocation**. Asset allocation is the process of dividing a portfolio among different assets such as stocks, bonds, cash, etc. [45].

We can think of portfolio as a pie chart, where every piece represents one asset. All assets in pie chart are displayed in their value against same one asset, generally fiat currency USD. In Figure 3.2 is shown how this pie chart could look like if portfolio was evenly divided into 4 parts. For example if \$1,000 was initial investment, then we would invest \$250 in each asset. Note that cash can also be part of the pie chart portfolio. After a while, some assets will perform better than others, and the initial pie chart would change. Therefore, actual asset allocation would shift from target allocation. Rebalancing would dismantle this

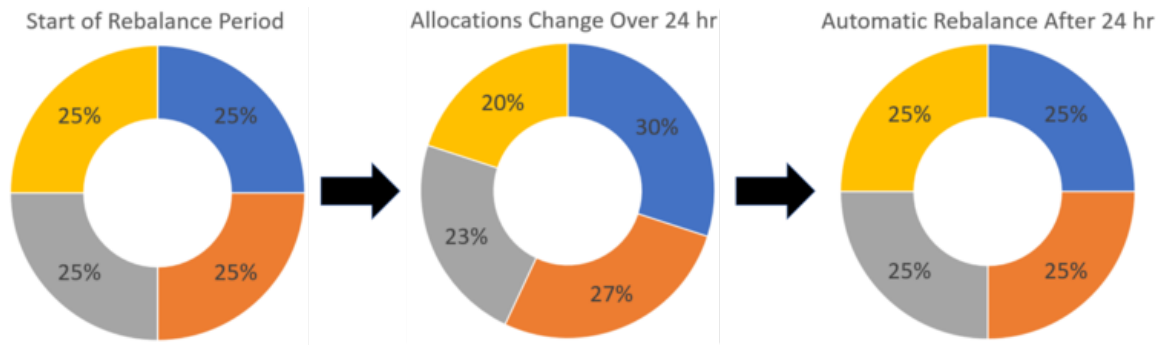


Figure 3.2: The pie chart of portfolio after initial investment, after a certain time and after rebalancing performed [28].

shift by selling the better performing assets and buying the worse performing ones. The question is when and how exactly this would happen.

There are several types of rebalancing strategies, including calendar-based, threshold-based, and combination of both. **Calendar-based** rebalancing would occur once per predefined period of time. Rebalancing trigger would be, for our example an hour. **Threshold-based** would occur after any asset deviates by a predefined threshold. In example Figure 3.2 the threshold would be 20%. Calculation would be: $25\% \cdot 120\% = 30\%$ **The combination** of these two types is possible in two ways. We can rebalance every time any of the conditions occur. Or do the calendar-based but only if the threshold condition was also reached at that time.

The main advantage of rebalancing is that it helps investors maintain their target asset allocation, which can help manage risk and potentially improve returns. Rebalancing can also help investors take advantage of market oscillations and volatility, buy undervalued assets, and sell overbought assets. The rebalancing weakness is **transaction costs**. Transaction costs consist of fees to stock exchanges for trade mediation. **The spread** of the order book, which affects both the sale and the purchase of assets, requires a deeper analysis of the price data. **Price impact** on illiquid markets as was explained in section 2.5.4, where larger orders results in worse entry then available best price. And the **opportunity cost**, which is the risk of selling good performing assets or buying poorly performing assets too soon or too late. Transaction costs are the reason why it is important to choose the type of rebalancing and its parameters carefully.

Every portfolio can have different optimal parameters. For example, by study [40] for huge portfolios and funds, there is assumption that best possible settings for rebalancing is annual or biennial with 1 to 5 % threshold. But this study focuses on huge portfolios and so transaction cost rises due to need of large positions. On the other hand, another study by the same company [28] focused on cryptocurrencies rebalancing. They tested different amount of assets in portfolio, different market capitalization of assets, different asset allocation, and different frequency of rebalancing. The results show the need for more assets in the portfolio. Better results were with even distribution, mid-cap assets and higher frequency of rebalancing, specifically best results were with the highest tested frequency per hour. Similar results were achieved by study [44] which is investigating possibility of high frequency rebalancing and is comparing rebalancing periodically from 1 hour to 24 hours and their best results are also with hourly rebalancing similarly with previous study. This result is probably due to much smaller orders and transaction costs and also due

to greater volatility of cryptocurrencies. Another study on rebalancing [48] among other things is researching impact of correlation, volatility and return difference on rebalancing performance. Its performed on simulated data, but it shows valuable insights. This study found that it is desired to rebalance uncorrelated or negatively correlated volatile assets, but with similar rates of return. There is also a study already mentioned that compares lump sum, DCA and rebalancing [26]. This study shows that rebalancing is the best method to invest in any asset even if it is only one asset and cash. The problem with this study is overlooking opportunity cost of unused cash. Using strategy lump sum with whole portfolio might have better performance then using only part of it. Rebalancing is not capable of the investing a whole portfolio in one asset due to the nature of algorithm. Rebalancing strategy on portfolio consisting of 1 asset would become lump sum strategy.

3.5 Stop hunting

Liquidation and stop-loss hunting is potentially the most profitable short-term strategy, but also the strategy with the highest risk. It is taking advantage of liquidation of big portion of interest such as hedge fund or large institutions [35]. Identifying such activity is not hard, but it is never obvious if liquidation is or is not over yet. The characteristic of is huge volume and price spike as seen on example [Figure 3.3](#) of LDO token from 8.1.2023. In this spike trader wants to buy these liquidated positions on its maximum or position themselves before it even happens. On smaller scale this is happening all the time, but on key levels, thanks to a cascade of liquidations, it can give huge opportunities. Algorithms, huge funds and traders with inside information about where are liquidations want to find these levels all the time because of their ability to sell there larger amount for better price. Retail traders usually put their stop losses above or below the local minimum or maximum, and the price would go where most stop losses and liquidations are. This phenomenon is one of the biggest influences on lower time frames. There are paid tools that estimate these data for cryptocurrencies, such as [hyblock](#)¹ or [thekingfisher](#).² The [hyblock](#) example is shown in [Figure 3.4](#) The alternative free way to guess liquidations levels is to analyze open interest, which is publicly available from brokers and exchanges.

3.6 Strategies based on technical analysis

These strategies are mostly part of day trading and swing trading. Traders usually master many of them and, when more of these strategies are congruent, they open a trade. Technical analysis works better on lower time frames and illiquid markets. But this makes it more vulnerable for manipulations and not a small part of traders uses stop losses, which makes liquidation hunt lucrative strategy.

3.6.1 Supports and resistances

Support and resistances are price levels where the asset had difficulty getting through. The level is called the support when it is below the actual price, and the resistance when it is above the actual price. It means, when price breaks through resistance, this level is considered as support in the future. This concept is considered as basic knowledge and is

¹Hyblock available from <https://hyblockcapital.com/>.

²Thekingfisher available from <https://thekingfisher.io/dxm6>.



Figure 3.3: Process of liquidations ending with the last cascade of liquidations making a move of more than 50 % in 1 minute with volume of approximately \$30 millions.

very often recommended to beginners. On these levels it is good to consider starting a trade or taking profit from running trades [36]. Alternatively trend lines could be also supportive or resistive to price as seen on [Figure 2.1](#)

3.6.2 Consolidation

In consolidation price goes up and down generally between support and resistance. If this range is detected soon enough, it is possible to trade it for a small profit in both directions until the price breaks out of consolidation. It's a sign of indecision in the market. During a consolidation, funds are redistributed between buyers and sellers until one of them runs out of capital and the consolidation breaks into a trend in some direction [5].

