

**Bachelor thesis**



**Czech  
Technical  
University  
in Prague**

**F3**

**Faculty of Electrical Engineering**

**Foreign exchange market management**

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**Field of study: Software engineering**

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Pokyny pro vypracování:

Seznamte se s problematikou obchodování na devizových trzích a automatickými obchodními systémy (AOS). Vyberte vhodné indikátory a strategie obchodování, které může využívat AOS. Navrhněte a implementujte takový systém. Proveďte analýzu strategií a na základě této analýzy vyberte tři vhodné strategie, které použijete ve vámi navrhovaném systému AOS. Navržený systém implementujte a otestujte. Pro testování použijte reálná data za vybrané období. Porovnejte implementované strategie a výsledky zhodnoťte. Na základě tohoto vyhodnocení proveďte doporučení strategie, která se bude jevit jako nejlepší.

Seznam doporučené literatury:

1. Mark Douglas: Trading in the Zone - Tajemství úspěchu na burzovních trzích, Impossible, s.r.o. 2019
2. Roger S. Pressmann Bruce Maxim: Software Engineering: A Practitioner's Approach , ISBN-10: 9780078022128
3. What is forex? <https://www.babypips.com/learn/forex>

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especially my girlfriend for their support.

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## Abstract

This bachelor thesis focuses on exploring the use of algorithmic trading strategies in forex trading. The concept of trading and its basic terminology are introduced, followed by a detailed discussion of various algorithmic trading strategies and indicators. In order to evaluate the effectiveness of these algorithmic trading strategies, some representative strategies were selected, implemented and backtested using real data. Each combination of strategy parameters was tested and evaluated to determine the best strategy and set of parameters. The results show that implementing an algo trading strategy can be effective in forex trading. However, selecting the right strategy and parameter settings is critical to maximising profitability. Overall, this thesis provides valuable insights into the world of forex algo trading for traders and investors interested in implementing and/or optimising their trading strategies.

**Keywords:** forex, algo-trading, trading strategy optimisation

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## Abstrakt

Tato bakalářská práce se zaměřuje na zkoumání využití algoritmičtých obchodních strategií pro obchodování na forexu. Je zde představen pojem obchodování a jeho základní terminologie a následně jsou podrobně rozebrány různé algoritmičtější obchodní strategie a indikátory. Za účelem vyhodnocení účinnosti těchto algoritmičtějších obchodních strategií bylo vybráno několik reprezentativních strategií, které byly implementovány a zpětně otestovány na reálných datech. Každá kombinace parametrů strategie byla testována a vyhodnocena s cílem určit nejlepší strategii a sadu parametrů. Výsledky ukazují, že implementace algoritmičtější obchodní strategie může být při obchodování na forexu účinná. Výběr správné strategie a nastavení parametrů je však rozhodující pro maximalizaci ziskovosti. Celkově tato práce poskytuje cenný vhled do světa forexového algoritmičtější obchodování pro obchodníky a investory, kteří mají zájem o implementaci a/nebo optimalizaci svých obchodních strategií.

**Klíčová slova:** forex, algoritmičtější obchodování, optimalizace obchodní strategie

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# Chapter 1

## Introduction

Since the beginning of the Covid-19 pandemic, the number of retail traders has increased dramatically and this phenomenon can be seen everywhere. And it is not just the forex market, other markets have also experienced various extremes that the media like to pick up on. For example, when the global pandemic was on the rise, the S&P500 stock index fell by nearly 30% in the first quarter of 2021, at the same time as a cryptocurrency market began its bull run, an extremely rapid rise in a relatively short period of time of not tens but hundreds of percent, and for cryptocurrencies with smaller market caps, even thousands of percent. About six months later, gold was at an all-time high. With the huge increase in popularity of market trading in general, and among retail traders in particular, the drive to automate trading is greater than ever. Automated trading systems, also known as algorithmic trading, take trading to a new level with an approach that cannot be implemented by humans.



### 1.1 Motivation

During the Covid-19 pandemic, I also came across trading in the form of advertisements such as "make tens of percent a day", although most people who tried it ended up losing their entire investment. Unfortunately, I stumbled too quickly and realised that trading was not nearly as easy as the ads made it out to be. However, this failure was the main motivation for me to start studying trading in depth and now, after almost three years, I have relatively enough experience that, together with the experience I gained at university, I

could apply and hopefully create my own algorithmic trading strategy that could generate a passive income.

## ■ 1.2 Goal

The aim of the bachelor thesis is to analyse possible algorithmic trading strategies, select some representatives and implement them. Many optimisations based on strategy parameters will be tested on historical data. These results will be properly evaluated and hopefully future improvements will be concluded.



## Chapter 2

### Theory



#### 2.1 Foreign exchange

The decentralised foreign exchange market, commonly known as forex, is the world's largest financial market, enabling easy currency trading across the globe. Due to real-time fluctuations in exchange rates, the forex market is always active, with the exception of weekends. Trading can be done in a number of different ways, although this thesis will only focus on the spot market. This market also involves trading currency contracts rather than trading currencies directly. These contracts represent a commitment to buy or sell a specific amount of currency at the current exchange rate. In addition, these contracts allow for leveraged trading, where traders have increased buying power ranging from 2:1 to 500:1, depending on the degree of leverage used. This feature allows trading with smaller accounts and opens up the possibility of larger profits; however, it also increases the risk of loss, including the potential loss of capital [1].

The vast majority of transactions that take place in the foreign exchange market are speculative in nature, with only a small percentage attributed to genuine needs such as tourism, international trade and others. Currency traders or speculators seek to buy currencies in the hope of selling them at a higher price in the future. The \$6.6 trillion daily trading volume of the foreign exchange market seems colossal compared to the daily volume of the New York Stock Exchange (\$22.4 billion). However, this figure reflects the entire foreign exchange market, not just the spot market we're interested in, which has a daily trading volume of only about \$2 trillion. Retail traders like

us, account for only 3-5% of this figure, with the remaining percentage being traded by banks, funds and other similar entities [2].

The forex market is a 24/5 market that only closes on weekends. Unlike the stock or bond markets, it doesn't close at the end of each business day, but unlike the cryptocurrency market, it remains closed on weekends. As a result, trading shifts between different financial centres around the world, resulting in different behaviour of currency pairs depending on the time of day. The forex market was my preferred option due to several factors such as convenient trading hours, accessible data, high liquidity, leverage, low impact of fundamental news and my extensive experience with the market.

## ■ 2.2 Trading basics

### ■ 2.2.1 Basic trade positions

The aim of trading in the forex market is to exchange one currency for another in the expectation that its price will change in your favour. This can be achieved by buying and then selling the currency or by selling and then redeeming it. Remember that you are trading contracts, so even if you don't own anything, you can sell. In trader terminology, buying is called a long position and selling is called a short position. There are other additions to these positions, but we will only cover the main ones.

A stop loss is placed on positions at a specific price. The position is closed at a loss if the market reaches that price. This defines the maximum possible loss for an open position, which is crucial for successful trading. The opposite of this is take profit, which defines the price at which the position will be closed at a profit. Closing a position means opening an opposite position of the same size, so that the positions fill each other.

The trailing stop is set to a fixed number of pips, pips are described later 2.2.3, which marks a distance of the stop loss level from the current price, where the stop loss level trails behind the price at a distance[3]. Basically, the name trailing stop is very descriptive, the stop loss "follows" the current price by a fixed number of pips.

### ■ 2.2.2 Spread

Forex brokers provide quotes with two different prices for each currency pair. These quotes include the bid and the ask.

- The bid represents the selling price of the base currency.
- The ask represents the buying price of the base currency.

The difference between the bid and ask price is known as the spread. This spread can be either fixed or variable, depending on the broker's policy. As a trader, understanding these terms is crucial to effectively buying and selling currencies in the forex market [4].

### ■ 2.2.3 Basic concepts

The basic unit for expressing the change in value between two currencies is called the pip. Most currency pairs have 4 decimal places, but some, such as USD/JPY, have only 2 decimal places, where the last digit is the pip [5].

Currencies are quoted in pairs, for example EUR/USD. Whenever you have an open position in the foreign exchange market, you exchange one currency for another. base currency is the one to the left of the /, the quoted currency is the one to the right. The base currency represents how much of the quoted currency it takes to get one unit of the base currency. This is called a ticker. For example, the currency pair EUR/USD with an exchange rate of 1.1313, by selling €1 you get \$1.1313.

The forex market trades in specific amounts. These are called lots. In the past, when trading was not available to retail traders, lots were the only size available, but today, in order to allow smaller accounts to trade, there are also mini, micro and nano fractions. The standard lot is 100,000 pips of the base currency, so for example for the currency pair EUR/USD with an exchange rate of 1.1313, 1 pip equals €8.84 for 1 lot. Basically, at 1 lot, 1 pip is 10 units of the quoted currency, and if you are interested in converting to the base currency, simply divide the number by the exchange rate [6].

## ■ 2.3 Market analysis

There are three types of market analysis, fundamental, technical and sentiment analysis.

Each currency belongs to one country or an entire region. Fundamental analysis of the forex market focuses on the overall state of a country or region's economy, such as employment, production, international trade and interest rates [7].

