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Quantitative construction of diversified Trading System Portfolio

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Introduction

For several years, finance has been my greatest passion, dedicating the majority of my resources, study, and time. I began this long journey by researching discretionary trading. I've been looking for a way to outperform the market using technical analysis, first in forex and then moving on to equities, through active short-term strategies. Thanks to my university career, I was able to devote time and study to deepening asset management by employing more advanced portfolio management and risk management techniques. So, rather than purely following a stock-picking approach, I switched from an active short-term operation to one more linked to medium-long term asset allocation through the use of instruments that guaranteed greater diversification, such as funds and ETFs. With this thesis, I decided to return to my initial path, which brought me closer to this world in the first place but improved this discretionary approach by making it systematic and combining it with the most advanced portfolio and management theories learned during my course of study.

A financial portfolio is a group of financial assets, also known as securities or investments, like stocks, bonds, futures contracts, or exchange-traded funds (ETFs). Building a financial portfolio is a well-known problem in financial markets that necessitates a thorough analysis to select the most profitable assets. Portfolio creation is made up of two interconnected tasks. The first is an asset allocation task in which the investor must decide how to divide his or her wealth between risk-free securities and a set of N risky securities. The second refers to the creation of a risky portfolio to decide how to allocate wealth and risk among the N risky securities. As a result, to build a portfolio, investment objectives must be defined by focusing on the acceptable level of risk for a given return. Portfolio management is the process of determining which assets should be included in a portfolio, how much capital should be allocated to each type of security, and when to remove a specific investment from a holding portfolio while keeping the investor's preferences in mind.

There are two types of management: passive and active. Passive management is when an investor focuses his goal on tracking a market index. This is related to the notion that beating the market index is impossible. A passive strategy aims only at establishing a well-diversified portfolio without trying to find under or overvalued stocks. Active management is a strategy in which the investor's primary goal is to outperform an investment benchmark index. (Maginn J.L., Managing investment portfolios: A dynamic process. 3rd ed, ed. C.I.I. Series, Wiley (2007)).

As stated, a typical equity portfolio is built and managed in relation to an underlying benchmark. An indexed equity portfolio is a passive management style designed to track a benchmark, with no active returns and residual risk constrained to be close to zero. While an indexed equity portfolio may underperform the benchmark after costs are taken into account, enhanced indexed portfolios are intended to provide index-like performance plus some excess return after costs. The latter is permitted to relax the residual risk constraint by slightly overweighting securities expected to perform well and slightly underweighting securities expected to perform poorly (Jacobs B., Levy K., Enhanced active equity strategies. Journal of Portfolio Management, 32, pp 45–55 (2006)). Active equity management seeks portfolios with a natural level of risk that is consistent with the investor's risk tolerance and based on the return opportunities available. The majority of active equity portfolios seek to produce attractive risk-adjusted returns (or alpha).

This thesis aims to provide a step-by-step practical guide to developing trading strategies, risk management, and portfolio construction using a balanced and systematic approach. It is intended for both newcomers to the trading world and more experienced readers who want to learn more about classic portfolio management from a different perspective and diversify their capital allocation. This dissertation will examine how to build a diversified portfolio of active strategies. In contrast to traditional asset allocation portfolios, the final portfolio, in this case, will be based not only on diversified asset classes and markets but also on diversified active strategies applied to these markets.

I will go over the steps involved in identifying trading signals, developing quantitative strategies, estimating expected returns, measuring and scoring strategies, and allocating portfolios. This is accomplished with the assistance of various published articles cited throughout this thesis, as well as financial and economic textbooks. The process starts with defining what a trading system is. There is no better system than another, but a good system fits the goals, timing, starting capital, and even trader personality. Following that is the trading system infrastructure, which provides a solid foundation for the systematic trading environment by listing the main resources to be considered for its development, namely Data Feed Providers, Platforms, and Brokers. For all processes, data, tools, codes, and examples in this thesis, TradeStation is used as a data feed provider, MultiCharts as a trading platform, and PowerLanguage as a coding language. The second chapter aims to provide all the steps and tools needed to build a trading system. It begins with the so called "trading system essential", which includes the structure of scripts and strategies, the main classification of strategies, an introduction to patterns, how to perform a meaningful backtest and the test generators in order to determine the different time windows and periods to be used as In Sample (IS) and Out Of Sample (OOS). The chapter continues with a detailed explanation of the strategy performance report with the

strategy, trade and periodical analysis. After that it is introduced the optimisation process, from the standard optimisation through Exhaustive Search (ES) and Genetic Algorithms (GA) methodologies to the periodical re-optimisation using the Walk Forward Optimisation (WFO). This subsection ends with a focus on overfitting which mostly arises from optimisation processes. The last subsection regards the trading system evaluation with a focus on psychological and technical metrics from the performance report and robustness analysis through the Walk Forward Analysis (WFA). Finally, there is a detailed example to put at work all the concepts and methodologies presented.

The third chapter is one of the most relevant to enhance the performance with a focus on risk management. As stated in the multiple examples, there is no return without exposure to risk, but an excessive exposure could imply the bankruptcy of the trading account. Moreover, note that the markets compensate traders only for non-diversifiable risk, so even if higher profits are implied by higher risk the opposite is not true. This chapter starts by providing a precise definition of risk, going forward there is a deepening in the single position management with the definition and setting of stoploss, take profit, and trailing stops. The next section is related to Money management and position sizing with a focus on the main position sizing models that can be applied to a single strategy or portfolio. Subsequently, there is a subchapter dedicated to the Montecarlo simulation with the definition of the Method used and its properties and limits. Finally, this chapter ends with a practical example of Money Management application on a trading system. The fourth and final chapter is related to the main aims of this dissertation, the "portfolio construction". It starts with the introduction of the evolution of portfolio theory, from Markowitz to Post Modern Portfolio Theory. The next section is related to Pearson's Linear correlation coefficient, which is fundamental to understanding the subchapter related to diversification both in terms of asset selection and strategies. Subsequently, different types of portfolios are presented. The following subchapter is related to the position sizing with the introduction of capital allocation and position sizing models for portfolios. Next, there is the section dedicated to the portfolio management with focus on how to filter, select, and stop the strategies inside a fully diversified portfolio. Finally, also this chapter ends with a practical example of the application of mentioned concepts.

All chapters conclude with a practical example of how the theories explained can be applied to improve understanding of the processes described. The numerous examples aim to give this dissertation a more practical rather than theoretical perspective, allowing traders to test and replicate the results and concepts presented in the most user-friendly way possible.

Chapter 1

The Trading System and its functioning

1.1 Trading System

When we talk about the "quantitative" approach to analysing a phenomenon we refer to the ability to establish measurable and comparable references. One of the foundations of the scientific method is that of verifiability and reproducibility of the results. Once the operational variables of an experiment have been provided and the boundary conditions are known, it must be possible for anyone to reproduce the published results.

Trading is no exception. The numbers tell us whether a system is drifting away from its operational regime or whether it is still robust and healthy (http://gandalfproject.com/). The growing use of quantitative methods has significantly changed finance and investment theory. The most significant advantage is the power of automation, applying a systematic investment approach and a structured and unified framework through the Trading System. The implementation of fully automated risk models and mark-to-market processes provide powerful tools for analysing and monitoring portfolio performance in real time and they also provide the foundation for comprehensive process and system backtests. The request for a backtest (or a forward test) with notification of the validation criteria is now taken for granted. This is because financial markets are changeable and static models often suffer from cyclical phenomena (regular or irregular) of adaptation and asynchrony with the application market. The quantification of the decision chain allows a portfolio manager to more comprehensively understand, compare and calibrate the underlying investment strategies, objectives, and policies (A Practical Guide to Quantitative Portfolio Trading Daniel Bloch 30th of December 2014).

The Trading System is the set of blocks of market operating rules that formulate signals (buy and sell) without any ambiguity or any subjective element to guide the user in the decision-making process and compose a trading strategy. The rules are programmed in code to be automatically translated by an operating platform. The process can therefore be divided into 3 stages: the idea of trading is expressed in the programming code, the programming code is tested to see if it is profitable, and the programming code operates automatically without the assistance of the trader by buying and selling. If the results are positive and reflect certain stability and robustness parameters, then you can move on to the operational phase.

A trading system is simply the process by which equity is risked in search of profit (Chande, T. (2001) Classifying your trading system. Futures). In fact, the main objective of a trading system is to manage risk and increase profitability in any market environment and, optimal levels of risk and return are achieved by changing the different parameters within each system rule. The strategy tells what and when to trade, but it is the overall system that will tell how to trade. Indeed, one of the advantages of

the Trading System is the removal of emotions from trading. The System, therefore, will not carry out a high-risk operation due to the frustration deriving from a previous loss-making operation.

George Pruitt, the author of several books on the Trading System, states that to operate in increasingly stressed markets it is necessary to implement trading systems that remove human emotions by guaranteeing a complete and agile trading plan, characteristics more important than ever given the kinetic rhythm of the markets. Trading, therefore, means that traders have to put aside all their emotions and feelings about the market and follow only the signals of the system (Pruitt George, Building Winning Trading Systems with TradeStation, 2012).

Trading is known to be riskier than investing in the long term, however, it offers opportunities for greater profits. Indeed, the first step to investing is to study the basic fundamentals of the market, but economic factors can take several years to reflect the market, so a long-term view is required. Trading, on the other hand, involves a study of the technical factors that govern short-term market movements, as well as the psychological makeup of buyers and sellers in the market. From time to time, we hear that "the markets have changed since the technological revolution", but in the 1950s the markets were just as volatile on a percentage basis as they are today (Hill JR, Pruitt G., Hill L., The ultimate trading guide John Wiley & Sons, Wiley Trading Advantage, 2000). However, it is only thanks to the technological revolution that it has been possible to reduce execution costs, increase the ease of placing orders, and the possibility of creating trading systems capable of obtaining consistent profits from the sample avoiding large withdrawals (Dempster, M. A. & Leemans, V. (2006) An automated FX trading system using adaptive reinforcement learning. Expert systems with applications).

Another advantage of a trading system is being able to set the risk parameters that allow you to adopt good Money Management techniques compatible with the risk appetite of each trader. No system is better than another, but a good system is one that fits the traders' goals, their time window, their starting capital and even their personality. Furthermore, the main resources to be considered for the development of the Trading System are the Data Feed Providers, Platforms and Brokers (McDowell (2012). Resources: Front-End Platforms, Brokers, Data Providers, and More. In Survival guide for traders how to set up and organize your trading business / (pp. 243–254)).

1.2 Data Feed Providers

Data feeds are one of the most important choices an investor has to make. They enable global connectivity to the market in order to retrieve price, open, close, high, low, tick and volume information from trades and these data will be provided via a data service. The high accuracy of the data avoids the problem of errors on historical data. The use of incorrect or inaccurate data in the

backtesting phase and the study of strategies can cause the false reports and, consequently, this could lead to opting for a type of operation that does not reflect the actual market structure or inefficiencies. The importance of data quality is inversely proportional to the granularity of the time frame: the shorter the time frame (1 minute bars), the more the data quality is important on the performance, vice versa this impact decreases as the time frame rises (daily, weekly or monthly bars). Strategies that aim to execute many operations in the very short term, will implicitly be much less capable from the point of view of average profit ("average trade" metric), compared to daily or weekly operations. An error of a few "ticks" (minimum amount of variation of a financial instrument) can be very expensive for the first type of system and be practically irrelevant for the second (Strategie di trading con Python. Modelli di analisi quantitativa al servizio dell'investitore –2020 Giovanni Trombetta).