3.6.3 Supply and demand zones

The supply zone is the area where a large number of traders are willing to sell assets that push the price down, and the demand zone is the area where more traders are willing to buy and push the price up. These zones are usually created during consolidation, and it is more likely that in this zone the price will move in the corresponding direction in the future [7]. Supply and demand zones are often called order blocks, which are created with a large number of orders and a high volume, often caused by large institutional traders. There are more ways to find it and mark it. For example price starts consolidate near support area and ends with strong push up, ideally with FVG.

3.6.4 Volume imbalance

Volume imbalance or order imbalance is a situation where there is a large difference between buy and sell orders, making it impossible to match them [24]. This can result in a big price movement, leaving a zone full of unfilled orders and unsatisfied trades. Volume imbalance is also very similar to the fair value gap (FVG). FVG is created when price moves very fast and does not naturally oscillate up and down, resulting in candles that are not overlapped by their neighbor [33]. It is very easy to spot on the candlestick graph. The difference between

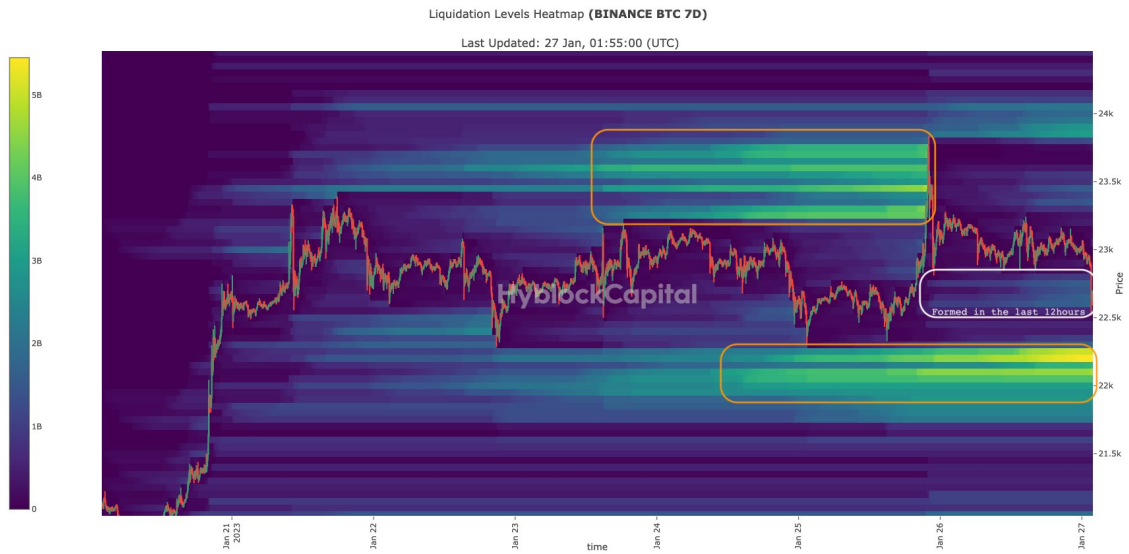


Figure 3.4: Example of hyblock capital liquidation heatmap [23].

imbalance and FVG is the appearance in the graph. FVG is a long candle untested by its neighbors. Volume imbalance is the jump in price between last matched trades and creating a gap between the candles. It often happens in illiquid markets and also during after-hours trading or market closure. Price movement this fast is often caused by some kind of news or FOMO and tends to correct back to these imbalances and FVGs. But when price returns in these FVGs and imbalances there is higher probability of the old unfilled orders and demanding waiting traders to redirect price movement again in direction of original move.

3.6.5 Indicators

Indicators are mathematical calculations or statistical models applied to historical market data such as prices and trading volumes. Indicators may be built using a variety of ideas and methodologies. For example oscillators, moving averages and MA based indicators such as moving average convergence divergence (MACD) are price trend indicators. Others may monitor the volume of trade in other ways, such as accumulation/distribution or on-balance volume. Many indicators based on statistical computations, such as the relative strength index (RSI) or moving average convergence divergence (MACD), are also available. There are several commonly used and well-known indicators, as well as many developed by the community. This section highlights a few of the most well-known and often utilized indicators.

Moving averages

Moving average is a statistical calculation that smooths out price data over a specified period to identify trends and determine potential support and resistance levels [15]. Moving averages are effective in smoothing data and reducing noise, but they introduce lag due to their inherent calculation methodology. They are suitable for smoothing various types of data, including price data, trading volume, or even already processed data such as indicators. When using moving averages, one important parameter to consider is the input data



Figure 3.5: Example of support, resistance, consolidation and demand zone on ETH/USD pair.

length, which can be adjusted to smooth out more noise but also increases lag. There are several ways to calculate moving averages. The simple moving average (SMA) is calculated as the mean of the last n data points. The exponential moving average (EMA) gives more weight to recent data points, while the weighted moving average (WMA) assigns different weights to each data point. Another variation is the smoothed moving average (SMMA), which applies a smoothing formula to the data.

Moving average convergence divergence

Moving average convergence/divergence (MACD) is a trend-following momentum indicator that indicates a relation between two EMAs of a security's price [10]. By subtracting the longer EMA from the shorter EMA, the MACD line is calculated. Longer EMAs reflect a more lagging trend on higher time frames and are often displayed with a length of 26. The shorter EMA reacts quicker, and its length is often set at 12. Another EMA is computed from the MACD line and is known as the signal line, which typically has a length of 9. The signal line is drawn atop the MACD line and can be employed for producing buy or sell signals. Traders tend to buy when the MACD line crosses above the signal line and sell or short when the MACD line crosses below the signal line. MACD may be read using crosses, divergences, and quick rises/falls. It can be used to determine overbought or oversold levels, the intensity of a directional advance, and future price reversals. Divergences between MACD and price can also indicate future failures and reversals.

On-balance volume

On-balance volume (OBV) is a technical momentum indicator used to predict changes in stock price based on volume flow. Developed by Joseph Granville [19], OBV focuses on volume as a key force in the market. When volume increases significantly without a corresponding change in price, Granville believed that a price jump or drop would eventually occur. Traders and analysts use OBV to track institutional investors and identify divergences between volume and price, indicating opportunities to buy against prevailing trends. However, large spikes in volume on a single day can distort the indicator, so caution is advised when interpreting such anomalies.

The formula for calculating OBV is as follows:

$$OBV_t = \begin{cases} OBV_{t-1} + Volume_t, & \text{if today's closing price is higher than yesterday's closing price} \\ OBV_{t-1} - Volume_t, & \text{if today's closing price is lower than yesterday's closing price} \\ OBV_{t-1}, & \text{if today's closing price equals yesterday's closing price} \end{cases}$$

where OBV_t represents the OBV value at time t , OBV_{t-1} is the previous OBV value, and $Volume_t$ is the trading volume at time t .

Relative strength index

In technical analysis, the relative strength index (RSI) is a common momentum indicator. It assesses the speed and amplitude of recent price swings in order to discover overpriced or undervalued circumstances in the price of an investment. The RSI was invented by J. Welles Wilder Jr. in 1978 [47][16].

The following formula is used to compute the RSI:

$$RSI = 100 - \left(\frac{100}{1 + \frac{AverageGain}{AverageLoss}} \right)$$

The RSI is calculated by comparing the average gains and losses over a given time period parameter. The RSI value gives information about the relative strength of a security and may be used to discover possible trading signals and trends. Traders commonly look for two key levels:

- A reading above 70 indicates an overbought situation, suggesting that the security may be overvalued, and a price correction or pullback could occur.
- A reading below 30 indicates an oversold condition, suggesting that the security may be undervalued, and a potential price reversal or rebound could take place.