Technical analysis is based on the analysis of historical data and the assumption that, under certain trading conditions, price movements can be repeated. Traders who use technical analysis believe that all current market information is reflected in the price. There are thousands of different indicators that are supposed to help with analysis, but very few are useful to the normal trader sitting behind a computer. However, for algorithmic trading it is different [8].

Sentiment analysis is about analyzing the mindset of other traders. What matters is not so much what the trader thinks about the market situation, but what others think. For example, if you are convinced that the market will rise, for whatever reason, if others think and trade the opposite, there is nothing you can do about it [9].

Technical analysis, as opposed to fundamental analysis, is well suited to algorithmic trading because the amount and form of data is vast, and sentiment analysis is very limited but feasible.

## ■ 2.4 Candlestick chart

To analyse and track the price of a currency pair, you need a way to look at its historical and current price movement. There are many types of charts, but the line, bar and candlestick charts are among the most commonly used.

The candlestick chart is the most common type of chart used for technical analysis, and with more data than, for example, a line chart, it is also ideal for automated trading. The main element is a candle-like shape that represents

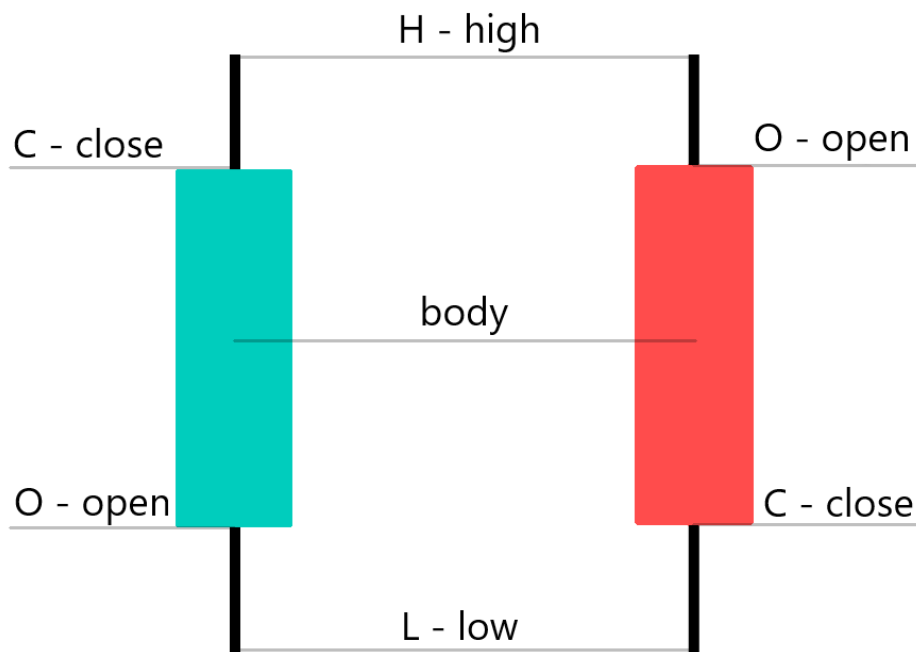


the price change over a given period of time, for example an hour. The period is called the time frame and can vary from seconds to months and even years. OHLC is a term used to describe the data that can be read from a single candlestick [10].

- O - open, indicates the price at the beginning of a given candlestick
- H - high, indicates the highest price
- L - low, indicates the lowest price
- C - close, indicates the price at the end of a particular candlestick

By changing the time period to a shorter one, we can perform a more accurate analysis due to the larger volume of data. On the other hand, by increasing the time period, we remove unnecessary granularity in the data, making it easier to analyse the market over a longer time frame.

For simplicity and readability, only line charts are used in this thesis.



**Figure 2.1:** Description of the OHLC candlestick.

## ■ 2.5 Trading sessions

The forex market is open 24 hours a day on weekdays, allowing traders to potentially trade all day and all night. The best time to trade is when the market is active with many forex traders opening and closing positions, creating a large volume of trades.

The forex market can be divided into four major trading sessions:

- London session, 7:00 - 16:00 UTC
- New York session, 13:00 - 22:00 UTC
- Sydney session, 21:00 - 6:00 UTC
- Tokyo session, 0:00 - 9:00 UTC

The London and New York sessions are the most active. Depending on the session, currency pairs will behave differently as the vast majority of all institutions trade during working hours [11].

## ■ 2.6 Algorithmic trading

Algorithmic trading, also known as automated trading or algo-trading, uses a computer program that executes trades based on a predetermined set of instructions, i.e. an algorithm. The goal is to generate profits with much greater speed and frequency than a human trader could achieve.

These instructions are primarily based on timing, price, quantity or some other mathematical model. In addition to generating profit opportunities, algorithmic trading makes the market more liquid and systematic by eliminating the impact of human emotion on trading activity and the ability to monitor markets 24/7.

### ■ 2.6.1 How it works

Consider a trading strategy with the following buy/sell signals:

- Buy when the price goes above the 200-period moving average, moving averages are described in the Technical Indicators chapter 4.1.
- Sell when the price falls below the 200-period moving average.

An algorithmic trading system uses these simple instructions to monitor the stock price (along with the moving average indicator) and execute buy or sell orders when certain conditions are met. This eliminates the need for traders to manually monitor live prices, charts or place orders [12].



## Chapter 3

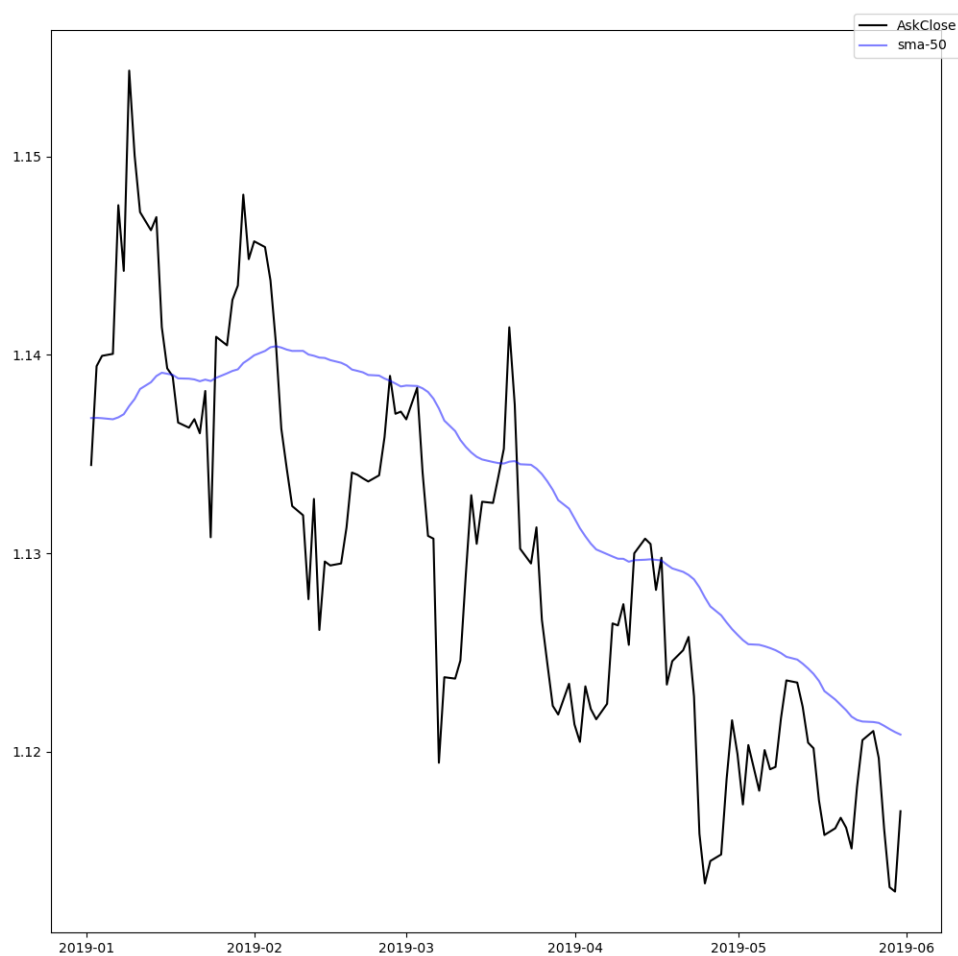
### Algorithmic trading strategies

Algorithmic trading strategy types are not the same as retail trading strategy types due to the limitations of human trading. There are eight main types of algorithmic trading based on the strategies used. Of course, you can mix and match these strategies, resulting in many possible combinations [13].

#### 3.1 Mean reversion strategies

Mean reversion refers to the tendency of the price to return to an average. This average can be a moving average or another type, such as a value line in a channel. Typically, mean reversion occurs when asset prices become too high or too low [14].

A healthy trend is characterised by a gradual, step-like movement in one direction until it reaches a peak, indicating the end of the trend. The price action may show some degree of reversal near the blue line, as shown in the figure 3.1. Although it is easier to read on a candlestick chart.