The companies listed here all provide quality data.

TradeStation (www.tradestation.com), as proprietary API for Trading Stocks, Options, Futures and Cryptocurrency, provides high quality real-time and historical data. It covers a wide range of products, from US equity to major futures markets, both European and US, at affordable prices. TradeStation provides a large selection of real time and delayed data from different market, including 1 minute and tick-by-tick data, for free with a deposit (with no minimum requirements) on its broker platform.

Quandl (www.quandl.com) is a partially free alternative with good quality data. It is a portal that provides thousands of conventional time series from different markets, fundamental data, and even alternative data, such as sentiment curves, obtained by aggregating big data. There are instances where some funds consider alternative data designed to be better than traditional data (Global Hedge Fund Benchmark Study 2021 in: www.aima.org/educate/aima-research/global-hedge-fund-benchmark-study.html). Lazard says alternative data can offer a whole new way of analysing a company, such as examining how workforce culture affects a stock price (Funds hunt for the real McCoy in alternative data jungle in: www.risk.net/asset-management/6605516/funds-hunt-for-the-real-mccoy-in-alternative-data-jungle). Quandl delivers market data from hundreds of sources via API, or directly into Python, R, Excel, and many other tools.

IQFeed (www.iqfeed.net) is data provider that ensures its data is of high quality albeit at high prices. It is a very fast data service, especially in times of fast market, i.e. when releases are made. This data feed provider has very low average latency, which results in minimal delay when it comes to downloading data from the exchange's servers to the local platform. Therefore, it is a tool that can certainly help the investor to keep the strategies functioning properly. IQFeed provides data relating to different types of instruments and markets. Through this historical data service provider, it is

possible to obtain data related to stock markets of many countries, futures markets, and Forex market. A peculiarity of IQFeed is that it provides, as regards the futures market, both the prices relating to the single contractual maturities and the continuous contracts, i.e. the union of previous contracts and all the different maturities combined in a single contract, to facilitate the study of the entire historical period available. Furthermore, it is possible to download the data of both the back-adjusted continuous contract and the non-back-adjusted continuous contract (a back-adjusted contract is a continuous contract in which the maturity gaps have been corrected and therefore does not foresee the variations of the gaps due to contractual deadlines).

1.3 Platforms

There are several platforms that can be used for systematic online trading. The main advantages and disadvantages are analysed below, taking into account the evaluation criteria. Among the advanced platforms widely accepted around the world and used by traders are MetaTrader, TradeStation and MultiCharts.

MetaTrader is a popular trading platform among retail investors. It is produced by a Russian company, called MetaQuotes, and was quickly adopted by dozens and dozens of brokers, who offer it to their clients for trading on Forex and indexes. MetaTrader allows you to use broker data or external data that can be purchased separately. Let's briefly see the features, strengths and weaknesses of MetaTrader (Malverti, E. (2016) I segreti dei trading system). The advantages of MetaTrader can include that it is a free platform and therefore accessible to any beginner with no barriers to entry. It is provided and supported by most brokerage firms and contains a wizard, which helps to create codes even for those who don't know how to program. It also has very active online communities. In fact, thanks to the wide diffusion of the platform, numerous forums dedicated to MetaTrader developers have been created. The most significant drawback of MetaTrader is the MetaQuotes Language 4 (MQL4) programming language which is very similar to C ++, but compared to other languages it is more complex, and this could be an obstacle for those with no programming experience. Also, the data cannot be exported to Excel for further processing and the underwater equity line is also missing. The time represented on the graph is that of the broker's server and therefore it is not possible to view the time charts of the reference stock exchange or to use the local time zone. A further limitation is that there is no possibility to test a portfolio, but only individual strategies and this undermines the idea of diversifying systematic operations on different asset classes and underlying, with different logics and different timelines.

TradeStation has its own brokerage firm called TradeStation Brokerage which offers proprietary data and brokerage services. It is therefore an "All In One" solution, with the internalisation and supply of data services, platform and brokerage activities. It represents a versatile solution also for those who want to switch to a slightly more open platform towards other solutions such as intermediation services and data supply. Furthermore, the programming language (Easy Language) is quite simple and allows, subsequently, also migration to MultiCharts. The TradeStation language is in fact 99% identical to that of MultiCharts, a platform that allows the direct import of scripts created with TradeStation. The platform also integrates a dedicated tool for portfolio backtesting (Maestro Portfolio). An additional selling point is that it is a free platform that does not require the purchase of licenses if a deposit is made on TradeStation Brokerage. The online community is also excellent. In fact, sharing the same language also in MultiCharts, over the years mutual help forums have been created with the relative exchange of scripts. Among the drawbacks of the platform is its main strength. In fact, TradeStation's clients are bound to "All In One" also as an intermediary. The platform, therefore, cannot be used to place orders on other brokers, unless it is used only as a data feed. It is also not developed in 64-bit, but 32-bit. This means that even with a high-performance infrastructure, the platform won't be able to take full advantage of the resources.

MultiCharts is a professional technical analysis platform for automated trading, which allows traders to build solid trading strategies. It is the most efficient and versatile platform for algo-traders. Among the strengths of the platform is the easy-to-use coding language, called "Power Language", which is very similar to TradeStation's "Easy Language". MultiCharts can import data from various data sources and providers into Quote Manager. Furthermore, users have the freedom to choose the brokers on which MultiCharts automatically runs trading systems. When designing and developing trading systems, it relies on advanced input optimisation features, such as exhaustive search optimisation (ES) and genetic algorithm optimisation (GA), furthermore, it is possible to implement these processes with the Walk Forward Analysis validation tool. Additional benefits include the ability to backtest the portfolio. The Strategy Performance Report is complete with statistical elements, which allow investors to deepen the analysis of the trend of trading systems. Finally, the platform is built in 64-bit and consequently is able to use hardware solutions that are also very performing. However, although the statistical elements of the backtesting strategy report are numerous, some useful data is missing, such as trade efficiency (which needs to be recalculated in Excel, while it was present in TradeStation 2000). A further disadvantage is the high monetary cost of purchasing licenses. In addition, automatic trading is a bit of a challenge as it has to be enabled on a chart-by-chart basis and is complex to keep track of (Malverti, E. (2016) I segreti dei trading system).

1.4 Brokers

When it comes to selecting your broker, there is a variety to choose from, but in research, it is needed to make sure that they are suitable for the investor's personality, trading and investment needs, and budgets. Each broker has different levels of customer service, available markets, and service fees. Other questions are: does this broker also provide data feeds? What historical data does it provide? What are the timeframes? Data has been back-adjusted, does it have any gaps? These evaluations are very important, they vary according to the trader's needs and are added to those on the broker's technological validity.

Interactive Brokers is one of the largest brokers in the world, among its clients there are both hedges and other funds and therefore its primacy is based on safety and reliability. However, it is a broker for very experienced traders. Traders in order to pass the eligibility process may also be required to show statements showing that 100 trades have already been completed and also proof of available liquidity above 50,000 to obtain access to the margin account (McDowell, B. (2008) The ART of trading combining the science of technical analysis with the Art of Reality-based Trading; Hoboken, N.J. , John Wiley & Sons). Through Interactive Brokers, the investor can trade Forex Spots and CFDs, stock and options markets, stock indices, and futures worldwide, without limitation, including the Asian market and other niche markets. IBKR Lite offers retail clients to trade commission-free on US listed stocks and ETF operations. IBKR Pro is the Interactive Broker plan for sophisticated investors and active traders and fees apply (www.interactivebrokers.com).

TradeStation is a broker that caters to both the trading beginner and the experienced trader, through a full suite of powerful trading technologies, online brokerage services and trading training. Through this broker it is possible to trade stocks, ETFs, futures, options or cryptocurrencies. TradeStation also recently developed the FuturesPlus plan powered by Trading Technologies, a platform for futures options traders with free-market data e no platform fees. TradeStation clients can trade major international exchanges and liquidity platforms, including CME and ICE, on the web or on a mobile device (www.tradestation.com).

Saxo BG was born from the partnership between Banca Generali and Saxo Bank. It is highly regulated in several countries around the world, including the Danish Financial Supervisory Authority (FSA) and Consob, and has a very high standard of quality, reliability, and safety All these characteristics are combined with Banca Generali's new trading account, leader in financial planning and at the top of the banking system for solidity and safety. Boasting trading volumes of over 17 million transactions per year, it offers institutional and private investors a good number of products to trade

on. Saxo BG also offers innovative pricing, detailed market analysis, and professional support (www.home.saxo).

1.5 Virtual Private Server (VPS)

One of the tools to operate in systematic trading is the Virtual Private Server. It is a remote virtual computer on which it is possible to install applications, such as MultiCharts or TradeStation platform, and then execute automatic strategies with greater security than home PC. The added security comes from the fact that the data centers where these remote servers are kept have uninterruptible power supplies that compensate for any connection drops, latency, or power outages. Therefore, they offer greater stability than a hypothetical home connection. Proceeding step by step, the first choice to make is that of the provider. There are several, but the main ones for this type of service are Aruba, Microsoft Azure, Amazon AWS and OVHcloud, Vultr. The next step is to configure the VPS model according to the needs and requirements necessary to operate on the market. Finally, it is necessary to download of the chosen platform and install it. Regarding the configuration of the virtual server the features on which it is recommended to opt are:

- for small-sized portfolios (from 5 to 15 strategies approximately) in a short time a CPU from 2 to 4 cores, at least 6 gb of Ram, 50/60 Gb Hard Risk;
- for medium-sized portfolios (from 15 to 50 strategies approximately) in a short time a CPU from 4 to 8 cores, 19 gb of Ram;
- for large-sized portfolios with over 50 strategies in a short time a CPU with 18 cores, 32+ gb of Ram
- for dedicated hosting a CPU with 4+ cores and 32-64 gb of Ram.

Hence, the main features are the CPU and RAM. The greater are the demands, the more physical CPUs will be needed. The CPU capabilities are divided into virtual n-processors. The same goes for RAM, which allows websites to be kept stable, especially when the traffic volume is high. Finally, to return to the security aspect, each Virtual Server is hosted by a hypervisor, or virtual machine monitor, which makes the hardware resources of a physical server virtual, dividing them among all the connected users. As a result, everyone accesses and operates on the same machine, enjoying a 100% protected and secure environment as happens when using a dedicated server which would have much higher costs. What affects the cost of the server: resources subscribed, guarantees on resources subscribed, location of the data center, and cost of the license (e.g. Windows license). A virtual server also allows the choice of software, Windows or Linux as needed. The user often has full root access and, in some cases, has full control over the virtual machine, for example with dedicated hosting. The

VPS is in fact seen as a cross between a dedicated hosting and a shared server. VPS is a virtual instance that is rented and hosted by a server and, an operating environment (such as Windows) is virtualized within this instance. When traders connect to the specified address, they only have access to the instance made available, not the entire server. The server hosting the instance can host and virtualize other similar instances. The entire server is rented on dedicated hosting. So, there is a substantial difference that in the case of the VPS investors rent an instance / virtual machine, while dedicated hosting investors rent the entire server. In short, VPS works on a shared virtual server, where traders host their website along with others; dedicated hosting, meanwhile, gives them their own server to work on. With dedicated hosting, the operating environment works natively and not via virtualization. VPS and dedicated hosting differ in several ways.