These levels of overbought and oversold might assist traders in identifying possible buying or selling opportunities. When evaluating RSI readings, traders frequently utilize it in conjunction with other strategies and take into account the current trend. Traders may prevent misleading signals and match the RSI with the actual market circumstances by changing the overbought and oversold levels based on the security's principal trend.

RSI divergences can also give useful information about impending trend reversals. Bullish divergences occur when the RSI makes higher lows while prices make lower lows, indicating the possibility of upward momentum. Bearish divergences, on the other hand, occur when the RSI makes lower highs while prices make higher highs, signaling probable negative momentum.

3.7 Smart money concept

Smart money refers to cash invested by institutional traders or investing banks with inside information and analysis that retail investor would not be able to access. Studies dealing with the issue of smart money are for example [49][25]. The idea that high-volume trades belong to an experienced and informed investor is the key to entering the trade. Identifying

these transactions and copying them with the belief that investors of smart money know something that we do not, might help to be profitable. Some possibilities how to spot smart money are, for example, supply and demand zones, trading volume analysis or trading transactions data providers such as the Commitment of Traders report³. There are many small traders and whole communities who are making strategies using technical analysis trying to identify smart money and take advantage of it.

3.8 Fibonacci retracement

It is a method to find supports and resistances. Its significance could be questioned, and it is not recommended to use it independently. However, it is good to confirm existing supports and resistances and to estimate future resistances in places of graph, where the price has never been. This retracement is created by dividing the price between two extremes by the Fibonacci sequence. The idea of Fibonacci retracement is widely used in indicators, in other strategies, or in combinations. The paper [2] is investigating statistical evidence if security prices shows such patterns. It found that *„there is some predictive utility associated with Fibonacci sequences used as filters in automated trading systems“*, but also that *„this is merely indicative and by no means conclusive empirical evidence“*. These conclusions confirms the importance of combination of strategies.

3.9 Elliott waves theory

The Elliott Wave Theory is a principle based on the idea that markets do not behave in a chaotic manner [21]. It was founded in 1939 by Ralph Nelson Elliott and is very extensive and complex. This complexity and also obsolescence is often target of criticism. However it's basis is that market prices moves in waves. These waves can be divided to impulse wave and a corrective wave. The impulse wave is composed of five smaller waves, while the corrective wave is composed of three smaller waves. Every smaller wave should be able to be analyzed as another whole Elliot wave. Each part of these waves has its characteristics and comes in many forms, which will not be discussed here. The Elliott wave theory uses Fibonacci retracements to identify heights of waves. It is based on psychology of the human being, who behaves in a rhythmical pattern. The fact that human lives are a circle of repeating events even supports this idea.

³Availble from <https://www.cftc.gov/MarketReports/CommitmentsofTraders/index.htm>

Chapter 4

Available simulation and trading tools

Creating working algorithmic strategy, that can execute profitable trades by itself has its requirements. Those are testing its profitability and execution. For testing a strategy as a trader, there are many tools, where it is possible to manually invest virtual money and test your strategy on historical data. But testing algorithms is more complicated. This chapter covers some of the most popular tools used by traders and some possible solutions to achieve algorithmic trading and its testing.

4.1 Simulations

Simulating presented concepts can be achieved with many tools. But unfortunately most of these tools are suitable only for manual testing of alive trader and are behind pay wall. They offer realistic view on markets and give an option to trade on historical data with imaginary money. But they do not offer any API for their own bots related to simulation of algorithmic strategy. For example almost any broker has its own „paper trading“ or there are specialized applications like tradingsim¹.

Fortunately, the largest player in the charting industry, **tradingview**², offers tools that partially meet the needs. This powerful platform is mainly used for viewing charts and drawing in charts. But it offers whole spectrum of other tools like mediate trades to exchanges, rewind charts and simulate strategies, news and articles related to traded asset, alerts and most importantly pine scripts³ for traders own indicators. Pine script is the language created by tradingview. It is simple and it's biggest advantage is build-in data. Unlike the local solution where the programmer would need to download data from the data provider, in pine script it is a fast and easy function. On the contrary, if you need any other data than tradingview offers, you cant do anything about it. In summary, tradingview has easy access to data, it is easy to implement its own strategy, and it is easy to backtest profitability. Unfortunately it is not easily possible to enter real trades even though tradingview can be linked to exchanges. However, there is workaround for it using

¹Tradingsim available from <https://www.tradingsim.com/>.

²Tradingview available from <https://www.tradingview.com/>.

³Pine script documentation available from <https://www.tradingview.com/pine-script-docs/en/v4/index.html>.

alerts via a REST webhook endpoint. Tools such as tradelab.ai⁴ or algojojo⁵ can mediate trade between the tradingview webhook alert and the selected exchange.

4.2 Data providers

For own solution it is important to download and update prices data. These can be obtained from various sources. Some examples of data providers could be polygon.io⁶, alphavantage⁷ or yfinance⁸. Polygon.io is a large and experienced business partnered with Google or Revolut. They have a free subscription option, but with data age limitations. The oldest data are 2 years old, and the latest data are 1 day old, which is not usable for real-time trading. Solution would be buying a better subscription. The other solution with alphavantage is overall similar. It is even partnered with polygon.io, but offers a free API with live stock market data. The most straightforward method would be to use exchanges' data itself. Many of exchanges offers its own API and it is possible to not only download data but also open trades. Its disadvantage could be age of data if exchange did not list wanted asset soon enough or did not complete its database with older data and also need of implementing all features from scratch.

4.3 Trades executors

As stated above, trade executions can be done only by brokers and exchanges themselves or via their API. It is appropriate to consider delay of some solutions and risk of failure. On larger scale, it is good to consider a solution with paid cloud with a fast Internet connection and a close link to exchange itself. For demonstration solution with tradingview means data traveling from exchange to tradingview, where it gets processed, over REST API to tradelab.ai where trade is created and sent to broker who will open the trade. It's clear that communicating with the broker itself could make a difference in performance.

Another trading tool worth considering is freqtrade⁹, which is an open-source trading bot written in Python. It offers many features such as downloading data and opening trades via brokers APIs, Web UI for monitoring, testing run for back-testing strategy, and many more. Its advantage and disadvantage is the need to know and understand its features. After mastering it, this tool or similar tools might be the best complex solution.

There are probably many other tools that would be sufficient or even better to use than those mentioned, but it was not in authors powers to cover all existing tools.

⁴Tradelab.ai available from <https://tradelab.ai/>.

⁵Algojojo available from <https://algojojo.com/>.

⁶Polygon.io available from <https://polygon.io/>.

⁷Alphavantage available from <https://www.alphavantage.co/>.

⁸yfinance for python available from <https://pypi.org/project/yfinance/>.

⁹Freqtrade available from <https://www.freqtrade.io/en/stable/>.

Chapter 5

Design and implementation

This chapter delves into the design of the proposed strategy and the subsequent implementation of a simulation tool. It provides a comprehensive exploration of the underlying rationale behind the chosen design of the strategy, clarifying the considerations that led to its formulation and laying out the necessary steps to be undertaken. Moreover, within this chapter, an extensive outline is presented, describing the programmed aspects of this work. There is explanation of each part, specifically downloading and preparing data, creation of testing investment horizons and detailed description of each implemented strategy. By diving into these crucial elements, this chapter lays the groundwork for a comprehensive understanding of both the strategic design and the technical implementation.