**Figure 3.1:** The EUR/USD chart on a 1-day time frame shows a blue line - SMA with period of 50.

## 3.2 Trend-following strategies

Trend traders analyse the trends of an asset in order to develop effective strategies. A trend-following strategy assumes that the price direction will continue in its current form without a reversal in the trend.

For example, if you are trading during an uptrend, you can continue to hold your long position and watch the asset increase in value over time. Conversely, if the trend is down, you can sell your asset to avoid losses.

During an uptrend, the trend pattern shows higher highs and higher lows, while a downtrend shows lower lows and lower highs, as shown in the figure 3.1. In contrast, sideways or horizontal trends show no significant up or down

movement, making it difficult for trend traders to make profits unless they are implementing short-term scalping strategies [15].

### ■ 3.3 News-based strategies

News trading is a strategy that takes advantage of market opportunities when important economic data and information makes headlines. This strategy offers significant opportunities for price changes, making it an attractive option for traders. However, as with any trading approach, there are inherent risks. Because of its event-driven nature, news trading differs from traditional technical and fundamental trading methods [16].

### ■ 3.4 Market sentiment strategies

Market sentiment is the general mood of the financial markets, reflecting the outlook and attitudes of traders, whether they specialise in forex or stock market trading. Sentiment allows investors to gauge whether a market is bullish or bearish about the future price of a security, such as a currency or stock. If the market is optimistic, it's called a bull market, and if it's pessimistic, it's called a bear market. However, determining market sentiment can be difficult as it depends on a number of factors that shape attitudes and outlooks. Investors need to do extensive research to gain insight into a constantly evolving market in order to make informed decisions [17].

### ■ 3.5 Arbitrage strategies

The use of arbitrage in algorithmic trading means that the system looks for price imbalances between different markets and takes advantage of them. However, as forex price differences are usually measured in micro pips, you'd need to trade very large positions to make significant profits. Triangular arbitrage, which involves two currency pairs and a currency cross between them, is also a popular strategy in this classification [13].

### ■ 3.6 High-frequency trading strategies

High frequency trading (HFT) is a type of trading that uses powerful computer programs to rapidly analyse multiple markets and execute trades in fractions of a second. This high-speed trading strategy is characterised by sophisticated algorithms, high turnover rates and the use of electronic trading tools. HFT uses high-frequency financial data to identify profitable opportunities, and its key features include co-location with the exchange server and very short trading durations. Institutional traders use HFT primarily because of the resources required to identify and act on short-term opportunities before other traders can [18].

### ■ 3.7 "Iceberging" strategies

This type of strategy is used by large financial institutions that are very secretive about their forex positions. Instead of placing one large long or short position with one broker, they break their trade into smaller positions and execute them with different brokers. Their algorithms can even allow these smaller trade orders to be placed at different times to prevent other market participants from finding out! In this way, financial institutions are able to execute trades under normal market conditions without sudden price fluctuations. Retail traders who monitor trading volumes are only able to see the "tip of the iceberg" when it comes to these large trades [13].

### ■ 3.8 Stealth strategies

The practice of iceberg orders has become widespread in recent years, with hardcore market watchers even developing algorithms, stealth strategies, to piece together smaller trades and identify whether a big player is behind them, making a stealth strategies a counterpart to iceberg strategies [13].



## ■ 3.9 Summary

Only the first four strategies are applicable to retail traders, the other four are technically challenging. Also, news-based strategies are closely tied to the currency and changes are immediate, so a time frame is not applicable. The primary source of market sentiment is news, but a few selected technical indicators are also applicable to forex. Therefore, mean reversion, trend following and market sentiment strategies will be used in future chapters.





## Chapter 4

### Technical indicators

Technical indicators play a crucial role in predicting the future direction of the market and can be used as trading signals depending on the trading strategy. Traders often combine several indicators to obtain more precise market signals. Also the strategies used in the next chapter are based on technical indicators.

It's important to note that most indicators have specific settings that directly affect the signals they give. Using multiple technical indicators exponentially increases the number of possible settings adjustments, making it more difficult to accurately test and analyse each combination to select the best possible settings.

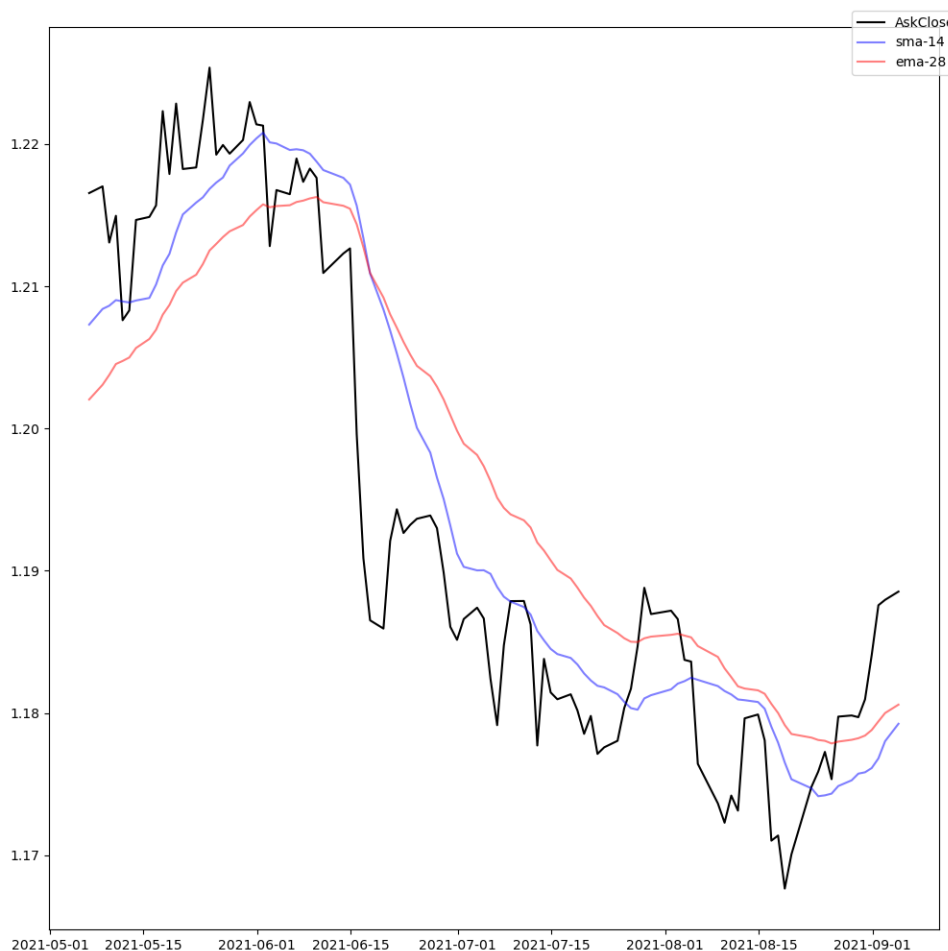


#### 4.1 Moving average

Moving averages (MA) are one of the most commonly used technical indicators. Two types of moving averages are widely used - Simple Moving Average (SMA) and Exponential Moving Average (EMA). The only difference between them is the way they are calculated, which is reflected in the speed at which they show changes.

Moving averages are obtained by calculating the average price, such as the closing price, of a currency pair over the last X periods, where X is the input

variable for this indicator and the period is represented by candles. The result is a curve that smooths out price fluctuations, making it easier to distinguish between market noise and the actual direction of the trend [19].