As for resource allocation with VPS, you share all resources with the ability to use them from other websites on the server. With dedicated hosting you get all the resources you want, they are flexible from month to month according to customer needs, without having to rely on someone else even if of course the cost will be higher than the VPS.

Thinking about security if using VPS it is possible to install security software, but traders are still quite vulnerable if other sites on the server have a security breach. Dedicated hosting is like owning your own property. Traders are responsible for their security and can install software to protect their sites without relying on others. So, the system can still be hacked, but you can't be put at risk by the neglect of others. Both types of hosting allow you to install your own security software, but with dedicated hosting, you are in full control of any security breaches.

Good performance depends on how fast the website loads and how well it performs for users. VPS offers fast loading speeds unless multiple sites on the server are experiencing traffic spikes at the same time, but dedicated hosting ensures superfast loading speeds based on available website resources. Technical configuration can be done for both VPS and Dedicated Hosting with a managed plan, resources are flexible based on site and server performance, and operators can customize the site with additional software. Scalability is the extent to which your hosting plan can grow with your website. VPS is a great type of hosting that can grow with the site, given its flexibility and generous resources but whit Dedicated Hosting ensures all the resources, security, and performance you could ask for, so there's not really any room to scale.

As you can imagine, dedicated hosting is more expensive than VPS hosting. VPS offers a lower price in relation to the lower guaranteed power, while Dedicated hosting is more powerful and therefore more expensive (www.websitebuilderexpert.com).

Chapter 2

Methodology to build Trading System Strategies

This chapter aims to provide all the steps and tools needed to build a trading system. It begins with the so called "trading system essential", which includes the structure of scripts and strategies, the main classification of strategies, an introduction to patterns, how to perform a meaningful backtest and the test generators in order to determine the different time windows and periods to be used as In Sample (IS) and Out Of Sample (OOS). The chapter continues with a detailed explanation of the strategy performance report with the strategy, trade and periodical analysis. After that it is introduced the optimisation process, from the standard optimisation through Exhaustive Search (ES) and Genetic Algorithms (GA) methodologies to the periodical re-optimisation using the Walk Forward Optimisation (WFO). This subsection ends with focus on overfitting which mostly arises from optimisation processes. The last subsection regards the trading system evaluation with focus on psychological and technical metrics from the performance report and robustness analysis through the Walk Forward Analysis (WFA). Finally, there is a detailed example to put at work all the concept and methodologies presented.

2.1 Trading System Essential

2.1.1 Structure of Trading System script

In short, a script is a program or sequence of instructions that is interpreted or executed by another program rather than by the computer's processor. Speaking of technical analysis, the script is the sequence of instructions given to the platform to make the trading system work by specifying the market entry or exit points used to send orders to a broker. Therefore, it can be seen as the basic building block of strategies. In Multicharts, trading strategies are called signals and the main features of the script are the inputs, variables, definitions, and conditions.

The inputs are elements used in the calculation of the signal that can be modified in the external strategy mask by users, so that their values do not change during the execution of the script. The main advantage is that the user can optimize the input based on specific parameters, such as the period of the Moving Average, to find the optimal value and maximize the net profit, minimize the drawdown, or other characteristics of the performance report. It is mandatory their declaration (a name is assigned to each input) and the assignment of the initial value that determines the type of input: numeric, boolean (true/false), or string.

The variables are elements which can vary during the script execution as they depend on the computation process, they are involved in. Again, it is mandatory to declare one or more names as variables and specify the initial value to determine the type of the variable (numeric, true/false, string).

The definitions are the processes in which it is possible to assign values to the variable using the function. The main advantage of assigning the value of the variable through the function is that it is later possible to recall the variable without using the function again, avoiding unnecessary use of CPU and RAM.

Finally, the conditions are the processes in which is possible to change the value of the variables. This is the section of the code where we set up the entries, exits, and filters that determine the true functioning of the system.

2.1.2 Strategy composition

A trading strategy is a systematic methodology used for buying and selling in securities markets based on predefined rules and criteria to make trading decisions. The main triggers for signals are entries, filters and exits.

Entries allow the computer to open long and short positions based on the determinate pattern's individuation. Here we set the different types of orders to execute (market, stop or limit), the size of the position (number of contracts or cash per trade), and the condition that must be satisfied to send the order to the market. Focusing on the type of order, it is important to make a distinction between stop, limit, and market order. The stop order is the typical breakout entry, where the entry price is set to a higher (buy stop order) or lower (sell stop order) price than the current market. A Stop order will buy or sell a security when its price exceeds a certain level defined by the trader, thus ensuring a greater probability of reaching a predetermined entry or exit price. The limit order is used for retracement entries, where traders expect the market to reach a more favourable entry price. So, in this case, the limit order is set lower than the market price for long orders and above the current market price for a short position. The market orders are used for bias strategies that follow a cyclical movement. These orders simply enter at the current market price.

Filters are useful for reducing the likelihood of the strategy entering a false signal. The false signal can be interpreted as a market condition where the required setup is met, but the position generates negative return. Filters can be set following different methodologies based on temporal bias, volatility, pattern recognition, or other custom values set by the trader. Filters are applied using logic operator "if", "and", "or". The command "and" requires that both condition A and B are verified, indeed the logic operator "or" requires that only one of the two condition is occurred.

The exits are the setting that the algorithm follows to close the current open positions by placing orders of opposite sign. There are different types of exits: Stoploss, Take Profit, Reverse, or Time stop. Stoploss and Take Profit are limit orders and can be set in predetermined percentages or

monetary distances. Reverse (opposite in position, direction) implies closing a position only in the presence of an opposite signal. The Time stop is a programmed exit after a given period or at a certain time.

Following there is an example of how to write a code using the metrics cited above through the power languages editor.

```
//declaration of inputs and varables
inputs:FastLength(50), SlowLength(200);
inputs:SL(1000),TP(0);
variables: FastMA(0), SlowMA(0), LongEntry(false), ShortEntry(false);

//definitions
FastMA = AverageFC(Close, FastLength);
SlowMA = AverageFC(Close, SlowLength);
LongEntry = FastMA crosses over SlowMA;
ShortEntry = FastMA crosses under SlowMA;

//conditions
//entry
if LongEntry then Buy ("LE") next bar at market;
if ShortEntry then sellshort ("SE") next bar at market;

//exit
setstopcontract;
if SL>0 then setstoploss(SL);
if TP>0 then setprofittarget(TP);
```

This code represents a basic 2 moving average (MA) crossover strategy. The inputs value of 50 days for the fast MA and 200 days for the slow MA are based on the Golden Cross and Death Cross definition from Nasdaq website (https://www.nasdaq.com). The Golden Cross is a bullish signal generated when the 50-day (short-term) moving average crosses above the 200-day(long-term) moving average, so it is used as trigger for long entry. The Death Cross is a bearish signal generated when the 50-day (short-term) moving average crosses below the 200-day (long-term) moving average and it implies the short orders of the trading system cited above. In this system the exits are based both on monetary input, such as stoploss and take profit, and implicitly by reversing the long into short position and vice versa.

2.1.3 Type of strategy

During several trading tests, three main types of trading strategies were discovered: trend following, countertrend, and swing trading strategy.

More specifically, as the name suggests, the trend following strategy seeks to enter the market in the bullish trend and signal investors to exit when the trend reverses (Min Dai, Zhou Yang, Qing Zhang, Qiji Jim Zhu (2016) Optimal Trend Following Trading Rules. Mathematics of Operations

Research). So, trend following strategy enters in the same direction as the underlining market trend and tries to follow it as much as possible. The direction of the market is shown by the break of the previously tested level. In the following figure, it is possible to see market wave with relative maximum and minimum. The break of these levels corresponds to the entry level. These signals are used to place stop orders.

In this example let's introduce a trend following strategy from Strategy Trading and Development Club (in short "STAD") of Omega Research. Omega Research System Trading and Development Club was learning tool offered by Omega Research to help traders to improve their strategies and find new ideas through the reading of Omega's trading systems periodical journals called STAD. The strategies were thought for TradeStation and EasyLanguages environment, in this dissertation they are translated into PowerLanguages code to avoid problems if replicated on Multicharts. One particular and non-traditional example of this methodology is the Stad05 Channel Breakout system provided by Omega Research.

One of the best known and most profitable trading systems is the price channel breakout. They use a 10-bar price channel as starting point. The top line of the channel is simply the high of the last 10 bars; the bottom line of the channel is the low of the last 10 bars. Buy on a close above the top line and sell short on a close below the bottom line is the traditional strategy. They try to overcome the main the price channel breakout system disadvantage. Not all closes above the 10-bar high or below the 10-bar low follow through in the direction of the breakout. They develop a Channel Breakout with Pullback System to attempt to mitigate this disadvantage by waiting for a pullback (a countertrend reaction) after a breakout to gain a more favourable entry price. For example, in the case of a bullish breakout, the system would wait to enter on an ensuing decline rather than buying automatically after a close above the previous 10-bar high. The downside to waiting for a pullback is that a market may not pull back after a breakout.

```
Input: Channel(10), RetrBars(10), NewLo_Hi(4), TrailStp(8);
Vars: HiChannel(0), LoChannel(0);

{Assignment of Channel calculations}
HiChannel = Highest(Close, Channel)[1];
LoChannel = Lowest(Close, Channel)[1];

{Long Entry LE}
If MRO(Close > HiChannel, RetrBars, 1)>-1 AND Low < Lowest(Low, NewLo_Hi)[1]
then
     Buy ("LE") next bar at Market;
{Short Entry SX}
If MRO(Close < LoChannel, RetrBars, 1)>-1 AND High > Highest(High, NewLo_Hi)[1]
then
     sellshort ("SE") next bar at Market;

{Long exit=LX, Short exit=SX}
If High>Highest(High,TrailStp)[1] then Sell ("LX") this bar on close;
If Low<Lowest(Low,TrailStp)[1] then Buytocover ("SX") this bar on close;

{StopLoss and TakeProfit adjustment}
inputs: SL(0),TP(0),BE(0);
setstopcontract;
if SL>0 then setstoploss(SL);
if TP>0 then setprofittarget(TP);
if BE>0 then setbreakeven(BE);
```

The main input that can be optimised subsequently are the Channel, RetrBars, NewLo_Hi, and TrailStp. The Channel is the length value, expressed in bars, used in the Highest and Lowest functions which form the basis of the channels. The RetrBars are the Retracement bars is a length value, expressed in bars, used to define the maximum number of bars after the retracement at which a signal can occur. The NewLo_Hi is a length value, expressed in bars, for the new Highest/Lowest value following a valid retracement and the TrailStp is a length value, expressed in bars, for the trailing stop. One important note is the MRO function which is used to perform the evaluation for a close that has exceeded the upper boundary or has broken below the lower boundary within the specified retracement period. For long orders, in order to identify a new low, the current low is compared to the most recent lowest low for the previous NewLo_Hi bars. For short positions to identify a new high, the current high is compared to the most recent highest high for the previous NewLo_Hi bars. The paper refers also to certain starting value of stoploss and breakeven, which are not included in the original code but are implemented in the modified one above.

The countertrend strategy implies orders in the opposite direction of the trend only when a pullback is expected. These strategies are used in markets characterized by mean reverting bias. The strategies turn out to be against the trend because the investor is risk averse and it is assumed that the stock market follows a Brownian geometric motion (phenomenon linked to the world of physics which in finance is based on the work of Robert C. Merton and Paul A. Samuelson , as extensions to the one-period market models of Markowitz and William F. Sharpe) with constant drift and volatility (Min Dai, Zhou Yang, Qing Zhang, Qiji Jim Zhu (2016) Optimal Trend Following Trading Rules. Mathematics of Operations Research). So, the market prices use to come back to a determined mean level. In this approach, the entry level is the test of the relative maximum and minimum and the orders are executed in the direction of the mean value. Signals of these strategies are used to execute limit orders.