5.1 Building own strategy

The goal was to create a strategy that can be used in multiple different time frames. For example, strategy should work on graph with daily candles and also on minutes candles. However, the moves of underlying asset are very diverse. For example on daily graph we would want to trade a 10% price move that would be rising over 10 candles. In similar situation but in a 1 minute time frame it would be only 1 % over 10 candles. This would have a significant impact on the transaction cost. Another problem is, that out of the 10% move over 10 days, 8 % move could occur just in few hours or even few minutes. In other words its average movements also deviation vary on different time frames and assets. These situation makes it very hard to make versatile strategy. The least requirement is to adjust its parameters.

The first attempts that failed without success were built on moving averages calculated from price. Idea behind was that price is always trending on certain time frame. The world economy is based on inflation and so the price is always rising in a long enough investment horizon. This bias can then be transferred to lower time frames like months, then weeks, days, hours, and even minutes. By trend determination on each level of time frame and opening trade when all of them align, we could achieve profit. However, moving averages are lagging indicators and it would be always too late to open trade. The test results seemed random, and optimization of the parameters had a high risk of overfitting the model and therefore being unprofitable in the future. Despite the rejection of the development of this method, it is still lucrative to use in combination with other methods for confirmation or supporting biases. Some ideas, as the inflation bias or confirmation with higher time frames, should be considered and were not proved wrong.

The next attempt was to upgrade the DCA strategy. Original publicly known DCA strategy is defined as periodical investing over investment horizon and so averaging entry price. Idea behind upgrade tested in this work is to also average closing price by periodically closing portions of position. It means that exposure would be linearly ascending, the highest exposure would be in the middle of investment horizon, and then it would be linearly descending.

The last strategy that is proposed uses price momentum and excessive price fluctuations. It was named by the author of this thesis **Momentum and overheating strategy**. The main component of the strategy are the RSI and MA indicators. RSI indicates the strength of the asset and also if the price is overheated (overbought or oversold). Derivatives of moving averages tells us price direction and if calculated from RSI it tells us if strength of asset is rising or falling. Note the huge disadvantage of MA, that it is lagging indicator. Despite this disadvantage, MA calculated from RSI can detect top if there is at least short consolidation on top. On the other hand if price is rising too long without pullbacks, RSI can formulate top due to its nature and therefore indicate top too soon even when price still goes up, just not that strongly as it was few candles before. The whole strategy then consists of sum of weighted signals. Strategy was applied to one-hour frames, so all indicators are calculated from one-hour data. The signals ranked by influence are:

- RSI14
- RSI14_MA100 first derivative
- RSI14_MA100
- RSI14_MA4 first derivative

RSI14 is common RSI indicator with 14 last candles input. It is indicating strength of asset and also its price fluctuations. The following cubic function is used to transform RSI to signal weight:

$$f(x) = -0.01 \cdot (x^3 - 324 \cdot x)$$

where x is $RSI14 - 50$. Its roots are areas where signal weight is neutral and bias doesn't exist so no direction is preferred. $RSI > 70$ indicates overbought market and selling is preferred. $50 < RSI < 70$ indicates strong market and buying is preferred. Opposite for $RSI < 30$ indicates oversold market and buying is preferred and $30 < RSI < 50$ indicates weak market and selling is preferred.

RSI14_MA100 first derivative is simply RSI14 moving average direction. MA100 means it is calculated from last 100 data of RSI14. RSI14_MA100 derivative is saying if market is gaining or losing strength. To transform this indicator into signal it is using cubic function:

$$f(x) = -0.01 \cdot (x^3 - 100 \cdot x)$$

where x is $RSI14_MA100 - 50$. Its shape is similar to transformation function for RSI14.

RSI14_MA100 is used to support the RSI itself, which can have large unexpected jumps. MA helps mitigate these jumps at the cost of lagging signals. Its signal is calculated by multiplying by 4.

RSI14_MA4 first derivative is derivative of moving average calculated from the last 4 RSI values. This derivative react much faster then derivative of MA100 but also has higher frequency of inaccuracy. Therefore, its signal is calculated by multiplying by only 2.

All these signals are summed and determine how much of the portfolio is invested in the moment.

5.2 Simulation tool

This section discusses whole tool and its components, how to use them and what options does it provide. How data are downloaded, prepared and stored and test investment horizons are generated. And lastly, the implementation of lump sum, dollar cost averaging and its upgraded form, reduced form of rebalancing, and momentum and overheating strategy are described.

5.2.1 Preparing data

This section describes how the data downloading and processing is approached. The entire application focuses on analyzing data from the Binance exchange, specifically BTCUSDT data. To analyze other assets such as indexes, ETFs, stocks, currencies, and commodities, the application would need to be extended with additional data sources. One of the reasons for choosing this approach is that it does not require an API key and can be executed without other complex accessories.

- The file *classes/binanceData.py* contains the *binanceData* class to store candlestick data. It includes information such as open price, close price, volume, open time, etc. It also includes a method called *to_dict()* that returns a dictionary with the information.
- The file *enums/binanceSymbol.py* contains the *binanceSymbol* class, which represents symbols for data retrieval. Currently, it includes the symbol „BTCUSDT.“ Later simulations are tested using data from this symbol.
- The file *enums/binanceInterval.py* contains the *binanceInterval* class. It enumerates the possible time frames for candlesticks and provides conversion to milliseconds since the timestamp values are always in milliseconds.
- The file *tools/dateTools.py* contains constants for converting milliseconds to other time units and functions for converting milliseconds to dates and vice versa.
- The file *tools/fileTools.py* includes functions for saving and loading JSON files with data. Important functions are:
 - *load_json_from_file(filename)*: Loads a file from JSON format.
 - *save_json_to_file(data, folder, filename, pretty=False)*: Saves data as a JSON file. The *pretty* parameter adds extra whitespace for better readability but increases file size.
- The file *tools/binanceDownloadTools.py* contains functions for data downloading. It includes a constant for the URL from which to download and a *batch_size* constant. These tools are optimized for downloading minute-level time frames, and the minimum interval that can be downloaded is 1 day. Important functions include:

- *data_to_dict*: Completes missing data and transforms the data from a list to a dictionary for computational speed optimization.
 - *download_1_day_data(SYMBOL, BinanceInterval.ONE_MINUTE, START)*: Downloads 1 day of data in one minute candlesticks.
 - *test_data_ok*: Tests if the data is valid, ensuring it contains all the candles with correct start and end timestamps.
- The main file *downloadAndPrepareBinanceData.py* downloads data within a specified interval, by whole days. Complete missing or corrupted candlesticks and save the data as a dictionary in a file. Utilizes the above-mentioned files.

5.2.2 Creating test investment horizons

This section describes the process of creating test investment horizons.

- The file *tools/intervalTools.py* contains functions to generate random intervals within a specified period and with a given minimum and maximum length. Important functions include:
 - *make_random_intervals(start, end, min_length, max_length, count)*: Creates a list of intervals.
 - *test_intervals_ok*: Tests if the intervals are valid and if corresponding price data can be found for each interval.
- The main file *createTestIntervals.py* generates random intervals within a specified range and length. Adjusts the start of each interval to align with the candlestick in which it lies, and saves the intervals to a file.

5.2.3 Simulations

This section outlines the simulations performed in the project.

- The file *enums/simulationAlgorithmDict.py* defines individual functions for different strategies and constants representing those strategies.
- The file *tools/simulationTools.py* contains programmed functions for each simulation and auxiliary functions. Some notable functions include:
 - *get_profit_statistics(results)*: Computes statistics from the simulation results.
 - *calculate_profit_lumpsum(start_price, end_price, amount_invested)*: Calculates the profit between the start price and end price (applicable to strategies other than lump sum as well).
- The file *tools/graphTools.py* contains functions for graph visualization.
- The main file *runSimulation.py* serves as an interface that connects the individual strategy files with the required functions. It includes functions for graphing and displaying statistics. It loads the data, runs the specified algorithm from *simulationTools*, obtains the results, processes statistics and graphs, and saves them to a file. This part remains the same for all algorithms.