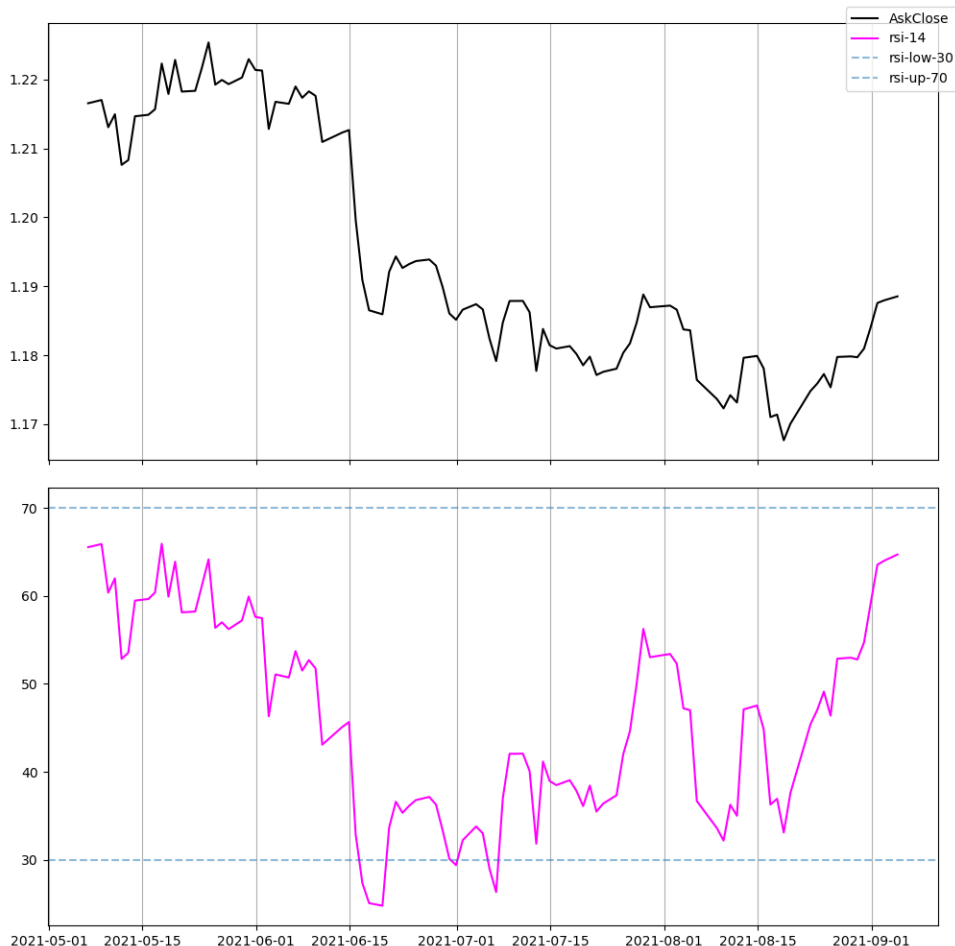


**Figure 4.1:** The EUR/USD chart on a 1-day time frame shows two lines - A blue line representing Simple Moving Average (SMA) with a period of 14 and a red line representing Exponential Moving Average (EMA) with a period of 28.

## 4.2 Relative strength index

The Relative Strength Index (RSI) is a technical indicator that helps to identify overbought and oversold markets and to determine the direction of the trend. It ranges from 0 to 100, with values below 30 indicating an oversold market with a higher probability of price appreciation. On the other hand, values above 70 indicate an overbought market with a higher probability of a price decline.

In a downtrend, the RSI can indicate the end of the trend and a possible reversal, while in an uptrend it can indicate the end of the trend and a possible change in direction. As with the MA, the input variable for this indicator is known as the period, which plays a crucial role in its calculation by indicating how many past candles the RSI should be calculated from. The second parameter sets the extreme levels, with a default of 70 and 30 [20].

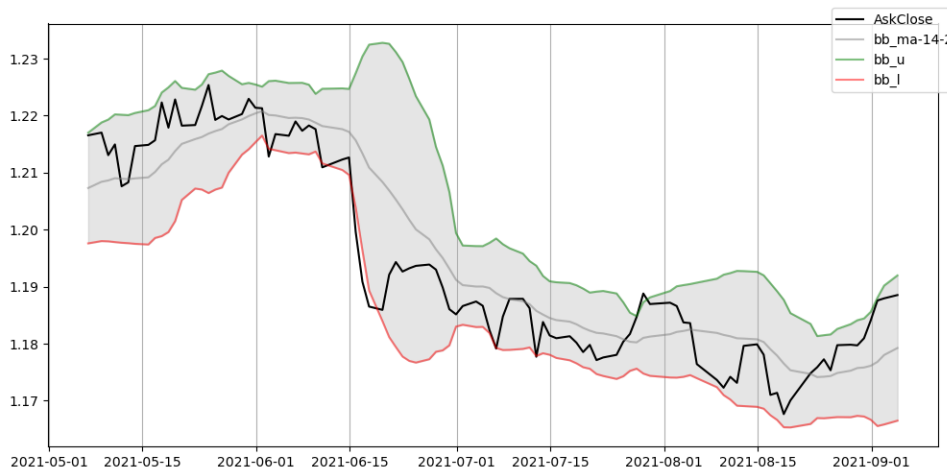


**Figure 4.2:** The EUR/USD chart on a 1-day time frame shows an RSI indicator of period 14, along with overbought and oversold levels set to 30 and 70 respectively.

## 4.3 Bollinger bands

Bollinger Bands (BB) are used to determine market volatility and to identify oversold or overbought conditions. By measuring the expansion and contraction of these bands, it is possible to determine whether the market is calm or turbulent. The BB has two input variables that need to be set:

the period, which determines how many past candles are used to calculate the indicator, and the bandwidth (stdDev), which determines the half-band width in multiples of the standard deviation [21].



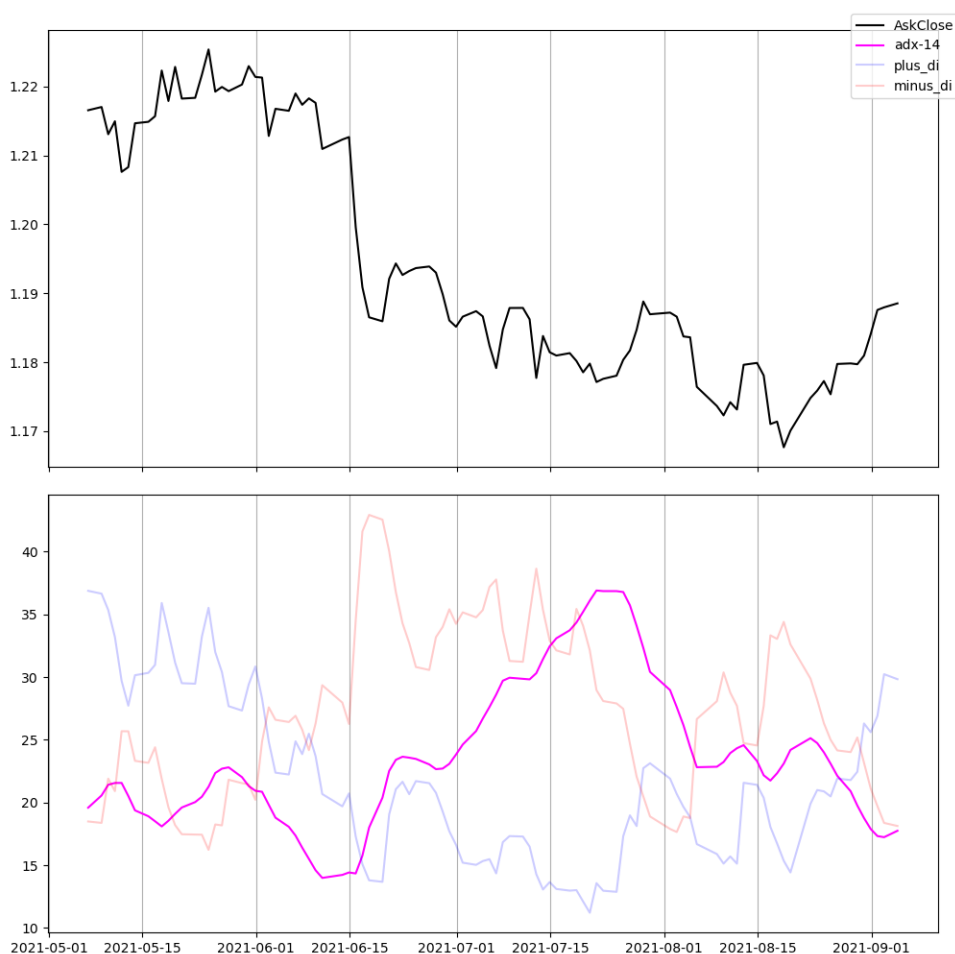
**Figure 4.3:** The EUR/USD chart on a 1-day time frame shows a Bollinger Bands (BB) having a period of 14 and a standard deviation of 2.

## 4.4 Average directional index

The Average Directional Index (ADX) is a widely used technical analysis tool consisting of three lines. Its primary function is to determine whether the market is trending and, if so, the strength of the trend. ADX values range from 0 to 100. A value above 25 indicates a trend, but in general, the higher the value, the stronger the trend. As a trend strength indicator, it allows traders to enter the market in the direction of a strong trend.

The ADX is usually displayed with two other indicators, the Positive Directional Indicator (+DI) and the Negative Directional Indicator (-DI). These additional lines help traders decide whether to go long, short or stay out of the market altogether.

The formula of the ADX indicator includes the calculation of the +DI and -DI, which is determined by calculating the "up-move" and "down-move". Some strategies only use the ADX line as the +DI and -DI is only used to calculate the ADX [22].