This example of countertrend strategy is inspired by Stad03 Support & Resistance System provided by Omega Research. If any assumption can be made about sideways markets, it is that over periods of time where support and resistance levels are constant, the distribution of the prices traded will tend to be normal (i.e., distributed normally in the shape of a bell curve). In other words, if we counted the instrument traded at each price, we would end up with a graph similar to the one shown in Figure.

In the above graph, the x-axis is the price, the y-axis is the frequency, and the vertical lines at the right and left are the support and resistance levels. While these support and resistance levels are not broken, prices will sometimes touch these levels and then return to the 'normal' prices. This distribution curve can be mathematically described by two numbers, the average price traded (which will be at the center of the distribution) and the standard deviation lines (which represent the support

and resistance levels). The standard deviation will indicate how much prices have varied from the average. The bigger the standard distribution number, the flatter the distribution curve, and the smaller the standard distribution, the taller the curve. Approximately 96% of the prices will fall between the two standard deviations plus or minus the average price. If there are true support and resistance lines, we can attempt to find them by calculating Bollinger Bands, which are two standard deviations above and below the average price of the instrument analysed.

```
inputs: Length(20), NumDevs(2);
inputs: SL(0.016), TP(0.04);
inputs: starttime(2000), endtime(1100);

vars: UpperBand(0),LowerBand(0);
vars: timewindow(false);

UpperBand = BollingerBand(close, Length, +NumDevs);
LowerBand = BollingerBand(close, Length, -NumDevs);
timewindow= tw(starttime,endtime);

//entry
if timewindow then begin
if close crosses under UpperBand then sellshort ("SE") next bar at market;
if close crosses over LowerBand  then buy ("LE") next bar at market;
end;

//exit
setstopcontract;
if SL> 0 then setstoploss(SL);
If TP > 0 then setprofittarget(TP);
```

The system is based on the assumption that if the price reach levels outside of the Bollinger bands this should implies a mean reverting of the price to the average value. In addition to this assumption is added the condition that the close of the bar should be inside the range of the bands in order to confirm the possible reversal. Moreover, in order to filter false signals is added a time window in which the entry orders can be executed. Finally, in addition to the implicit exit condition of reversal of the positions, inputs for monetary stoploss and take profit are included. The default setting refers to the application of the strategy on EURUSD with timeframe 60 minutes per bar and session and time zone adopted relates to New York (UTC-4).

Swing trading approaches are all the types of strategies that are not trend following or countertrend. In the operational method, entry level is based on the research for sudden, extreme, or recurring market movements, or, as Larry Williams (trader, who achieved a performance of over 11,000% in 1987 during the Trading World Championship) suggests, the market reaction to specific candlestick configurations named patterns. In this type of trading approach, it is possible to find the bias strategy. Trading bias is a predisposition or perspective of the financial markets whereby traders believe there is a higher probability of a certain outcome as opposed to any other alternate possibilities. They are determined by technical and/or fundamental factors that support a specific outlook that explains market behaviour.

For this example of bias strategy let's use the strategy DAX first hours presented by Andrea Unger into one of its webinar. Andrea Unger, the only 4 times world trading champion, in one of his webinars presented the First Hour Breakout strategy on the Dax Future. He managed to identify a particular bias of the Dax according to which it is possible to build a breakout strategy that takes into account only the first hour of the session. The system enters at the second hour with stops orders (long and short) at a level equal to the maximum/minimum, marked in the first hour, adjusted by portion of range between the maximum and minimum of the day already formed. This portion is added to maximum of the day in the long setup, and subtracted from the minimum of the day in the short setup. The exit setup is based on the market retracement. The long positions are closed if the price come back to the maximum of the day and the short ones if the price retraces to the minimum of the day already formed, morover, if these exit stop orders are not met the open positions are closed at the end of the day. In addition to the main idea temporal and volatility filters are added. In the temporal filter he removes the Friday due to the presence of most of US economic news and set the close time of the trades 5 minutes before the end of the session in order to avoid problem with the filling of the orders. The second filter is called daily factor which is a indecision patter based on the volatility of the previous day. Larger is the body of bar compared to the range, higher is the significance of the movement of the day, a lower body implies more indecision in the market. The assumption is that if the day before had strong directional movement in general the following day the market will be more stable with lower volatility and movement, so the filter avoid trading after these days since the strategy want to catch only possible large movement. It strates to enter only if the body of the day before is lower than 75% of the range of yesterday. In addition is added also a monetary stoploss of 1000 in order to avoid large and unexpected drawdown.

```
input: RangeMultiplier(0.95);
input: BegTime(0900), EndTime(0955), CloseTime(2155), SkipDay(Friday);
input; MyContracts(1), StopLoss(1000);

variables: minSetup(0), maxSetup(0);
variables: slLong(0), slShort(0), daily_factor(false);

If Date <> Date[1] then begin
    maxSetup = 0;
    minSetup = 0;

    daily_factor = absvalue(opend(1)-closed(1))<0.75*(highd(1)-lowd(1));
end;

If daily_factor and Time >= BegTime and Time <= EndTime and Dayofweek(date) <>
SkipDay and EntriesToday(date) = 0 then begin
    If maxSetup = 0 then begin
        maxSetup = HighD(0) + RangeMultiplier * (HighD(0) - LowD(0));
        slLong = HighD(0);
    end;

    If minSetup = 0 then begin
        // do once @ BegTime
        minSetup = LowD(0) - RangeMultiplier * (HighD(0) - LowD(0));
        slShort = LowD(0);
    end;

{entries}
    Buy("LEx") MyContracts contracts Next Bar at maxSetup stop;
    SellShort("SEx") MyContracts contracts Next Bar at minSetup stop;
end;

{exit}
Sell("LXx") from entry("LEx") Next Bar at slLong stop;
BuyToCover("SXx") from entry("SEx") Next Bar at slShort stop;

If Time >= CloseTime then begin
    Sell("TimeLXx") from entry("LEx") Next Bar market;
    BuyToCover("TimeSXx") from entry("SEx") Next Bar at market;
end;

Setstopcontract;
SetStopLoss(StopLoss);
SetExitOnClose;
```

2.1.4 Pattern

After several tests and research, many traders end up with the individuation of several pattern configurations, based on the candlestick chart, which is essential for filtering or building strategies on their combination. The main patterns provide a practical indication of the uncertainty, volatility, or directionality of the market. An important note is that the following patterns are useful only if applied in short term strategies, so with a time horizon, for each operation, from intraday to a maximum of 5 days. Indeed, if the position stays in the market for several months, choosing patterns based on just a few candlesticks will not be profitable, since graphical configurations cannot affect these market conditions in the long term.

Some of these configurations can be considered mirror patterns. It means that if exists an up directional pattern with a specific configuration, in a certain case, it is possible to find its specular composition indicating a down directional signal. In general, if the up directional pattern is profitable with long positions, the down directional pattern should also be profitable or at least breakeven with short orders. If the down directional pattern generates large losses with short trades, this could also compromise the validity and stability of the up directional trade in that specific instrument or market. More in detail, the profitability of specular trade is influenced by the reference markets, and below it is explained how the symmetry works in the different markets. In the stock markets, the upside is generally slow and composed, while the downside is frenetic (the phenomenon of "panic selling"). In these cases, it is expected that the response to the patterns, so the graphic configurations that ultimately show the excursion of the candles and their combination, are different. For this reason, asymmetries between long and short of various kinds are accepted on the stock markets. On commodities, asymmetries are a little less acceptable. Considering that in this market the excursions are large, it is preferable to find similar behaviours with respect to symmetrical patterns. In the forex and futures markets, symmetry is essential. If a pattern earns well on long trades, the speculating pattern is expected to earn symmetrically short. Otherwise, it would be thought that it is pure overfitting and that therefore these patterns are not able to effectively analyze the behaviour of that market. The next page presents a list of 42 possible patterns including the information these configurations provide, the specular setup. A special note about patterns 41 and 42. These patterns are used as default patterns to start the optimisation.

Pattern	Type	Opposite	Description
1	volatility (indecision)		yesterday body < 50% of range
2	volatility (indecision)		open yesterday - close 5 days ago < 50% of (high 5 days ago - close yesterday)
3	volatility (indecision)		open of 5 days ago - close of yesterday < 50% of the range of last 5 days
4	directional - up	6	high to open today so far > high to open of yesterday
5	directional - up	7	high to open today so far > 1.5 * (high to open of yesterday)
6	directional - down	4	open to low today so far > open to low of yesterday
7	directional - down	5	open to low today so far > 1.5 * (open to low of yesterday)
8	directional - up	9	3 consecutive up closes
9	directional - down	8	3 consecutive down closes
10	directional - up	11	2 higher highs and higher lows
11	directional - down	10	2 lower highs and lower lows
12	expansion	13	range of today > 0.75% of low of today
13	compression	12	range of today < 0.75% of low of today
14	directional - up	15	price advanced yesterday
15	directional - down	14	price declined yesterday
16	directional - down	17	yesterday closed below the open
17	directional - up	16	yesterday closed above the open
18	directional - down	19	price declined > 0.5% yesterday
19	directional - up	18	price advanced > 0.5% yesterday
20	directional - up	22	today has traded above yesterday's high
21	trend - up	23	yesterday high was above 5-day-ago high
22	weakness today	20	today has traded below yesterday's low
23	trend - down	21	yesterday low was below 5-day-ago low
24	trend - up	26	yesterday high was the highest in 4 days
25	not trend up	27	yesterday high was lowest in 4 days
26	trend - down	24	yesterday low was lowest in 4 days
27	not trend down	25	yesterday low was the highest in 4 days
28	trend - up	29	yesterday close was highest in 3 days and today open is higher
29	trend - down	28	yesterday close was lowest in 3 days and today open is lower
30	strength yesterday	31	yesterday close was in the top 20% of yesterday's range
31	weakness yesterday	30	yesterday close was in the bottom 20% of yesterday's range
32	movement		today open gapped either above yest. high or below yest. low
33	big gap down	34	Today's open is at least 0.5% below yesterday's close
34	big gap up	33	Today's open is at least 0.5% above yesterday's close
35	indecision		today is an inside day so far
36	volatility contraction		yesterday range < 2/3 (66%) of prior 2-day Average. range
37	volatility contraction		yesterday was the second consecutive range contraction day
38	volatility contraction		yesterday was an inside day
39	volatility contraction	40	yesterday was not an outside day
40	volatility expansion	39	yesterday was an outside day
41		42	Always true
42		41	Always false

The patterns should be applied as filter in order to improve the reliability of the signal and improving performances. Following there is an example of the pattern application of the Bollinger Band Strategy on EURUSD.

```
inputs: Length(20), NumDevs(2);
Input: PatLY(41), PatSY(41), PatLN(42), PatSN(42);
inputs: starttime(900), endtime(1700);
inputs: SL(0.01), TP(0.04);

vars: UpperBand(0),LowerBand(0);
vars: timewindow(false), LE(false),SE(false);


UpperBand = BollingerBand(close, Length, +NumDevs);
LowerBand = BollingerBand(close, Length, -NumDevs);
timewindow=tw(starttime,endtime);
LE=close crosses over LowerBand;
SE=close crosses under UpperBand;

//entry
if timewindow then begin
if PatternFilter(PatSY) and PatternFilter(PatSN)=False and SE then sellshort
("SE") next bar at market;
if PatternFilter(PatLY) and PatternFilter(PatLN)=False and LE  then buy ("LE")
next bar at market;
end;

//exit
setstopcontract;
if SL> 0 then setstoploss(SL);
If TP > 0 then setprofittarget(TP);
```

The code is similar to the one presented in the example of reversal strategy, but with the addition of the pattern filter. Patterns are applied through the PatternFilter function. The function includes 42 patterns that effectively describe the different scenarios of uncertainty, volatility, and directionality of the market. These patterns are used in impulsive swing-type strategies, or in any case short-term strategies. There are two different types of inputs related to patterns, the graphical configuration that should be present in addition to the standard signal to execute the orders, and the patterns to avoid and so even if the base trigger is present the trades are not executed if these configurations occur. For the long trades they are called PatLY and PatLN, and the specular for short trades are PatSY and PatSN. The default setting for the patterns "yes" is the pattern 41 since it is always true and so it is always verified and for patterns "no" the default setting is pattern 42 which is always false, and this implies that patterns are never verified.