- An additional file, *compareStrategies.py*, compares the resulting statistics of different strategies and plots graphs. It assumes that the results are already saved in files within the *results* directory.

Dollar cost averaging simulation

The DCA simulation utilizes the same arguments as the lump sum simulation, along with an additional parameter called the investment interval.

For each interval, the simulation first calculates the number of purchases to be made during the investment horizon based on the investment interval. Then, based on the timestamps, an array of prices at those moments is created.

For each point, the *calculate_profit_lumpsum* function mentioned earlier is used to calculate the profit to a unified endpoint and the profits are summed. This sum represents the overall profit of the DCA strategy for the corresponding interval. These interval profits are stored in a results array and further processed in *runSimulation.py* following the standard procedure.

DCA upgrade

This enhanced version of DCA differs from the original version in terms of the calculation of the number of investments. If the number of investments is odd, it needs to be reduced by one to account for the middle investment, which would otherwise be both bought and sold simultaneously.

Furthermore, the calculation of profit differs. The array of values at the moments when trades are planned is expanded to include the endpoint. Each investment then uses the *calculate_profit_lumpsum* profit calculation function, starting from the i -th point to the i -th point from the end. In other words, the first from the last, the second from the penultimate, and so on.

Rebalancing simulation

Rebalancing simulation is implemented for a single asset to assess its effectiveness compared to other methods. Rebalancing against a fiat currency has the advantage that their correlation is negligible, making implementation easier. However, there is an opportunity cost and a significant reduction in the main benefit of rebalancing, which is capitalizing on the diverse movements of two or more assets, all of which tend to rise in the long run. In contrast, fiat currency does not appreciate.

The implementation utilizes multiple parameters, including the invested capital, the frequency of rebalancing, the percentage of capital to invest, and the threshold to trigger rebalancing. For each interval, the moments and prices at which the portfolio will be checked and adjusted are calculated based on the frequency parameter.

Then two values are created representing the invested portion (*invested*) and the uninvested portion (*wallet*) of the portfolio. In a loop, for each point, it is checked whether the change exceeds the designated threshold. If it does, a portion is sold or bought to rebalance the ratio.

The condition for determining whether the change is sufficient is calculated as follows:

$$\left| \frac{\frac{invested}{wallet+invested}}{percentage_invested} - 1.0 \right| > threshold$$

The profit is then calculated up to the next point, added to *invested* and *wallet*, and the loop continues. At the end of the interval, the invested portion is summed with the uninvested portion and subtracted by the initial invested amount at the beginning, resulting in net profit. This profit is returned and further processed in *runSimulation.py*.

Momentum and overheating strategy simulation

The simulation parameters used in this strategy are the investment amount, signal weights, and allocation ratio, which represents the percentage of the portfolio to be invested in each trade. The implementation of this strategy differs from the previous ones. While the previous strategies could be statically divided without sequential traversal, the Momentum and Overheating Strategy (MOS) utilizes indicators calculated from the recent data. However, these indicators are precalculated for faster simulation.

The strategy is set to recalculate the investment every hour. Precalculation utilizes the *pandas* and *pandas_ta* libraries. First, a *DataFrame* is created containing the timestamp and the price at each moment. From this data, the RSI and the moving average of the RSI are calculated, along with two derivatives with different input lengths. By adding the weighted indicators, a signal record is created that is used to determine the opening and closing of the positions.

The indicators are weighted using the specified weights and two cubic functions prepared in *simulationTools.py*. Once all the data are prepared, each row is traversed for every interval, and the value is invested based on the remaining portfolio, the allocation ratio parameter, and the calculated signal at that moment.

For recalculating the invested capital and the remaining capital, the function *recalculate_exposure* is available. However, it only supports buying and selling of previously purchased assets and does not support short positions.

At the end of each interval, all positions are closed, and the resulting profit is stored in the results. These results are further processed in *runSimulation.py*.

Chapter 6

Simulation results and strategies comparison

This chapter focuses on simulating and optimizing various strategies and analyzing their results. It discusses the data used to test the strategies and provides explanations for why specific strategies were chosen. Each strategy is thoroughly discussed, and hypotheses are formulated to explain their behavior. Additionally, a table presenting basic statistical metrics after testing on a set of intervals with optimized parameters, as well as the same parameters on a separate and larger set of intervals for confirmation, is included. Finally, all strategies are compared using two comprehensive box plots.

6.1 Data and intervals selection

Due to the complexity and the need to customize strategies for various specifications such as timeframes and assets, it was decided that all strategies would be tested using BT-CUSDT data. Bitcoin exhibits repeated behavior in cycles, which is why data from one cycle spanning from May 23, 2019, to January 1, 2023, was selected. This period covers approximately one cycle, starting from a local minimum just before a significant upward movement and ending in a similar situation almost four years later. It is important to note that this simplification may lead to misleading results regarding individual strategies, and there is also a chance that the assumption of Bitcoin's cyclical behavior is incorrect.

The first set consists of 100 intervals generated within the selected data range, with intervals created evenly and randomly with a minimum duration of 1 year. The second set comprises 400 intervals generated with a minimum duration of 6 months.

Each strategy will be tested using \$1,000 on all intervals, and the resulting profits will be used to calculate the desired statistics.

6.2 Lump sum

The Lump Sum strategy is the closest to random investing among all the strategies. It has minimal transaction costs and, most importantly, minimal opportunity costs. The expected return is the average growth of Bitcoin. The maximum potential profit and maximum potential loss are the same as those of Bitcoin itself, which are a maximum of +1,666% (\$16,660 profit) and a maximum of -77.5% (\$775 loss), respectively.

The results are presented in [Table 6.1](#). The column „Lump Sum 500“ displays the results for investing only \$500, which will be useful for later comparison with other methods. The „Lump Sum 1000“ column contains data to use the strategy to its full extent. As observed, both the maximum and minimum profits closely approach the expected values.

Strategy set of intervals	LS \$500 set 1	LS \$1,000 set 1	LS \$500 set 2	LS \$1,000 set 2
Average profit	1,338.3	2,676.7	906.5	1,813.1
Max profit	5445.5	10,890.9	4,218.2	8,436.5
Min profit	-352.2	-704.5	-367.6	-735.2
Median profit	1,188.9	2,377.9	626.7	1,253.5
10 longest int. avg. profit	792.8	1,585.6	470.0	940.0
10 shortest int. avg. profit	800.7	1,601.4	36.9	73.9
Positive profit count	87	87	298	298
Negative profit count	13	13	102	102
Positive profit percentage	87.0%	87.0%	74.5%	74.5%

Table 6.1: Statistics of strategy Lump Sum on 2 different intervals set and with \$500 respectively \$1,000.

6.3 Dollar cost averaging

The Dollar Cost Averaging (DCA) strategy aims to reduce risk, which implies a lower maximum return and a higher minimum return. However, due to the gradual investment approach, the opportunity cost is significantly higher. The average amount invested during the investment period is only half of the total funds. Therefore, the expected average return is half that of the Lump Sum strategy. The advantage of investing only a portion of the funds is the ability to utilize the remaining money for other purposes, such as investing in a different asset. However, this advantage is offset by the gradual reduction or increase in funds over time. As a result, it is interesting to compare the profitability with Lump Sum 500, but the assignment specifies evaluating the \$1000 investment.