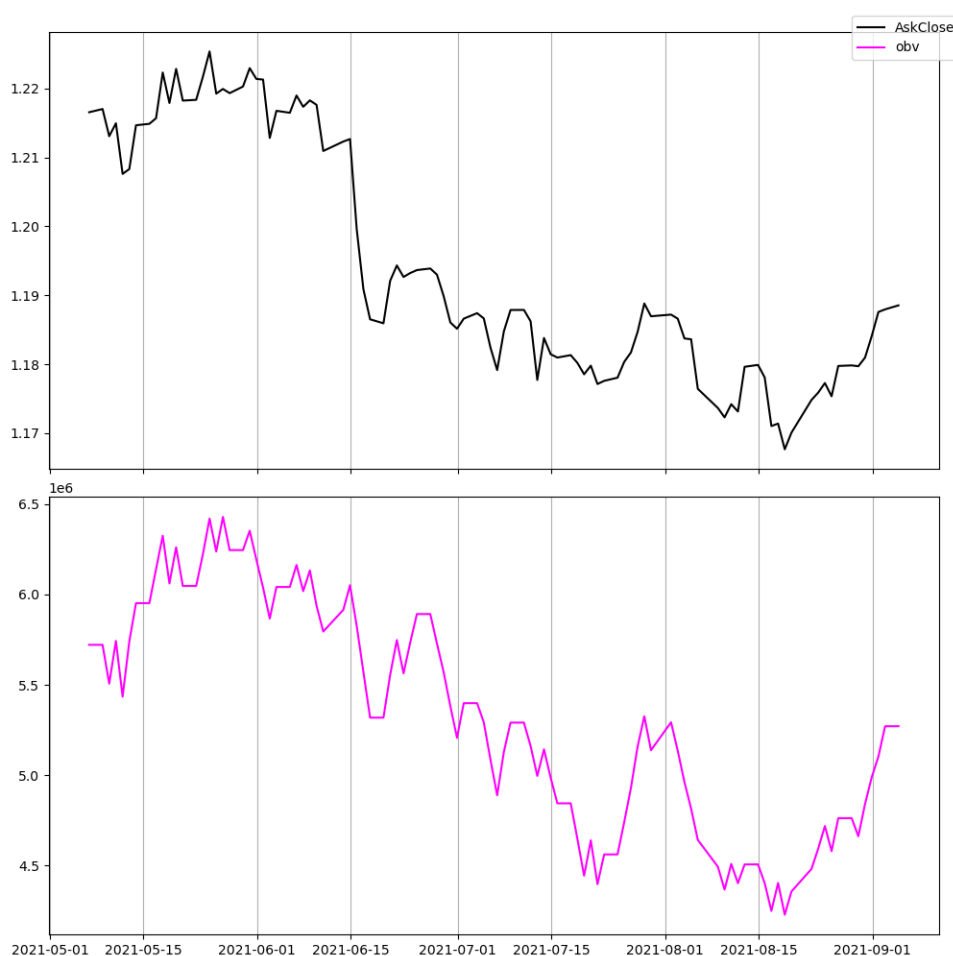
**Figure 4.4:** The EUR/USD chart on a 1-hour time frame shows a Directional movement index indicator of period 14, along with ADX, +DI and -DI lines.

## 4.5 On balance volume

The On Balance Volume (OBV) indicator is used to predict volume price changes and identify false prevailing trends. It is based on the belief that a sharp change in trading volume is followed by a significant price movement. For example, when large traders invest in securities, both the trading volume and the share price increase, with the asset price rising some time later.

The OBV line rises when the current closing price is higher than the previous closing price and falls when the current closing price is lower than previous closing price.

The OBV indicator provides various signals as described below:



**Figure 4.5:** The EUR/USD chart on a 1-day time frame shows an On balance volume indicator.

- **Trend confirmation:** If there is positive volume pressure and the price is rising. Conversely, when there is negative volume pressure and the price is falling, indicating that the current trend is likely to continue.
- **Trend reversal (divergence):** A bullish reversal occurs when the indicator line moves up (positive divergence) in the midst of the price chart's downtrend. Conversely, a bearish reversal occurs when the OBV line goes down (negative divergence) in the midst of an upward trend on the chart.
- **Spike in volume:** A sudden increase in volume may indicate significant market activity by institutional traders. Conversely, a smoother movement may indicate that other types of traders are entering the market.

Furthermore, all of the above signals are not contradictory; they often occur



simultaneously, which can provide additional confirmation [23].





## Chapter 5

### Trading strategy

A trading strategy is a fixed plan for executing orders in the markets to achieve a profitable return. It should outline the specific assets to be traded, the investor's risk tolerance, time horizon and overall objectives. A good trading strategy should be consistent, objective, quantifiable and verifiable [24].

Therefore, a slight change in an indicator's settings could produce completely different signals and a new strategy.



#### 5.1 Strategy settings

Strategies use different indicators that have different settings from which the indicators are calculated and therefore the signals from these indicators will change. I would also like to include other parameters or conditions for more comprehensive results. The strategies will trade on different currency pairs and time frames.

### ■ 5.1.1 Currency pairs

Each currency pair behaves differently, mostly due to the time zone of the countries involved and also the impact of certain fundamental news. To test the strategies I will use the following most liquid currency pairs:

- EUR/USD
- GBP/USD
- USD/JPY

These three are the currency pairs where we are likely to see the biggest moves.

### ■ 5.1.2 Time frame

The time frame plays an important role in determining trading signals. It directly affects the performance of indicators, with lower time frames resulting in a greater number of signals, but with increased market noise and potential for false signals. Conversely, higher time frames tend to generate fewer signals but are more accurate in their predictions.

To strike a balance between these factors, I have selected the following time frames:

- 1 day
- 4 hours
- 1 hour

These three time frames provide comprehensive coverage for several use cases.

## ■ 5.2 Strategies used

Since we have no criteria for selecting strategies and the only logical metric is the profitability of the strategy, which is a part of the evaluation, I decided to cover the maximum number of possibilities. So we have 3 strategies built on different foundations.

### ■ 5.2.1 Trend-following strategy

This strategy is based on the MA crossover of two moving averages with different periods and complemented by the ADX indicator to trade mostly during market trends. When the leading MA, the one with the lower period, crosses the lagging MA, the one with the higher period, a long or short signal is generated depending on the direction of the crossover. As the signals are opposite, only 1 trade can be open at a time. This strategy has been inspired by [25].

The strategy has the following open long / short position conditions.

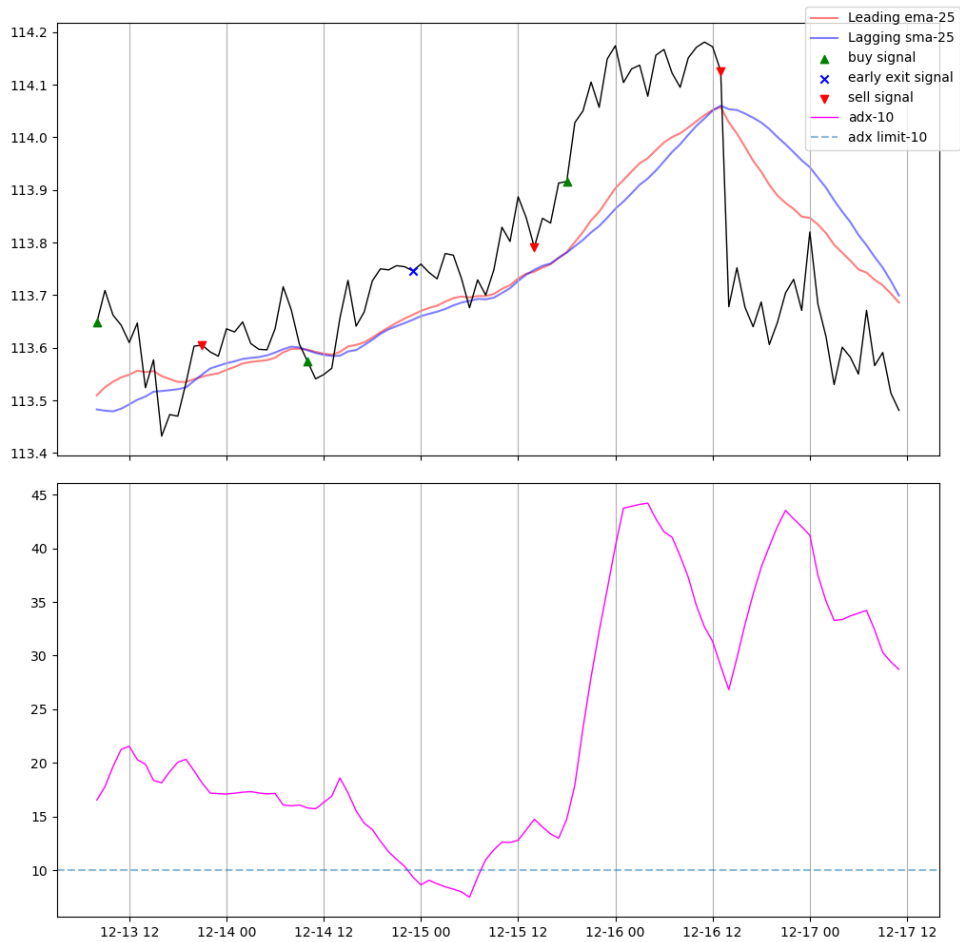
1. ADX is above a limit level
2. a leading MA crosses a lagging MA

The strategy has the following close long / short position conditions.

1. ADX falls below a limit level
2. or a leading MA crosses a lagging MA

A trade is closed when a leading MA crosses a lagging MA. This implies that only one trade can be opened at a time.

Therefore, the strategy will have the following parameters 5.2.1 with a total of approximately  $2 * (50 - 5) * 2 * (100 - 10) * (40 - 10) * (40 - 10) = 14,580,000$  possible optimisations of the strategy.