2.1.5 Backtest

The backtest is the procedure for testing a trading hypothesis on historical data that allows you to analyse the results giving you a general idea of how your strategy may perform. To consider the backtest trustworthy and as close as possible to reality, it is necessary to consider different matrices such as the operating cost, the length of the sample period with degrees of freedom, the multimarket test, the number of trades, and the structure of the bars.

Starting from the costs setting, it is possible to identify the bid/ask spread, commission, interests, and slippage. The bid/ask spread is the amount by which the ask price exceeds the bid price for an asset in the market. The bid-ask spread is essentially the difference between the highest price that a buyer is willing to pay for an asset and the lowest price that a seller is willing to accept. It is considered an implicit cost and can vary based on market volatility and liquidity. Lower is liquidity and higher is the volatility, higher will be the cost incurred. The commission is the cost to execute the long or short trade. It is applied and taken by the broker on every executed order, and its value can be set as a percentage of the transaction value (with cap and floor) or contractually fixed (usually on futures and forex markets). Interest is a charge paid by a borrower on a debt obligation over the life of the loan. In this case, it applies to the short selling trade and the leverage. The total cost depends on the broker's policy, but in general, the longer the position, the higher the interest paid on it. Slippage is the difference between the theoretical price for buying or selling an instrument and the real price at which the order is executed. In the more liquid market, the average slippage is around 2 ticks (1 for entry and 1 for exit) for less liquid ones it starts from 4 ticks. A tick is a measure of the minimum upward or downward movement in the price of a security.

$$Tick = Big\ Point\ Value * \frac{Min\ Movement}{Price\ Scale}$$

For example, consider the E-mini S&P500 (CME GLOBEX) where the BPV is $ 50, the minimum movement is 25, and the price scale is 1/100. Substituting the value in the formula, the tick value will be $ 12.5, so the slippage to be set in the trading system will be $ 25.

The length of the back-testing period should be decided considering the event affecting the underlying instrument. For example, if the financial instrument is a share, you need to consider whether there has been an M&A operation, LBO, or another company event that has permanently changed the value of the firm. More in general, the price series must be long enough to entail different market situations and to produce a significant number of trades. "Every system works when volatility is huge, but only a robust and consistent system will always work in normal conditions" (Jaekle, U. & Tomasini, E. (2019) Trading Systems 2nd Edition. Harriman House). It is mandatory to focus on the degree of

freedom, in particular, the number of variables/conditions, and data to be used must not exceed a fraction of 10% of the whole sample considered

$$Degrees\ of\ freedom\ left = 1 - \frac{degrees\ of\ freedom\ used}{sample\ data} \geq 90\%$$

For example, suppose that there is a system based on moving averages. It uses 3 years of backtesting, and considers high, low, open, and closing price. It is possible to determine the sample period by multiplying 260 days per years times 3 years times 4(data per day). We obtain 3120 data points. If the system is based on the MA at 50 period on close and the MA at 200 period on close, we consider only the latter +1 as the rule, so we have 201 degrees of freedom used. If the indicators considered are different, such as RSI and MA, they must be sum. Finally, the results will be $1 - 201/3120 = 93.55\%$, so in this case, the length of the period is acceptable since it is greater than 90%.

When testing a system, the trader should not limit the test to just one market, the more markets positively outperform the strategy, the better. It's almost impossible to find a system that generates positive results in all markets, but at least to check if a strategy is prone to overfitting, it is useful to test it in markets with a high correlation between them. In these markets, the system should demonstrate consistency in the return to pass the statistical validation. Examples of markets with high correlation are the S&P500 and the Nasdaq 100, the Dax and Euro Stoxx 50, or different instruments related to the energy sector. The backtest is significant if it produces a number of trades that allow you to keep the risk of making a mistake at the lowest level. To pass the test, the strategy should generate at least 100 trades in the testing period, but higher is the number of trades, higher will be the probability that system results will be repeated in the future. A system that generates 1000 trades requires less deep analysis to check the validity of backtesting compared to a system that generates 100 trades in the same testing period. When performing the backtest, Multicharts only considers the data of the bars such as open, close, high, and low but not the timing in which they occur. This is relevant when the range of the same bar touches both our level of price for stoploss and take profit. If Multicharts, as defaults, does not have information regarding the timing in which the price occurred, it gives priority to the take profit, but this implies a reduction in the trustworthiness of the system. Higher is the timeframe used, higher is the likelihood of getting into this problem. The solution is to use the "bar magnifier" tool, which allows reconstructing each bar with minutes bars. For example, a 30-minute bar will be decomposed in 30 bars of 1 minute and recomposed. In this way, it is also possible to integrate the timing into the analysis and avoid misleading results.

2.1.6 IS-OOS-Forward Validation and Test Generators

This section provides an explanation of the different time windows that must be used to evaluate the performance of a strategy: In Sample (IS), Out-Of-Sample (OOS), and Forward Validation. Below is the analysis of the Test Generators, which consist of the different use and combination of IS, OOS, and Forward Validation.

In-Sample is the time window in which the data are known during model creating and used to build that model and perform the optimisation.

The Out-of-Sample period uses data that was not seen and only the forecast is produced.

Forward Validation, also called Out-OOS, is the process by which the strategy is applied to live trading after passing the test in the IS and OOS simulation. The validation and testing of the strategy begin with the IS, after that the application of the OOS is not mandatory, so it can be done or not, and ends with the Forward Validation. Note that the OOS and Forward Validation should be analysed taking into consideration also the market condition and evolution. Another consideration is that the better the results in IS, usually the worse the results in OOS and Forward Validation due to the possibility of overfitting.

The test generator is a process of evaluating the developed strategy, in order to verify its performance and behaviour. The main difference between the following test generators is the different split and use of the time windows. This section looks at three test generators to accomplish this process. The most used are the optimized testing, the out-of-sample testing, and the Walk-forward testing.

Optimized testing involves performing optimisation on all data until today, thus using the IS time window. There is the evaluation of the strategy in the IS period, and then it is applied directly to the forward validation without passing for the OOS period.

	2013	2012	2015	2016	2017	2018	2019	2020	2021	Yesterday 2022	Today 2022	2023
Step 1												

In this figure, the IS period is 10 years from 2013 to 2022 and the Forward validation is approximately 1 year. The main drawdown of this application is that it is not known whether the parameters optimized in the test period will work well in the future as well. This assumption is too naïve and, in

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general, this method is the least significant of the others even though it is the most used by retail traders.

The second method is the Out-of-Sample Testing 80/20. This test generator with respect to the first adds the OOS windows by cutting part of the IS period. In general, the standard rule is 80/20, which means that the IS period should be 80% and OOS should be 20%.

	2013	2014	2015	2016	2017	2018	2019	2020	2021	Yesterday 2022	Today 2022	2023
Step 1												

In this process the strategy is optimized over a shorter test period, leaving out the last few years from proceeding. These years of OOS are used to evaluate the strategy performance in the most recent data without having optimized the parameter on them. In this approach, the strategy gains greater confidence as an additional validation test is added.

Finally, the last process analysed is the walk-forward testing. This process follows the walk-forward optimisation (WFO), so in the not anchored case, it considers a given number of IS years over which the strategy has been optimized and the following year is considered the OOS period over which the best combinations of parameters have been applied. This iterative process continues until all available data are used, after that it return a forecast inputs combination to be applied in the Forward Validation.

	2013	2012	2015	2016	2017	2018	2019	2020	2021	Yesterday 2022	Today 2022	2023
Step 1												
Step 2												
Step 3												
Step 4												
Step 5												
Step 6												

With this process, it is possible to drastically reduce overfitting and allows the generation of a higher OOS meaningful period. This method also implies higher robustness of the strategy as it provides a greater real expectation of performance than the real market.

2.2 Strategy Performance Report

The strategy performance report returns a set of results from the backtest of a strategy during the test period. The main aim of the Strategy Performance Report is to increase the knowledge of the system's behaviour during its activity. It is not sufficient to evaluate the effectiveness and stability of a system. The main element of the Performance Report can be divided into Strategy Analysis, Trade Analysis, and Periodical Analysis.

Let's introduce a strategy that will be used as example in the sections relate to performance report, optimisation process and strategy evaluation. The system used is a High-Low breakout strategy on Gold Futures (CME) on 60 minutes timeframe. The aim of the strategy is to execute a long order if the price reaches higher level than the high of the day already formed or send short order if price falls below the minimum level of the day already occurred. The temporal filter applied, through time window function, limits the operativity of the system, with the default value the system can place orders only between the 11:00 and 15:00 exchange time. The are 3 possible exit scenarios. The first two are the reversal of the positions, the stoploss and take profit, the last one is related to the number of bars per trade. The third exit condition ensures a limitation on the duration of the trades and can be set by the traders in the input selection. The default value is 80 bars, so approximately 3 days and 8 hours. Stoploss and take profit are applied.

```
Input: StartTrade(1100), EndTrade(1500);
inputs: LX_bar(80), SX_bar(80);
Input: SL(2500), TP(2500);
var: timewindow(false);

timewindow=TW(StartTrade,EndTrade);

{entry}
If timewindow then begin
    buy next bar at Highd(0)stop;
    sellshort next bar at lowd(0)stop;
end;

{exit}
if BarsSinceEntry = LX_bar then
    Sell ( "LX" ) next bar at market;

if BarsSinceEntry = SX_bar then
    buytocover ( "SX" ) next bar at market;


Setstopcontract;
If SL > 0 then setstoploss(SL);
If TP > 0 then setprofittarget(TP);
```

2.2.1 Strategy analysis

The strategy analysis area analyses the results of the strategy in terms of P&L, ratios and graphical representations. It can be divided into subset sections. The most relevant are the strategy performance summary, performance ratios, and the subset related to the equity curve.

Into the strategy performance summary, it is possible to find metrics related to Net Profit, Drawdown (DD), Return on Account and costs incurred.

The Net Profit is the difference between the Gross Profit and Gross Loss and indicates the cumulative return of the strategy in monetary terms for the reference period. For more reliable results in live trading, it is suggested to look at the Selected Net Profit, which is the Net Profit but adjusted for outliers. These trades, both positive and negative, are removed in the calculation of the Selected Gross Profit and Selected Gross Loss, the difference of which gives rise to the Selected Net Profit.