For an improved version of DCA, the situation is slightly different. It still aims to significantly reduce risk, but the average return may be higher. Unfortunately, the opportunity cost remains a persistent issue.

The results, shown in [Table 6.2](#), indicate that both methods reduce risk. However, the DCA strategy is highly inefficient, and the average profit is even less than half of the Lump Sum strategy. On the other hand, the modified version of DCA surpasses the standard method beyond expectations. It reduces risk further, and the average profit is nearly double that of the usual DCA strategy. The median profit is even tripled. However, it still falls behind the lump sum strategy in terms of average profit and median. An interesting observation is the profitability of the ten longest intervals. However, this figure may be influenced by the method of data selection.

Strategy set of intervals	DCA set 1	DCA Upgrade set 1	DCA set 2	DCA Upgrade set 2
Average profit	1,080.3	1,899.2	760.9	1,342.4
Max profit	4,448.1	4,078.1	4,692.1	4,050.8
Min profit	-501.2	-457.2	-531.1	-523.7
Median profit	629.0	2,087.3	259.9	959.1
10 longest int. avg. profit	410.8	2,781.7	142.0	2,576.3
10 shortest int. avg. profit	356.7	563.2	46.2	59.5
Positive profit count	65	86	265	306
Negative profit count	35	14	135	94
Positive profit percentage	65.0%	86.0%	66.25	76.5%

Table 6.2: Statistics of DCA strategy and upgraded DCA strategy on 2 sets of intervals.

6.4 Rebalancing

Rebalancing, as a recommended method, had the greatest potential, but is also more complex to implement. The strategy already has parameters that can be optimized and is intended for a different type of utilization, typically involving multiple assets. In this simulation, the main advantage of rebalancing is diminished. The allocation ratio between the invested and noninvested portion was established at 50%. Consequently, there is a high opportunity cost. However, under normal circumstances, the entire amount would be invested, allowing for a comparison between Rebalancing and Lump Sum 500. Alternatively, in the table, there is a column for rebalancing with double the initial investment, i.e., \$2,000. It is important to note that the actual benefits of rebalancing may be lower when applied to two risk-on assets compared to rebalancing between Bitcoin and a fiat currency.

The expected return of the strategy is that it should outperform Lump Sum in all aspects. Through periodic purchasing during growth and selling during decline, it should be possible to achieve better results than random investments. By optimizing the parameters, even better results can be obtained, but caution must be exercised to avoid overfitting. For parameter optimization, a script called *runSimulationRebalanceParametrOpt.py* was created, which used a brute-force method to search for the best parameters and then plotted them in [Figure 6.1](#). The optimized parameters include the rebalancing threshold (the level at which rebalancing is triggered) and the frequency of portfolio checks to determine if the threshold has been exceeded. The graph shows the impact of changing these parameters on the average profit. It is evident from the graph that overfitting occurs when the threshold value is set to 0.7, resulting in rebalancing occurring only once at the peak of the Bitcoin price. The results for a threshold of 0.0, which triggers rebalancing at every check, align with the conclusions from cited sources regarding rebalancing frequency. The frequency that performs best among those tested is rebalancing every hour, while rebalancing daily yields the worst results.

[Table 6.3](#) presents the results for a frequency of one hour and a threshold of 0.3. The results are mixed. Rebalancing exhibits significantly reduced data dispersion compared to other methods, slightly lower average profit, and slightly higher maximum loss. However, it has a considerably higher median. Additionally, interesting results can be observed for the ten shortest and ten longest intervals, showing a clear dominance of rebalancing over longer intervals and a weakness over shorter intervals, which can be considered as positive characteristic of the strategy.

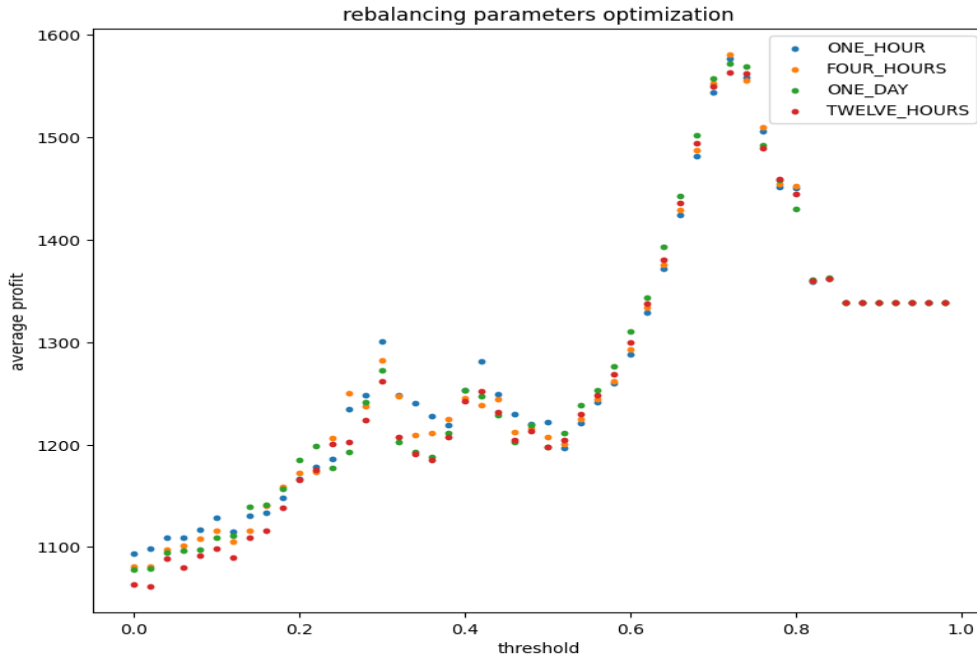


Figure 6.1: Rebalancing strategy - optimization of parameters: rebalancing trigger threshold and frequency of portfolio checking.

6.5 Momentum and overheating strategy

This strategy, based on the RSI (Relative Strength Index) indicator, has a significant advantage in its ability to be transformed into smaller or larger time frames and to increase the allocated funds. This theoretically allows for much higher returns than static methods. However, this feature is partially shared with the rebalancing strategy. Rebalancing, on the other hand, lacks the ability to be applied across multiple time frames. This is where the Momentum and Overheating Strategy (MOS) shines, as it can use higher time frames to confirm or refuse hypotheses. MOS also has multiple optimizeable parameters. While this can be a good feature, as it allows customization according to personal preferences and goals, it also presents the challenge of optimizing these parameters without overfitting the model. Another advantage of MOS is its ability to trade short positions without any issues, allowing profits from both rising and falling markets. Rebalancing does not possess this capability. The results in [Table 6.4](#) show that the strategy was very successful in the first set of intervals, outperforming the lump sum and rebalancing. However, it was not as dominant in the second set of intervals, indicating that the parameters may have been slightly overfitted. Despite this, the strategy still exhibits better results than Lump Sum and can compete with rebalancing.

Strategy	Rebalancing	Rebalancing	Rebalancing	Rebalancing
Investment amount	\$1,000	\$2,000	\$1,000	\$2,000
set of intervals	set 1	set 1	set 2	set 2
Average profit	1,300.5	2,600.9	918.0	1,836.0
Max profit	3,164.1	6,328.2	2,771.6	5,543.1
Min profit	-341.8	-683.5	-433.5	-867.0
Median profit	1,372.8	2,745.6	1,024.9	2,049.9
10 longest int. avg. profit	1,222.8	2,445.6	981.5	1,963.1
10 shortest int. avg. profit	576.0	1,152.0	36.1	72.1
Positive profit count	89	89	302	302
Negative profit count	11	11	98	98
Positive profit percentage	89.0%	89.0%	75.5%	75.5%

Table 6.3: Statistics of rebalancing method on 2 sets of intervals with and without opportunity cost compensations.