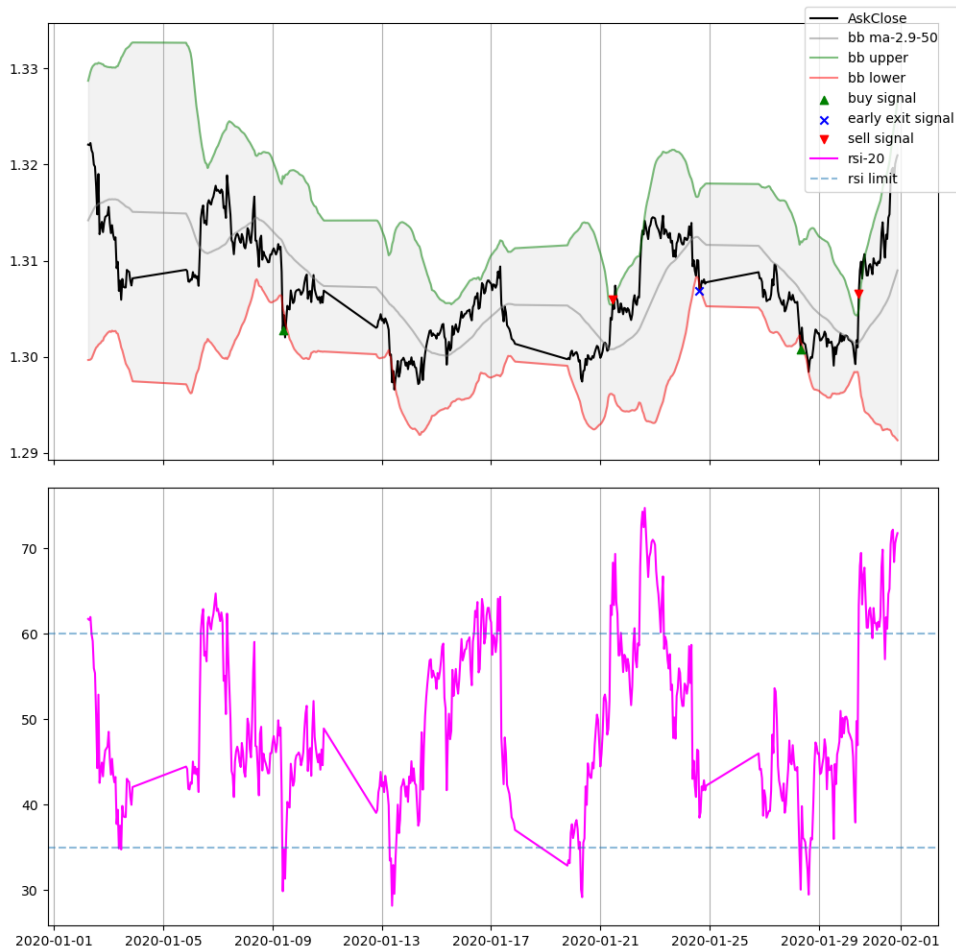


**Figure 5.1:** The EUR/USD chart on a 1-hour time frame shows the ADX with a period of 10 and its limit of 10. There are also two lines - a blue line representing the SMA with a period of 25 and a red line representing the EMA with a period of 25. The points of interest are marked.

- SMA and EMA as leading MA
- leading MA period, from 5 to 100
- SMA and EMA as lagging MA
- lagging MA period, from 10 to 150
- ADX limit level, from 10 to 40
- ADX period, from 10 to 40

## 5.2.2 Mean-reversion strategy

This strategy uses a Bollinger bands indicator, which identifies price spikes further away from the mean, and an RSI indicator, which helps identify that a price closing outside of a Bollinger bands is not a new emerging trend, but a temporary spike. This strategy has been inspired by [26].



**Figure 5.2:** The USD/JPY chart on a 1-hour time frame shows BB with a period of 50, std of 2.9 and RSI with a period of 20. The points of interest are marked. The data is skewed due to a provider that tracks weekends, even though the JPY is only traded on weekdays.

The following conditions for an open long position indicate that the price has fallen to an extremely low level and that the market is oversold.

1. RSI falls below lower limit level
2. price closes below the lower Bollinger band

The following conditions for an open short position indicate that the price has risen to an extremely high level and that the market is overbought.

1. RSI rises above upper limit level
2. price closes above the upper Bollinger band

A trade is closed when the price closes outside a Bollinger Band. This implies that only one trade can be opened at a time.

Therefore, the strategy will have the following parameters 5.2.2 with a total of approximately  $(100 - 5) * ((3.0 - 1.0) / 0.1) * (40 - 10) * (80 - 60) * (40 - 20) = 22,800,000$  possible optimisations of the strategy.

- BB std, from 1.0 to 3.0, step by 0.1
- BB period, from 5 to 100
- RSI lower limit level, from 20 to 40
- RSI upper limit level, from 60 to 80
- RSI period, from 10 to 40

### ■ 5.2.3 Divergence strategy

This strategy relies on a balance volume indicator to identify divergences. A long or short position is opened based on a type of divergence. The problem is that a divergence can only be identified after it has happened, i.e. with some delay. This strategy also uses a long period MA to eliminate false divergences by trading only with the trend. This strategy has been inspired by [27] and [28].

The strategy has the following open long position conditions.

1. bullish divergence is identified
2. a price is bellow MA





**Figure 5.3:** The EUR/USD chart on a 1-day time frame shows an OBV with a plotted bullish and a bearish divergence.

The strategy has the following open short position conditions.

1. bearish divergence is identified
2. a price is above MA

The strategy has the following close position conditions.

1. price breaks through MA
2. short - OBV rises above OBV where a divergence was identified
3. long - OBV falls below OBV where a divergence was identified

In order to locate peaks and identify divergences in our data, we need to define a peak period parameter. This parameter specifies the number of data points on either side of a peak that must be less or more than its value for it to be labelled as such. For example, peak period=5 means that a point

should only be identified as a peak if it is greater or less than any of the five neighbouring data points to its left and right.

Therefore, the strategy will have the following parameters 5.2.3 with a total of approximately  $(1 + 1) * (800 - 10) * (100 - 3) = 153,260$  possible optimisations of the strategy. Due to the small number of parameters, the number of possible optimisations is much smaller than possible optimisations of previous strategies.

- SMA and EMA, total of 2
- MA period, from 10 to 800
- peak period, from 3 to 100

## ■ 5.3 Summary

A trading strategy is a fixed plan for executing orders, and slight tweaks to the settings of dependent indicators will result in completely different sets of signals. Tweaking the settings of all 3 strategies gives a total of approximately 37,533,260 optimisations for each time frame and currency pair.



## Chapter 6

### Implementation and technologies

This chapter describes the technologies used, the implementation process and the selection of the data provider.

#### 6.1 Technologies used

I chose Python version 3 as the programming language because it is ideal for data analysis and has many libraries available for this purpose, which speeds up the analysis process. I also use Jupyter Notebook to better visualise strategies during implementation. I will use Git for version control.

During the strategy selection process, I had to visualise the possible strategies and select the appropriate indicators, so I used the web platform Tradingview [29], which offers a wide range of features, all the markets that can be traded and dozens of indicators.

##### 6.1.1 Python libraries used

I used Anaconda as the core set of libraries, and will only mention the most important ones below.

- forexconnect

ForexConnect API Python provides the ability to create analysis and trading applications in Python. The functionality of the ForexConnect API includes: downloading historical quotes, creating all available order types, getting quotes, managing positions, getting account reports, and more [30].

In order to use the ForexConnect API, you must have an account with FXCM Group. So I opened a demo account.

- pandas

Pandas is a fast, powerful, flexible and easy-to-use open source data analysis and manipulation tool, built on top of the Python programming language [31].

- numpy

NumPy is a basic library for scientists and analysts using Python. It defines a type for an n-dimensional homogeneous array (most often of numbers) and an API for working with such an array.

Almost all libraries where larger arrays or tables appear are either built on top of NumPy or support `numpy.array` [32].

- matplotlib

Matplotlib is a comprehensive library for creating static, animated and interactive visualisations in Python. Matplotlib makes the simple easy and the difficult possible [33].

- pandas\_ta

An easy to use Python 3 Pandas extension with 130+ technical analysis indicators. Can be called from a Pandas DataFrame or standalone like TA-Lib. Correlation tested with TA-Lib [34].

Unfortunately, I found this library after I had implemented all the indicators, otherwise it would have saved me a lot of time. It also contains several metrics.

## ■ 6.2 Implementation

The implementation process can be divided into several parts, which are described in this section.

1. Real data

Data is retrieved from the FXCM broker via the `forexconnect` library.

Due to the potential number of FXCM API calls during implementation, the data obtained is stored in csv files and then used.

## 2. Implementation of indicators

Each indicator used is implemented and visually tested against a Tradingview chart. Although the output charts are slightly off due to the different data providers used by Tradingview.

## 3. Implementation of strategies

Each strategy was first visualised on the Tradingview platform to test trading signals. The most difficult part was implementing strategies to correctly open signals on larger input data sets due to the difficulty of visualising each signal.

## 4. Implementation of metrics

Most of the metrics are commonly used in the stock market, so some metrics were more difficult to implement and produce a valid result.

## 5. Backtest

As mentioned in the backtest section below, each strategy is tested on each currency pair and time frame. The results are filtered by some PNL threshold and stored in csv files.