The Max Drawdown is the largest drawdown of losses from the previous highest equity run-up during the specified period. There are two different drawdown formats: the Max Close-to-Close DD and the Max Strategy DD. The first considers only realized losses, while the second also considers unrealized losses giving a greater sense of the evolution of potential losses during the test period. The return on Account is the P&L of the strategy in percentage terms. Return on initial capital represents the percentage return of the Net Profit on initial starting capital during the test period, assuming no leverage is used and is adjusted for commission and slippage. It is calculated by dividing the Net Profit by the Initial Capital. Moreover, it is also possible to observe the Annual Rate of Return which is the yearly average of the return obtained during the specified period. The costs indicated in this area are related to commission and slippage. Definitions and settings are explained above in the backtest subchapter.

Performance ratios are useful for evaluating the return in terms of risk bearing and calculating how much profit the strategy generates for each unit of risk taken. The main elements analysed are the $\frac{Net\ Profit}{Max\ Strategy\ DD}$, Profit Factor, the Annualised Sharpe Ratio, and the Rina Index.

The $\frac{Net\ Profit}{Max\ Strategy\ DD}$, as the name suggests, is the ratio between the Net Profit generated and the maximum drawdown borne by the strategy during the test period. For more reliable results it is suggested to use the Selected Net Profit as numerator. The Profit Factor shows the amount of gain realized per unit of loss. It is calculated by dividing the Gross Profit by the Gross Loss. To calculate the Selected Profit Factor, to eliminate the outlying trades, it is necessary to divide the Selected Gross Profit by the Selected Gross Loss.

The Sharpe ratio was developed by Nobel laureate William F. Sharpe and is used to help investors understand an investment's return versus its risk. The ratio is the average return earned in excess of the risk-free rate per unit of volatility or total risk.

$$Sharpe\ Ratio = \frac{(Rp - Rf)}{\sigma p}$$

Where Rp is the portfolio return, Rf is the risk-free rate and σp is the standard deviation of the portfolio's excess return. The portfolio excess return is the risk-adjusted portfolio return, so the difference between the portfolio returns and the risk-free rate. To calculate the Annualized SR is necessary to multiply the monthly SR by the square root of twelve to get a risk adjusted annual return ratio. For practical purpose the risk free rate in this dissertation is set equal to 2%.

Rina index was created by RINA systems (www.rinasystems.com) to find a performance metric that takes into account time, drawdown and profit. Represents the reward-risk ratio per one unit of time. One of the advantages of the RINA index over other performance metrics, such as the $\frac{Selected\ Net\ Profit}{Max\ Strategy\ DD}$ metric, is that it also includes time in the market in the calculation.

$$RINA\ Index = \frac{(Selected\ Net\ Profit)}{(Average\ DD\ \times Percent\ Time\ in\ the\ Market)}$$

The Equity Line is the graphical representation of the cumulative P&L. There are different types of Equity Line, and the two main ones are the Detailed Equity Line and the Close-to-Close Equity Line. The main difference is that the Equity Line Close-to-Close refers to the P&L generated only by realized positions and does not consider the intra-trade excursion of the account. It's quite difficult to contextualize as it is sorted by number of trades and not by time. The Equity Line Detailed also considers the unrealized P&L in the chart and follows a temporary timeline. Moreover, there are different visualisation of the Equity Line Detailed, which are the Equity Line Detailed Long, the Equity Line Detailed short and the Equity Line Detailed with DD. The first is the cumulative realized and not P&L only for long positions, the second is only for short positions and the third is the classic Equity Line Detailed but with the graphical representation of the drawdowns both in monetary and percentage terms. Below is an example of Detailed Equity Line with DD taken from a trading system on the Hi-Lo breakout on gold futures.

It is possible to observe that the maximum average monetary drawdown is around 20.000. The percentage drawdown is less relevant when algorithms of position sizing are not applied such as in this case.

2.2.2 Trade analysis

In this section, there is the analysis of the single trade of the strategy. It can be divided into subsections. The most relevant are Total Trade Analysis, Outliers, Trade Series Analysis, Maximum Adverse Excursion (MAE) and the Maximum Favourable Excursion (MFE).

The Total Trade Analysis provides useful information to understand the behaviour of the strategy's operations and related metrics. The main elements are the Total # of Trades, the Average Trade, the Percent Profitable and the Average # Bars in Trades.

The Total # of Trade represents straightforward the total traded executed and is essential to determine the statistical significance of the strategy.

The average trade, which is obtained by dividing the Net Profit by the total number of trades, represents the average money earned by the strategy per trade. It should be able to cover all potential costs for contract used borne by the strategy.

Profitable percentage is the percentage of winning trades generated by the strategy. It is calculated by dividing the number of winning trades by the total number of trades.

The Average # Bars in Trade measure represents the average number of bars elapsed during trades from their open to their close.

This is a temporary measure, in particular the average time taken to complete each trade can be calculated as follows:

$$Avg\ Time\ per\ trade = Avg\ \#\ Bars\ \times Timeframe$$

Suppose that the time frame used is 15 minutes, and the Average # Bars are 200. The calculation will be 15m*200= 3000m, 3000m/60m= 50h, and 50h/24h≅2 days. So, in this example, each trade stays open for on average of two days.

In the Outlier section, there is the individuation of abnormal trades, both positive and negative divergences from the mean. It is important to introduce the 68–95–99.7 rule, which refers to the percentage of values that lie within a range estimate in a normal distribution: 68%, 95 % and 99.7% of values lie within one, two, and three standard deviations of the mean, respectively.

$$P(\mu - 1\sigma \leq X \leq \mu + 1\sigma) \approx 68.27\%$$
$$P(\mu - 2\sigma \leq X \leq \mu + 2\sigma) \approx 95.45\%$$
$$P(\mu - 3\sigma \leq X \leq \mu + 3\sigma) \approx 99.73\%$$

Where P() is the probability function, X is an observation from a normally distributed random variable, μ (mu) is the mean of the distribution and σ (sigma) is its standard deviation. The rule of thumb for the determination of the outliers is to use $3\ \sigma$. The process starts from the calculation of 3 standard deviation of the average trade, after that a range of $\mp 3\ \sigma$ from the average trade is determined, finally the outliers are all the trades with results above or below the defined range.

The Trade Series Analysis provides information on the sequences of consecutive winning and losing trades, including the largest profit/loss of winning/losing series. Max Consecutive Losing Trade is made up of the maximum number of closed positions with a negative return.

To get a deeper understanding of trades distribution and observe their behaviour it is possible to use the MAE and MFE tools provided in the Trade Analysis.

MAE is defined as the maximum intraday price movement against the operation, so it represents the lowest open equity over the lifespan of a trade. Provides information on the drawdown of the single trades. The MFE is complementary to the MAE.

MFE is defined as the maximum positive price movement excursion for the position. It, therefore, corresponds to the highest open equity over the life span of a trade. Provides information on the runup of the individual operations.

Below there is an example of the graphical representation of MAE and MFE using a scatter plot, in which the green up arrows represent the winning trades and the red arrows the losing, taken from a High-Low breakout strategy on gold futures.

MAE (Max Adverse Excursion)   MFE (Max Favourable Excursion)

2.2.3 Periodical Analysis

In this area there are the metrics relating to the return achieved by the strategy divided by years, months, weeks, days, and hours. The main elements to take into consideration are the Annual Period Analysis and the Average Profit by Month.

The Annual Period Analysis shows the complete performance evaluation performed in both monetary and percentage term and also includes the total number of trade and the percentage of profit at the end of each year. The Average Profit by Month is the graphical representation of the average monthly profit through the histogram plot.

Below is an example of the Average Profit by Month and the Annual Period Analysis from Hi-Lo breakout gold future system.

It is possible to observe that on average on monthly basis the strategy provides positive return with the exception for October, with August as best month,

Annual Period Analysis					
Period	Profit	Profit (%)	Average Profit	# Trades	% Profitable
2021	- 2.480,00	-0,78%	- 24,80	100	48,00%
2020	39.630,00	14,19%	319,60	124	50,00%
2019	20.540,00	7,94%	193,77	106	46,23%
2018	- 1.700,00	-0,65%	- 17,71	96	47,92%
2017	15.010,00	6,12%	147,16	102	44,12%
2016	16.890,00	7,39%	174,12	97	55,67%
2015	12.510,00	5,79%	158,35	79	50,63%
2014	- 3.050,00	-1,39%	- 37,20	82	42,68%
2013	17.790,00	8,84%	157,43	113	46,90%
2012	30.020,00	17,53%	254,41	118	48,31%
2011	43.630,00	34,20%	340,86	128	49,22%
2010	- 3.740,00	-2,85%	- 31,43	119	43,70%
2009	16.440,00	14,31%	159,61	103	47,57%
2008	14.890,00	14,89%	127,26	117	47,86%

On annual basis the strategy provides quite positive and stable return with only 4 years over 14 with negative returns. The best year in the 2011 with a return of 34,2% and the worse is the year before, the 2010, with a loss of -2,85%. The average annual rate return of the strategy is 15,31%.

2.3 Trading system optimisation

In this section there is the analysis on how to perform a meaningful and reliable optimisation, going deeper in the methods used to change the parameters of the strategy in order to maximise the return, average trade and stability of the system also focusing on balanced risk exposure. Finally, this section ends with the introduction of the overfitting problem which is the most common and dangerous issue that could happen during optimisation process.

2.3.1 Optimisation

Optimisation is the process of evaluating a whole range of hypotheses (inputs) over a predetermined time period to obtain the optimal combination of inputs that maximises/minimises the designed objective function. Another goal of the optimisation process is to test the stability of the inputs in such a way that the best results are implied by a limited range of input combinations without incurring a high variation in the results with a small change on these inputs. This section describes the different types of optimisations and then the steps to follow to perform this process in the most efficient way. Multicharts provide 2 different optimisation tools: exhaustive search and genetic algorithmic optimisation. With both, it is possible to reach the final input optimisation, but they require different times to perform the process and they follow different methodologies.

2.3.1.1 Exhaustive search optimisation (ES)

This optimisation systematically goes through all the potential combinations in search of the best solution. The advantage of this approach is that every single combination is checked, and the absolute optimal solution is identified. The time required for Exhaustive optimisation is proportional to the total number of all possible solutions. The drawback of this approach is that, unless relatively few parameters are involved, the time required to reach a solution can be unacceptably long.During this process, it is necessary to set 3 values for each input: the start value, the end value, and the step interval which combined return the variable count that represents what it takes to reach the end value starting from the initial value.

The total number of combinations is calculated as follows:

$$Tot\ combination = \prod_{1}^{n} P_n(count)$$

Suppose we have a trading system with 5 inputs, and for each of them we want to perform 20 optimisation steps, the total number of combinations to be evaluated will be 3.200.000. If we assume that for each combination the computer requires 3 seconds, the time needed to perform the

optimisation will be close to 3 months. For this reason, even if the ES will return more optimal results, it may only be suitable when there is a limited number of possible solutions.

Considering that in this optimisation process the results are all the possible combinations, it is possible to screen the results looking for stable input areas in order to increase reliability and avoid overfitting. If the optimisation is performed with 2 inputs at time, it is possible to check these areas into a 3D chart, where on the X and Y axes there are the optimised inputs and on Z axis there is the objective function which can usually be the net profit, average trade, profit factor, or other custom function.