Strategy	MOS	MOS
set of intervals	set 1	set 2
Average profit	2,661.6	1,861.9
Max profit	9,093.8	7,304.7
Min profit	-762.8	-747.5
Median profit	2,826.3	1,366.2
10 longest intervals average profit	1,581.3	1,207.7
10 shortest intervals average profit	1,264.4	52.4
Positive profit count	85	299
Negative profit count	15	101
Positive profit percentage	85.0%	74.75%

Table 6.4: Statistics of MOS on 2 sets of intervals.

6.6 Summary and discussion

The illustrations in [Figure 6.2](#) and [Figure 6.3](#) depict the generated intervals and their characteristics. The color scheme provides insights into profitable and non-profitable intervals. Several common patterns can be observed, as well as differences among them. One interesting observation is the clustering of intervals in DCA2, where a clear cluster around the strongest bullish trend is evident, while the other strategies do not exhibit such a distinct clustering pattern.

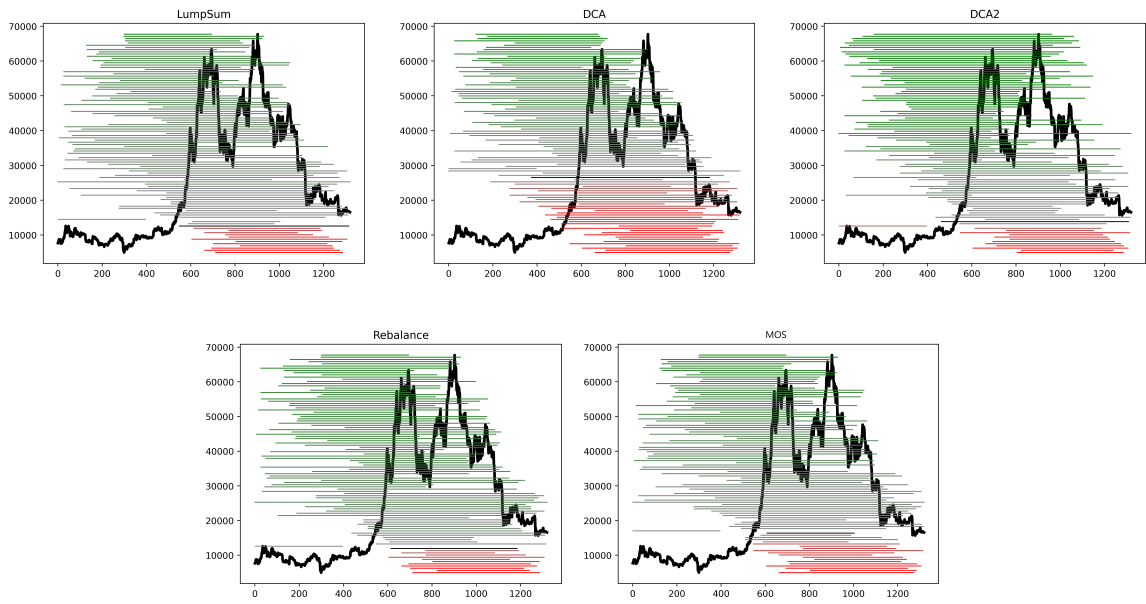


Figure 6.2: First set of 100 intervals and profitability of each strategy. Each horizontal line represents one interval horizon. Green lines are the most profitable, red are the least profitable and black is profitability borderline interval with profit closest to zero.

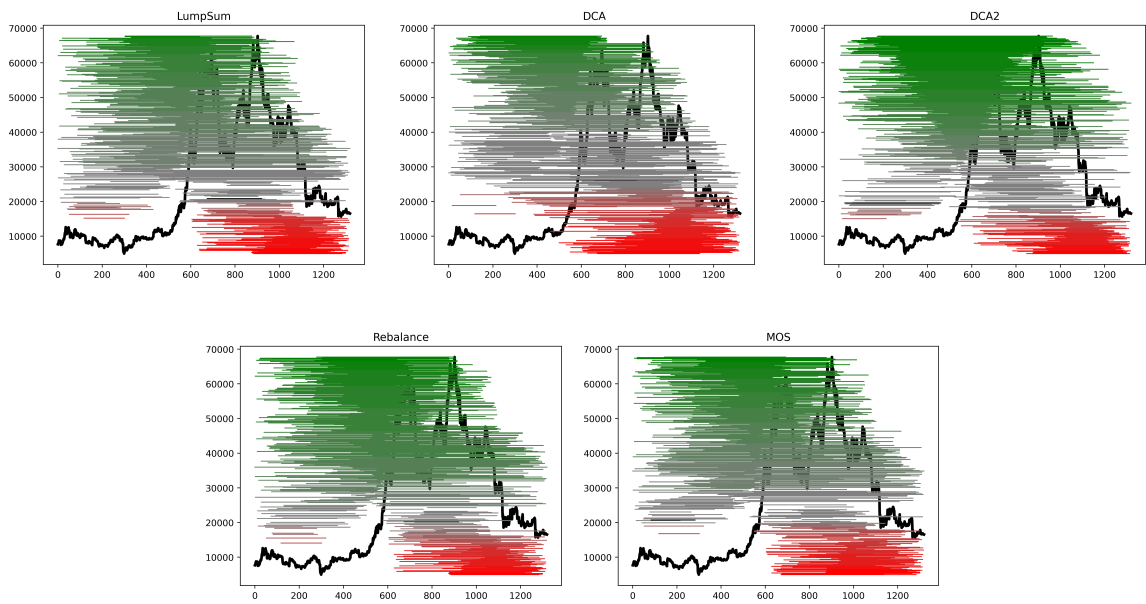


Figure 6.3: Second set of 400 intervals and their profitability for each strategy.

We compared four investment strategies: lump sum, dollar cost averaging, rebalancing, and momentum and overheating strategy. The most illustrative graphs comparing these methods are shown in [Figure 6.5](#) for the first set of intervals and [Figure 6.5](#) for the second set of intervals. Box plots were used to present the returns of each strategy.

Lump sum, despite its random nature, performed exceptionally well and surpassed expectations. It outperformed the commonly recommended DCA strategy, often favored by inexperienced investors. The improved DCA method achieved acceptable results and fulfilled the hypothesis of risk reduction. However, its average return and median did not reach the levels of Lump Sum, probably due to opportunity cost. Rebalancing, with the original investment amount of \$1000, further reduced risk even more than DCA2. With certain modifications, such as the use of derivatives and leverage, it would be possible to fully utilize the entire \$1,000, surpassing both Lump Sum and upgraded DCA. This is evident from the rebalancing \$2,000 box plot, which is equivalent to investing whole \$1,000. However, the rebalancing effect is the best when rebalancing between FIAT and Bitcoin. In reality, if opportunity cost was erased by rebalancing, for example, between bitcoin and ethereum, the effectiveness of the rebalancing would decrease. Lastly, the proposed MOS strategy will be compared to rebalancing, as rebalancing had best results out of simulated strategies. In first set of intervals it performed better in both average profit and median. It exhibited larger dispersion of returns and had on average similar profits on short intervals. On the other hand, it performed much worse on longer intervals and had slightly higher chance to end up being in loss. Tests on second set of intervals confirmed that it is competitive with rebalancing. Its average profit, max profit, and min profit is better, but median profit and average profit on long intervals are much worse. We assume that it might be due to overfitting parameters or pure coincidence. It would be reasonable to further more test these strategies on different price data. However, we believe that price action on lower time frames older than a few years is insufficient. We believe that price action is evolving fast due to high participation of learning algorithms and it is needed to create and optimize models for each time frame, asset and date separately. MOS advantage over rebalancing is flexibility of the model, the possibility to open short positions and the scalability of trade frequency. On the other hand, rebalancing due to its rigidity and robustness offers predictable returns. In simulation there were ignored transaction cost such as exchange fees and spread. This is also important to take into account. Lump sum has minimal transaction cost, DCA has huge opportunity cost, but fees and spread should not influence returns. On the other hand, rebalancing and MOS have relatively high all 3 components of transaction cost.