## 6. Evaluation

Data is retrieved from each backtest results file and then evaluated as described in the Evaluation section.

## 6.3 Real data

There are many data providers, and of course they differ in some aspects, mainly accessibility, granularity and volume. Some of the providers focus on a specific part of the market, for example forex. Some of these are FXCM, which is also a broker, or TraderMade, which offers free access to up to 1000 queries per month and minute data back to 1990, which is pretty crazy. However, only the FXCM broker provides volume data and is free. Volume is tracked from mid-2004.

Date	AskHigh	AskLow	AskClose	Volume
2021-12-30 22:00:00	1.13867	1.13036	1.13841	97390

**Table 6.1:** Sample data retrieved from FXCM provider. Columns that are not used are omitted.

## 6.4 Backtest

To find out if a strategy is viable, and which optimisation works best under which parameters, it is necessary to test the strategies, and this is best done on real data.

The total number of optimisations of all 3 strategies tested on 3 time frames and 3 currency pairs is approximately  $(3 * 3) * 37533260 = 337,799,340$ .

### 6.4.1 Conditions

As mentioned above, all possible optimisations of a strategy are tested on 1 day, 4 hour and 1 hour time frames and on the EUR/USD, GBP/USD and USD/JPY currency pairs. The strategies are calculated on the ask price of a close. The spread 2.2.2 is therefore not included. The data will cover a period of 20 years, from 2002 to 2022. The backtest result contains the current optimisation parameters and their PNL. These results are filtered by a PNL threshold to limit their size. Due to the long run times and to ensure that no work is lost, each backtest result is stored in a separate csv file.

### 6.4.2 Performance issues

During the implementation I encountered a problem when testing the Trend-following strategy 5.2.1 on 1D time frame and EUR/USD currency pair would take more than a day, for 1H time frame it would take about 4 times as long, although the input data has about 20 times more rows. With such times it was not in my power to test everything. These calculations were made on my personal desktop computer with an Intel i7-3770k overclocked to 4.2GHz and 16GB of RAM.

At the same time, it can be seen that reducing the number of rows does not bring too much speedup. I noticed that only 1 CPU core is used during the calculation, and there is room for speedup, but it would require a higher knowledge of parallelization, for which there is no time. There was also the option of doing the computations in the cloud, but as far as I could tell, most of the options were paid options, but without parallelization it would not

speed up the computations much anyway, but it would free up your own resources. I ended up using Google Colab [35] for development, which is free and allows me to do calculations offline (but still with limitations).

The only suitable solution I could think of was to drastically reduce the number of possible optimisations of strategies by reducing the number of input parameters, so for example for the MA indicator the period range remained unchanged but was added in increments of 4 instead of 1. This way it was possible to test everything in just a few tens of hours.

## ■ 6.5 Summary

In further implementations I would suggest to use the `pandas_ta` library to not worry about indicators implementation. Real data is retrieved from the FXCM broker and stored in csv files for backtesting to limit API calls. The total number of strategy optimisations should be reduced to make it realistic to test. There are several ways to do this, reducing the number of rows of input data, parallelizing the computations, cloud solution, reducing the number of iterated strategy settings by increasing the step, or after further observation, optimising the range of values in the settings. The ideal and high level solution is a combination of the above.







## Chapter 7

### Performance analysis and results

In this chapter, we evaluate the performance of the previously mentioned trading strategies through empirical analysis. We discuss the metrics used for evaluation, present the results of our backtesting, and offer a critical discussion of the implications and limitations of our findings.



#### 7.1 Metrics

It is not always clear which strategy is successful. Profitability is not everything, we are also interested in drawdown, i.e. the maximum cumulative loss, and other possible factors. There are several metrics to measure the success of an algorithm.



##### 7.1.1 Profits and losses

Profits and losses (PNL) refers to the amount gained from a successful trade and the amount lost in an unsuccessful trade.

This profit or loss would be the difference between the price at which you opened the trade and the price at which you closed the trade. In the forex markets, profit and loss is calculated in pips or percent [36].

### ■ 7.1.2 Compound annual growth rate

The Compound Annual Growth Rate (CAGR) is the percentage by which an investment must grow each year from its initial balance to its final balance, assuming that all gains are reinvested at the end of each period over the life of the investment [37]. As a benchmark, we can use the S&P 500 stock index, which has a CAGR of around 10% [38].

### ■ 7.1.3 Maximum drawdown

Maximum Drawdown (MDD) measures the maximum drop in value from peak to valley of an investment, with a low MDD indicating lower risk. It is expressed as a percentage. It should be considered in the context of the time period, as different investments may have different levels of risk over different time frames. A zero MDD means no losses, while a -100% MDD means the investment is worthless [39].

### ■ 7.1.4 Sharpe ratio

The Sharpe ratio is a widely used method of measuring risk-adjusted returns by comparing a fund's historical or expected returns to an investment benchmark and the variability of those returns. It helps to determine whether excess returns are due to wise investment decisions or simply to luck and risk. The higher the Sharpe ratio, the more attractive the risk-adjusted return and it can be used to assess the risk-adjusted performance of a portfolio. A negative Sharpe ratio means that the portfolio's return is expected to be negative or that the benchmark rate is higher than the expected return. We will use 2% as a risk-free benchmark [40].

### ■ 7.1.5 Volatility

Volatility is a measure of the rate of change in the price of an asset based on its returns. It helps to assess risk and estimate potential price fluctuations over a given period of time. High volatility occurs when prices fluctuate

rapidly and low volatility occurs when prices fluctuate slowly over a long period of time. The lower the volatility index, the better [41].

## 7.2 Evaluation of the strategies

In this section I will briefly evaluate the strategies and their optimisations. For a more comprehensive evaluation it would be necessary to analyse all the results, i.e. hundreds or thousands of results. However, based on the evaluation of the results with the highest total PNL, the trend following strategy came out better.



**Figure 7.1:** An account balance of the strategy optimisations with the highest total PNL in comparison.

### 7.2.1 Trend-following strategy

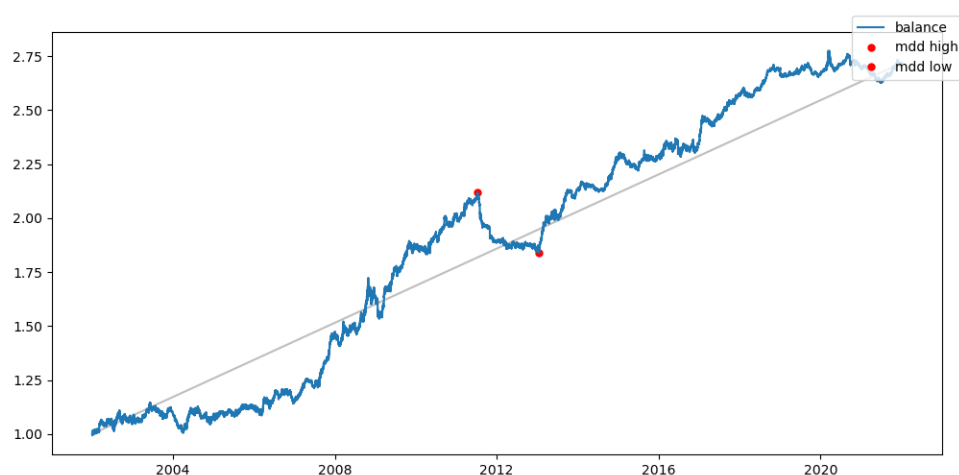
The first thing that can be observed from the trend-following strategy results table 7.1 is the "adx limit" parameter, which in most cases has a value of 10, the lowest value tried. The adx value will exceptionally reach a lower value, so the condition to open a trade with an adx higher than 10 is almost always met. The ADX indicator therefore has little influence on the strategy and it would be advisable to change the conditions for opening trades or replace it with another indicator to determine the trend. USD/JPY and EUR/USD have better results on H1 or even D1 time frames.