In the example, the optimised inputs are the number of bars to exit for long trades and shorts trades in the Hi-Lo breakout strategy on gold futures, and the objective function is the maximisation of the profit factor. The light blue plane is the "water level", so a plane that divides the combination outputs based on the results which can be below or above this predetermined level. The first screening is to discharge all the value below the water level.

In the graph, there are three different colours: red, blue and green. They represent the worst (red), average (blue) and better (green) inputs combination based on the objective function. The rule of thumb is to select the value based on a larger and more extensive area of the same colour, then those with more robust inputs to avoid overfitting. Robust means that with small variations in the inputs do not drastically change the value of the outputs. In general, the most stable area is the one with the same colour and without large excursion. In the example it is possible to notice that the area of values for LX_Bar from 40 to 80 and for SX_Bar from 60 to 80 is the most stable and most profitable area.

 The second screening is to find the most stable combination and perform deeper optimisation with the restricted range of values. Finally, the last step is the subjective choice of the specific combination of inputs identified in the stable and profitable areas. This choice can be made by looking at other psychological or analytical metrics present in the performance report.

2.3.1.2 Genetic Algorithms Optimisation (GA)

Genetic algorithms are considered as a research process used in computer science to find an exact or approximate solution for optimisation problems and in modelling systems where randomness is involved (for example, the stock market) introduced by John Holland in the early 1970s (Tsoukalas, L., and Uhrig, R. Fuzzy and Neural Approaches in Engineering, Wiley, 1997).

GA-based search algorithms use methods that mimic biological evolution such as hereditary mutation, selection, and crossover. The algorithms start by testing a number of random combinations, select the ones with the greatest potential, then combine them further and modify to finally arrive at the best input combinations. Instead of mechanically checking each conservable combination, genetic algorithms rapidly reduce the number of potential winners, finding and focusing on the areas where the objective function is most stable and optimised. The disadvantage of the GA approach is that the result will be a solution that approaches the absolute optimal solution, but not necessarily the absolute optimal solution itself. At best, this will perfectly match the variables to the response, at other times it will generate a response very close to the desired response ("Introduction to Genetic algorithms", http://library.thinkquest.org/18242/ga.shtml). This drawback, however, is largely offset by the processing power and time savings even with a large number of input combinations involved. Compared to the ES, the GA evaluates only the most promising combinations, finding near-optimal solutions in a fraction of the time that would be required by the brute force approach, making Genetic Algorithms optimisation quite powerful. The GA to evaluate the above 3,200,000 combinations takes approximately 1 hour. In general, GA's work is mainly concerned with two abstracts: an individual (or Genome) and an algorithm (i.e. the Genetic Algorithm itself). Each instance of Genome represents a single unique combination of inputs, while GA itself defines how evolution should take place. GA uses a certain trading strategy to determine how "fit" a genome is for survival.

Before continuing with the process is useful to provide a brief introduction of the terminology used in the explanation of the process. Genome (or Individual) is a unique combination of strategy input values. Each individual has one chromosome string encoding its data characteristics (Manoj Kumar , Mohammad Husian, Naveen Upreti, Deepti Gupta, "Genetic Algorithm: Review And Application", International Journal of Information Technology and Knowledge Management July-December 2010, Volume 2, No. 2, pp. 451-454). Gene is one of the input variables of a given strategy. Genetic algorithm is started with a set of solutions called population that are a group of individuals, all "born" at roughly the same time. A solution is represented by a chromosome, a set of genes, usually related in function (Wonjae Lee, Hak-Young Kim, "Genetic Algorithm Implementation in Python", Electronics and Telecommunications Research Institute).

Now let's introduce the definition of the process used within the optimisation. Crossover is a procedure for generating a "child" from two "parent" genomes. Although methods based on the use of two parents are more "biologically inspired", some works suggests that it is better to use more than two "parents" to reproduce a good quality chromosome (Eiben, A. E. et al, "Genetic Algorithms with Multi-parent Recombination". PPSN, III: Proceedings of the International Conference on Evolutionary Computation. The Third Conference on Parallel Problem Solving from Nature: 78-87).

 Crossover involves multiple genomes. Mutation is a process in which a gene is changed and receives a value that is neither from the "mother" nor from the "father". Mutation involves only one genome each time. Fitness is a metric for evaluating the overall performance of a Genome and Convergence is the magnitude of improvement in the average fitness between two consecutive generations (as the degree of improvement is decreasing, the generations are said to be converging).

During the process to perform this optimisation, the first step is determining the number of all possible combinations and optimal number of individuals. In the second step each individual is randomly selected, and these individuals form the first Generation or Population. To help traders Multicharts automatically provides the optimal number of individuals to benefit from a low number of generations to balance convergence with greater accuracy. After that, everyone's fitness is assessed, and the fewer fit individuals are discarded.

To better understand the underlined idea of the methodologies used by MultiCharts in selecting the population size (Step 2), it is possible to exploit the results discovered by Stanley Gotshall and Bart Rylander in the paper "Optimal Population Size and the Genetic Algorithm" (School of Engineering University of Portland U.S.A). During several empirical tests, they demonstrated two main dynamics involved. The larger the population size parameter, the greater the chance that the initial population state contains a chromosome that represents the optimal solution. An excessively large population size value will result in an increase in computation time. The optimal solution is obtained considering the advantages of both convergence time and accuracy.

The third phase is related to the generation of the new population of individuals from the remaining members of the previous population by applying crossover and mutation operations, as well as selection and/or replacement strategies that depend on the GA subtype. In the Step 3, there is the possibility to apply crossover and mutation techniques, below is a more detailed explanation to provide a deeper understanding of these methodologies. As for the crossover procedure, the "Array Uniform Crossover" is applied in which each of the child's genes can come from each of the parents with equal probability. Crossover probability is the probability of a crossover for each individual and the normal range of values is 0.95-0.99. Focusing on the mutation technique, the "Random Flip

Mutation" is selected. With this type of mutation, any gene can be replaced with any other possible gene on a random basis. In the Mutation Probability, the probability of a mutation is specified for each individual and the normal range of values is 0.01-0.05. Note that an excessively large Mutation Probability value will cause the search to become a primitive random search. Moreover, in the Step 3 the GA subtype used for parameter selection and / or substitution are introduced. Specifically, the GA subtype defines how GA creates new individuals and replaces old ones while creating subsequent generations. The main GA subtypes are Basic and Incremental. The Basic subtype uses non-overlapping generations with the possible implementation of the Elitism mode. For each generation, the algorithm creates an entirely new population of individuals and with the integration of the Elitism option, the fitter individuals move on to the next generation. The process of Elitism allows the fittest individuals to survive and produce "children" for several generations. The Incremental subtype does not create a completely new population for each generation. It simply adds only one or two children to the population each time the next generation is created. These children replace one or two individuals from the previous generation. People who need to be replaced as children are chosen based on the Replacement Schemes used. In this document, the Replacement Schemes are applied only for the Incremental subtype. These schemes define how a new generation should be integrated into the population. There are three schemes: Worst, Parent and Random. The Worst implies that fewer fit individuals are replaced. Parent replacement guarantees the replacement of the individual parents. Random implies a random substitution.

The last step is the iteration of the process until the final optimal results are reached. The process is repeated until the specified degree of convergence or generation number is reached. Genetic Algorithms optimisation process does not have an implicit final result and thus can proceed indefinitely. Therefore, you need to specify an "ending-point", which indicates when the optimisation process should end. It is possible to choose between two GA optimisation "ending-point" criteria: the "Terminate-Upon-Generation" and the "Terminate-Upon-Convergence". The first one will stop the optimisation process once the specified Maximum Number of Generations has been reached. "Terminate-Upon-Convergence" adds a second condition to the Maximum Number of generations, so it will stop the optimisation process even when the defined Convergence Rate is reached.

Finally, the GA calculation follows the following stop condition:

$$\frac{C[x - N]}{C[x]} \geq P$$

x is the ordinal number of the current generation, C [x] is the convergence value of the two most recent generations, N has defined the minimum number of generations and P is the convergence rate (the values used are generally close to 1, such as 0.99). An important note for the setting is that the Convergence Rate is not calculated for generations that have fewer than the minimum number of generations, so x must be greater than N.

2.3.2 Periodic re-optimisation

The markets are constantly evolving, for this reason it is essential to periodically check, adjust and evaluate strategies. Re-optimisation is the periodic analysis of the strategy, in order to verify whether the chosen inputs are still the most effective ones or not. In this analysis it is also possible to observe that the combinations of inputs previously discharged, with the change of the market structure, perform better than the initial ones. An important note is that this re-optimisation has to imply an improvement of the strategy which should not be casual. Furthermore, at this stage, it is very important to follow the metrics of evaluation of the strategy and the optimisation process. Re-optimisation, or periodic revision of the strategy, involves not only re-evaluating market conditions, but also understanding which inputs should be changed and which should not in order to retrieve positive risk-adjusted returns. The aim is to analyse and optimise the strategy, determine which are the best inputs in a given test period (IS) and apply these parameters into a new future time window (OOS).

2.3.2.1 WFO

This methodology of re-optimisation is called Walk Forward Optimisation (WFO). WFO is a process of testing a trading strategy by finding its optimal trading parameters over a certain time period (IS) and checking the performance of those parameters over the next time period (OOS). The traditional approach is to allocate a portion of your data for development, leaving the rest intact for OOS testing. More in-sample data is desirable because it trains the strategy to adapt to different market conditions. It is relevant also to maximize the amount of data available for OOS robustness testing. Walk-forward optimisation (WFO) helps address some of these issues.

The concept of WFO is illustrated in Figure below, using 6 periods with ratio IS-OOS of 3:1.

Not Anchored	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8
Run 1	IS	IS	IS	OOS				
Run 2		IS	IS	IS	OOS			
Run 3			IS	IS	IS	OOS		
Run 4				IS	IS	IS	OOS	
Run 5					IS	IS	IS	OOS

Anchored	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8
Run 1	IS	IS	IS	OOS				
Run 2	IS	IS	IS	IS	OOS			
Run 3	IS	IS	IS	IS	IS	OOS		
Run 4	IS	IS	IS	IS	IS	IS	OOS	
Run 5	IS	IS	IS	IS	IS	IS	IS	OOS

Tradional	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8
Run 1	IS	IS	IS	IS	OOS	OOS	OOS	OOS

In WFO, the backtest data is split into multiple IS and OOS segments. The strategy is optimised over each in-sample segment (yellow), and the optimal parameters are then applied to the immediately following OOS segment (light blue). This IS optimisation and OOS testing cycle is repeated as progress through the entire dataset is completed, creating a string of OOS backtests.

There are two forms of walk-forward optimisation, anchored and unanchored. In the anchored WFO, the start date of each in-sample period is fixed, meaning the in-sample periods get longer as the entire dataset progresses. In the unanchored WFO, the start date of each subsequent in-sample period is moved forward by an amount equal to the length of each OOS period. Unanchored WFO is more suitable for short-term strategies or if the market has a strong evolutionary bias because it allows for quicker adaptation of the strategy to prevailing conditions.

Now let's compare WFO to the traditional out-of-sample testing, in which the eight periods of the data are split into two equal segments, shown in the Figure. Note that WFO produced five years of OOS testing, whereas the traditional method only produced four. The total length of OOS tests can be even longer, depending on the WFO settings (covered below). With this procedure, the WFO provides a strict robustness test by lengthening the out-of-sample period and allows the strategy to adapt to prevailing market conditions through periodic re-optimisations.