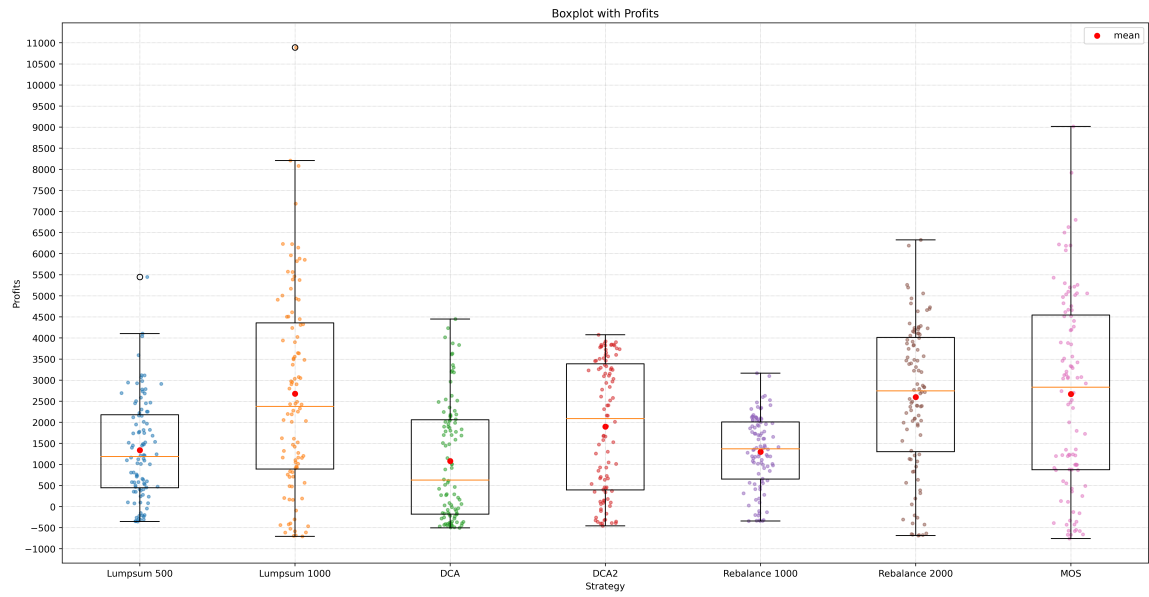


Figure 6.4: Each strategy Box-plot calculated from profits for first set of 100 intervals of length 1 to 3 years.

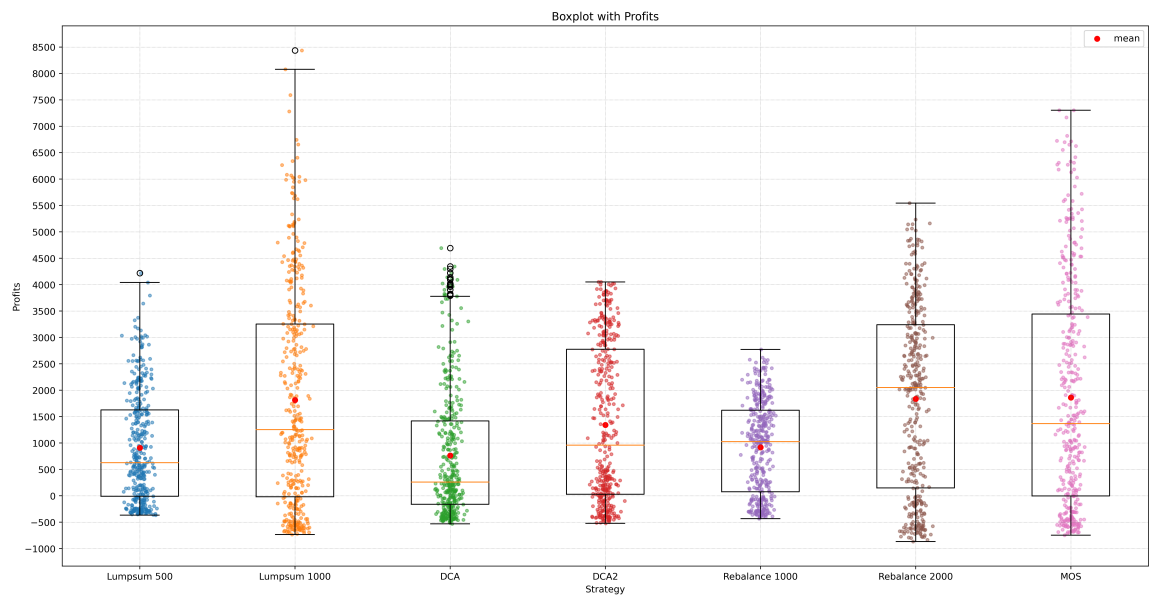


Figure 6.5: Each strategy Box-plot calculated from profits for second set of 400 intervals of length half to maximum length.

Chapter 7

Conclusion

The purpose of the thesis was to investigate the background of the markets and approaches in the field of trading. Then we try to create and compare our own trading strategy based on the information found. The thesis introduces some well-known approaches and shows how they affect the price of the underlying asset or how market behaviour and events can be used to profit from trading. Some of the most well-known trading strategies such as lump sum, dollar cost averaging, and rebalancing are described in detail and then studies regarding their performance are presented. The capabilities of simulation and testing tools are analyzed, their purpose, and whether they are suitable to meet the given objectives. Using the Binance API, a Python simulation and testing tool is implemented for selected strategies mentioned above. A custom strategy named momentum and overheating strategy is also designed, implemented and tested. The strategies are compared with each other and their statistical evaluation is graphically shown. Finally, the differences between strategies and their advantages and disadvantages are discussed.

The proposed MOS is competitive with the best of the strategies tested. Differences between strategies, their limitations, and hypotheses regarding their performance after implementation are also presented.

In the future, it would be advisable to look at multilevel trade confirmation, i.e. to perform the analysis on both higher and lower time frames. Furthermore, start to take into account transaction costs and not only exchange fees, but also opportunity cost or spread. According to the author, the use of derivatives, namely leveraged trading, also has great potential. With derivatives, it is possible to make money not only in a bull market, but also with the help of short positions in a bear market. By achieving a stable profit with low drawdown, it would be possible to multiply the profits and achieve the desired results due to leverage.

Forecasting the market is complex and requires a large amount of information and advanced analysis. The resulting strategy would then have a large number of parameters and a high chance of overfitting. One could compare market forecasting to weather forecasting. Trying to predict the weather based on wind direction and sky color would be impossible. Moreover, weather forecasting is attempted by large companies with very erudite scientists and many capabilities, both financial and computational. So, an individual has little hope of beating the big players and should stick to best practices. These may be, for example, the use of inflationary economics, participation in the market, and possibly the use of moderate leverage. However, it is certainly always good to be aware of the risks of the possibility of losing money, which cannot be avoided - even big companies can get the weather wrong and get wet.

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