The strategy optimisation with the highest total PNL, i.e. the first row

parameters	pnl	cagr	mdd	volat	sharpe	currency	tf
1/25/0/25/10/10	2.72	0.05	0.13	0.59	0.05	usd/jpy	h1
1/25/0/25/10/15	2.67	0.05	0.11	0.58	0.05	usd/jpy	h1
1/25/0/25/10/20	2.57	0.05	0.10	0.53	0.05	usd/jpy	h1
1/25/0/25/10/10	2.33	0.04	0.07	0.39	0.06	eur/usd	h1
1/25/0/25/10/15	2.20	0.04	0.09	0.37	0.05	eur/usd	h1
1/25/0/25/10/20	2.09	0.04	0.09	0.32	0.05	eur/usd	h1
0/55/1/85/10/25	2.01	0.04	0.10	0.33	0.05	eur/usd	d1
0/50/1/85/10/25	1.99	0.03	0.09	0.31	0.05	eur/usd	d1
1/30/0/30/10/25	1.96	0.03	0.15	0.28	0.05	gbp/usd	h1
0/60/0/95/10/25	1.96	0.03	0.09	0.33	0.04	eur/usd	d1
0/45/1/45/10/20	1.96	0.03	0.20	0.28	0.05	usd/jpy	d1
1/30/0/30/10/15	1.94	0.03	0.16	0.29	0.05	gbp/usd	h1
0/60/0/75/10/25	1.93	0.03	0.13	0.28	0.05	usd/jpy	d1
0/45/1/45/10/35	1.92	0.03	0.13	0.30	0.04	usd/jpy	d1
0/15/1/15/15/35	1.92	0.03	0.09	0.29	0.05	gbp/usd	h1
1/10/0/10/10/10	1.78	0.03	0.17	0.20	0.05	gbp/usd	d1
0/30/1/50/10/30	1.75	0.03	0.13	0.24	0.03	eur/usd	h4
1/25/0/25/10/25	1.74	0.03	0.28	0.37	0.02	gbp/usd	h4
0/30/1/40/10/35	1.73	0.03	0.14	0.22	0.04	eur/usd	h4
1/35/1/145/10/20	1.73	0.03	0.13	0.26	0.03	eur/usd	h4
1/15/0/15/10/15	1.72	0.03	0.21	0.23	0.03	usd/jpy	h4
0/70/1/85/10/35	1.72	0.03	0.20	0.29	0.03	usd/jpy	h4
1/40/0/40/10/10	1.72	0.03	0.17	0.21	0.04	gbp/usd	h4
1/40/0/40/10/15	1.71	0.03	0.16	0.21	0.03	gbp/usd	h4
0/75/1/75/15/10	1.70	0.03	0.20	0.24	0.03	gbp/usd	d1
0/70/1/70/15/10	1.69	0.03	0.21	0.23	0.03	gbp/usd	d1
1/15/0/15/10/10	1.69	0.03	0.22	0.21	0.03	usd/jpy	h4

**Table 7.1:** Table showing the top 3 results of the trend-following strategy for each currency pair and time frame of the backtesting strategy. Due to the size of the table, the optimisation parameters are truncated and in the order mentioned in the Trading strategy chapter 5.2.1. The pnl column is the total PNL.

in the table of relevant results 7.1, has a total profit of 172% over 20 years of trading, assuming a trade opening of the size of the initial deposit. As both strategies always have a maximum of 1 trade open, there is no need to consider the risk per trade. Not so good with a CAGR of 5% compared to the S&P500 CAGR benchmark of 10%. A maximum drawdown of 13% is pretty decent, depending on your expectations of an investment. The Sharpe ratio is far from good as we have a low CAGR and high volatility.



**Figure 7.2:** An account balance of a trend-following strategy optimisation with the highest total PNL over a 20-year period. The maximum drawdown is also plotted.

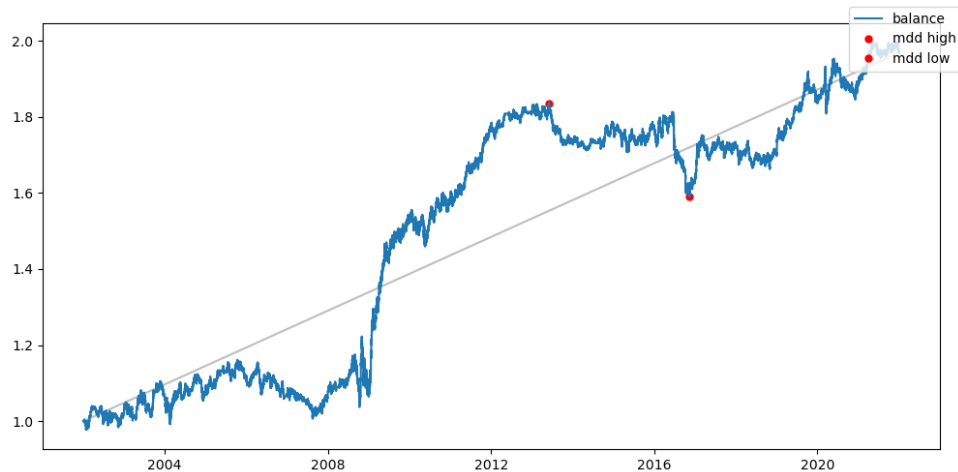
## 7.2.2 Mean-reversion strategy

Unfortunately, the results of this strategy do not even reach 100% of the total PNL. Nevertheless, some conclusions can be drawn. In the following table the results for the currency pair EUR/USD and the time frame D1 are missing, because no optimisation exceeded the threshold of 150% of the total PNL. It can also be seen that EUR/USD is the worst performing currency pair used. It is also interesting to note that some results differ in exactly one parameter, which could mean that the strategy opened the same trades and therefore they have the same results. It also indicates that changing this parameter does not have a major impact, which can be useful in a future backtest.

The balance curve 7.3 for the mean-reversion strategy is much more volatile than the balance curve 7.2 for the trend-following strategy, although it is almost twice as volatile, so perhaps it is better to measure volatility differently here. However, it is clear from this curve that it is not satisfactory, as the first 7 years did nothing, then came 3 rocket years and the next 10 years basically nothing. It would be good to take a closer look at the 3 extremely profitable years and find out where the difference was.

parameters	pnl	cagr	mdd	volat	sharpe	currency	tf
2.9/50/35/60/20	1.97	0.03	0.13	0.33	0.04	gbp/usd	h1
2.9/50/35/60/15	1.96	0.03	0.15	0.31	0.05	gbp/usd	h1
2.9/50/35/60/10	1.94	0.03	0.14	0.31	0.04	gbp/usd	h1
2.8/10/25/60/10	1.93	0.03	0.17	0.30	0.04	usd/jpy	h1
2.8/10/25/70/10	1.93	0.03	0.17	0.30	0.04	usd/jpy	h1
2.8/10/25/65/10	1.93	0.03	0.17	0.30	0.04	usd/jpy	h1
2.0/85/30/65/10	1.91	0.03	0.17	0.31	0.04	gbp/usd	h4
2.6/75/30/65/20	1.90	0.03	0.17	0.28	0.04	usd/jpy	h4
1.9/80/35/65/10	1.90	0.03	0.24	0.34	0.04	gbp/usd	h4
1.9/90/35/65/10	1.90	0.03	0.20	0.31	0.04	gbp/usd	h4
2.5/70/25/65/15	1.87	0.03	0.15	0.27	0.04	usd/jpy	h4
2.6/75/25/70/15	1.86	0.03	0.12	0.27	0.04	usd/jpy	h4
1.7/15/35/60/10	1.76	0.03	0.23	0.30	0.03	gbp/usd	d1
1.8/15/30/60/10	1.75	0.03	0.13	0.23	0.04	usd/jpy	d1
1.6/20/35/65/10	1.74	0.03	0.18	0.27	0.03	usd/jpy	d1
1.6/20/30/65/10	1.74	0.03	0.19	0.24	0.03	usd/jpy	d1
1.2/5/35/60/10	1.71	0.03	0.12	0.23	0.03	eur/usd	h1
1.2/5/35/65/10	1.71	0.03	0.09	0.21	0.03	eur/usd	h1
1.8/15/35/60/10	1.67	0.03	0.28	0.30	0.02	gbp/usd	d1
1.5/15/35/70/10	1.65	0.03	0.15	0.18	0.03	gbp/usd	d1
2.1/75/35/65/10	1.65	0.03	0.18	0.23	0.02	eur/usd	h1
2.8/75/25/60/10	1.59	0.02	0.22	0.20	0.02	eur/usd	h4
2.8/75/25/65/10	1.59	0.02	0.22	0.20	0.02	eur/usd	h4
2.8/80/35/60/10	1.58	0.02	0.22	0.22	0.01	eur/usd	h4

**Table 7.2:** Table showing the top 3 results of the mean-reversion strategy for each currency pair and time frame of the backtesting strategy. Due to the size of the table, the optimisation parameters are truncated and in the order mentioned in the Trading strategy chapter 5.2.2. The pnl column is the total PNL.



**Figure 7.3:** An account balance of a mean-reversion strategy optimisation with the highest total PNL over a 20-year period. The maximum drawdown is also plotted.

## ■ 7.3 Summary

In order to properly evaluate the results, some metrics need to be established. From the observations made, the trend-following strategy has achieved the highest PNL of 172% and almost tripled the initial investment over a period of 20 years, i.e. a CAGR of 5%, so it is still better to invest in the S&P500 index with a CAGR of 10%.







## Chapter 8

### Conclusion



#### 8.1 Summary of results achieved

The thesis analysed possible types of strategies for algorithmic trading, selected and created several full-fledged strategies with opening and closing signals, and defined input parameters for optimisation. Trend following and mean reversion strategies were implemented and many of their optimisations with different parameters were tested on real data. The results were evaluated using metrics. Several optimisations turned out to be relatively good, but unfortunately still far from realistic use. Nevertheless, the trend-following strategy performed better.



#### 8.2 Possible improvements

Due to the large number of possible optimisations and the long computation time, I had to reduce this number by stepping the parameters, so I did not try all possible combinations. It would be better to do the computations in parallel and in the cloud to make the computations faster and continuous. It would be useful to do an initial analysis of these parameters, as some did not have much impact on the results. Strategies would also need a better set of opening and closing conditions, as now strategies can only have 1 trade open at a time, which limits the potential profit.





## Appendix A

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