The key settings for the WFO are the number of runs and the Out-of-sample Percentage (OOS%). The number of runs is the number of times each optimisation and OOS testing cycle is run, in the

above example there was was 5 runs. The OOS% is the OOS data length compared to the IS data length, in the example the OOS% was 25%. In general, the rule of thumb for setting up the process is to have at least 10 runs and an OOS% of around 20%. With 10 runs, you can be confident that the results are not due to chance. The OOS% should not be too large, otherwise it implies having too few trades in the optimisation period for a reliable estimate of the optimal strategy parameters. Lastly, the choice of WFO settings should be in line with the premise of the strategy. For example, if there is a trend following strategy on the daily timeframe, it makes no sense to re-optimize monthly, but a semi-annual or annual re-optimisation should be better. This school of thought also believes that the market is changing and that a trading algorithm over the years should be suspended or carried over into the next year. Every system must change or adapt to the new structure and efficiency of the market.

Let's see how the periodic re-optimisations will take place in practice. Let's assume an unanchored WFO on the Hi-Lo breakout strategy on gold futures is applied. There are 4 different inputs to be optimized, the two numbers of bars for exit condition for both long and short trades, and the stoploss and take profit. The numbers of bar are optimized from 70 to 80 with step of 5, the stop loss from 1000 to 3000 with step of 500, and the take profit from 0 to 4000 with step of 500. The settings of this WFO are run=10 and OOS%=20 with application of the GA optimisation for the selection of the inputs using the maximization of the average trade as the objective function.

Begin IS	End IS	Begin OOS	End OOS	OOS Net Profit	OOS Total Trades	OOS % Profitable	OOS Average Trade	OOS Max Intraday Drawdown		OOS Profit Factor
gen-08	giu-11	giu-11	apr-12	35.350,00	104	43,27	339,90	-	14.240,00	1,40
nov-08	apr-12	apr-12	feb-13	9.780,00	100	43,00	97,80	-	17.810,00	1,13
set-09	feb-13	feb-13	dic-13	29.280,00	99	47,47	295,76	-	7.760,00	1,42
lug-10	dic-13	dic-13	ott-14	1.230,00	58	43,10	21,21	-	11.110,00	1,04
giu-11	ott-14	ott-14	set-15	14.740,00	55	50,91	268,00	-	14.430,00	1,44
apr-12	set-15	set-15	lug-16	19.210,00	66	51,52	291,06	-	15.980,00	1,44
feb-13	lug-16	lug-16	mag-17	17.350,00	81	46,91	214,20	-	9.550,00	1,50
dic-13	mag-17	mag-17	apr-18	9.720,00	80	45,00	121,50	-	8.990,00	1,28
ott-14	**apr-18**	**apr-18**	**feb-19**	**- 1.160,00**	**70**	**44,29**	**- 16,57**	**-**	**9.570,00**	**0,96**
set-15	feb-19	feb-19	dic-19	600,00	77	35,06	7,79	-	14.300,00	1,01

Begin IS	End IS	Begin OOS	End OOS	A_HiLo_gold LX_bar	A_HiLo_gold SX_bar	A_HiLo_gold SL	A_HiLo_gold TP
gen-08	giu-11	giu-11	apr-12	80	75	2000	3500
nov-08	apr-12	apr-12	feb-13	80	75	2000	2500
set-09	feb-13	feb-13	dic-13	70	80	2000	2500
lug-10	dic-13	dic-13	ott-14	70	75	3000	0
giu-11	ott-14	ott-14	set-15	80	80	3000	0
apr-12	set-15	set-15	lug-16	80	80	3000	0
feb-13	lug-16	lug-16	mag-17	75	75	2500	0
dic-13	mag-17	mag-17	apr-18	80	75	2000	3500
ott-14	**apr-18**	**apr-18**	**feb-19**	**80**	**80**	**2500**	**0**
set-15	feb-19	feb-19	dic-19	80	75	2500	0

In practice, the program runs GA optimisation for the first test period and subsequently selects the best parameter based on the objective function and applies it to the OOS period. The process continues iterating until the total backtest data is optimized. The main drawdown of this process is that it always chooses the best combination based on the objective function without additional check of the stability of the parameter or using other subjective valuation.

2.3.3 Overfitting

When trading system algorithms are built, they leverage a sample dataset to train the model. However, when the model trains too long on the sample data or when the model is too complex, it can begin to learn the "noise", or irrelevant information, within the dataset. When the model stores noise and fits too much into the training set, the model becomes "overfitted" and is unable to generalize well to the new data. If a model cannot generalize well to new data, it will not be able to perform the forecasting activities for which it was intended. Low error rates and high instability across input combinations are good indicators of overfitting. If the training data (IS) has a low error rate and the test data (OOS) has a high error rate, it signals overfitting.

If overtraining or model complexity results in overfitting, then a logical prevention response would be to reduce model complexity by eliminating less relevant inputs or setting more general combinations. However, if too many important features are excluded, it is possible to run into the opposite problem, and underfit the model. Underfitting occurs when the model's input variables are not significant enough to determine a meaningful relationship between the input and output variables.

Underfit (high bias)	Optimum	Overfit (high variance)
High training error High test error	Low training error Low test error	Low training error High test error

In most cases, the model will perform worse out-of-sample than in the sample where all parameters have been calibrated and optimized. This is due to the possible presence of overfitting. Overfitting occurs when a very complex trading system model fits optimally with the observed data because it is overoptimized. In other words, IS sample errors are drastically reduced by increasing the model instability.

More in detail, you can find the following relationship.

$$Total\ Model\ Error = Model\ Instability + IS\ error + Random\ Error$$

$$Overfitting = Model\ Instability - IS\ error$$

To minimize the Model Error, it is necessary to select the combination in which reducing the IS error does not imply an excessive increase in model instability. For this reason, when it is necessary to choose inputs after optimisation, it is better to select and adopt stable and robust parameters, where, in their surroundings, the results do not change frequently and without large excursions. Moreover, to avoid overfitting in the choice of the pattern for filtering the strategy, it is convenient to follow the opposite rule when it is required. If a market is fairly symmetrical and a long pattern is identified based on its performance, in case the opposite pattern performs very badly in the short direction it could indicate that the performance of the selected long pattern is not consistent, and its application implies a higher probability of overoptimisation. Finally, to identify the overfitting bias of the strategy it is useful to adopt the walk-forward testing as a test generator, in order to increase the number of OOS periods and retrieve more reliable results.

To provide an example of overfitting let's introduce a trend following strategy based on moving average crossover of Dax Futures.

```
inputs: MA1L_len(70), MA2L_len(130), MA1S_len(140), MA2S_len(60);
inputs: LX_bar(160), SX_bar(120);
inputs: SL(3000), TP(9500);

variables: MA1L(0), MA2L(0), MA1S(0), MA2S(0),LongEntry(false),
ShortEntry(false);

MA1L = AverageFC(Close, MA1L_len);
MA2L = AverageFC(Close, MA2L_len);
MA1S = AverageFC(Close, MA1S_len);
MA2S = AverageFC(Close, MA2S_len);

LongEntry = MA1L crosses over MA2L;
ShortEntry = MA1S crosses under MA2S;

{entry}
if LongEntry then Buy ("MA2CrossLE") next bar at highD(0) stop;
if ShortEntry then sellshort ( "MA2CrossSE" ) next bar at lowD(0)stop;

{exit}
if BarsSinceEntry = LX_bar then
    Sell ( "LX" ) next bar at market;

if BarsSinceEntry = SX_bar then
    buytocover ("SX") next bar at market;

setstopcontract;
if SL>0 then setstoploss(SL);
if TP>0 then setprofittarget(TP);
```

The idea of the strategy is based on 4 different moving averages. The long position places a buy stop order on the high of the day is the fast moving average for long entries (MA1L) crosses from below the slow MA for long entries (MA2L), according to traditional use of the MA crossover. For the short

side the application differs from the literature, since it is placed a sell stop order on the low of the day if the slow MA for short trades (MA1S) crosses from above the fast MA for short trades (MA2S). This idea is originated from the straightforward application of the 2 MA crossover and looking that the long orders perform quite well, indeed the short orders generated huge losses, and since the indexes have not symmetrical movement, the different triggers could be applied. As exit conditions are applied: the number of bars to exit from long/short positions; the stoploss and take profit parameters. The IS period starts from 01/01/2008 to 01/01/2018 and the OOS periods starts from 01/01/2018 to 01/01/2022. The comparison is between the strategy with the default setting, they are selected with an appropriate and not overfitted optimisation, and the over-optimised strategy.

Let's start with the comparison of the parameters selected.

Default		Overfitted	
MA1L_len	70	MA1L_len	86
MA2L_len	130	MA2L_len	121
MA1S_len	140	MA1S_len	148
MA2S_len	60	MA2S_len	71
LX_bar	160	LX_bar	160
SX_bar	120	SX_bar	104
SL	3000	SL	3350
TP	9500	TP	7550

It is possible to notice that the default values are not too specific, and this is due to larger step used in the optimisation process, indeed the overfitted one the parameters are very detailed with the objective to find the most profitable results.

Default		Overfitted	
Net Profit	133.750,00	Net Profit	169.500,00
Annual Rate of Return	13,41%	Annual Rate of Return	16,99%
Monthly Rate of Return	1,12%	Monthly Rate of Return	1,42%
Max Strategy Drawdown	- 15.325,00	Max Strategy Drawdown	- 11.300,00
Profit Factor	1,99	Profit Factor	2,63
Annualized Sharpe Ratio	0,81	Annualized Sharpe Ratio	1,15
RINA Index	743,69	RINA Index	1.116,87

Looking at the performance it is possible to observe that all relevant metrices are improved in the overfitted system, so traders should expect that the results in the OOS should be more profitable.

Default		
Net Profit		43.950,00
Annual Rate of Return		11,03%
Monthly Rate of Return		0,92%
Max Strategy Drawdown	-	27.400,00
Profit Factor		1,69
Annualized Sharpe Ratio		0,65
RINA Index		253,84

Overfitted		
Net Profit		3.575,00
Annual Rate of Return		0,90%
Monthly Rate of Return		0,07%
Max Strategy Drawdown		-27.450,00
Profit Factor		1,03
Annualized Sharpe Ratio	-	0,003
RINA Index		16,48

As expected, the overfitted system performance are drastically worst compared the default system due to the overoptimisation which implies an increasing in the model instability and a reduced reliability and replicability of the IS results in the OOS period.

2.4 Trading System Evaluation

The evaluation of a strategy is a fundamental step to determine the reliability of the results, the probability that they will persist in real trading and to check if they meet the requirements of the investor. This section discusses the psychological and technical metrics present in the performance report, some tips on how to perform a solid optimisation avoiding overfitting and the integration of the analysis on the WFO with the Walk Forward Analysis (WFA).

2.4.1 Psychological parameters

Starting from the analysis of the performance report, the psychological parameters are related to the risk aversion perceived by the investors, their trading style and how they are able to bear the losses.

The first parameters to consider are the Annual Period Analysis and the Average Profit by Month. In general, their results should be consistent and equally distributed across each month and year. It could be dangerous for a trader to use a strategy in live trading that on average has negative returns and only if under certain conditions or after an x number of years generate abnormal performance. In this case the probability that the trader will stop the strategy before the abnormal return occurs is very high.

The second parameter is the percentage profitability of the trades. It is not a reliable measure as a strategy can be profitable even if the ratio is below 50%. However, in this case, the strategy could have a psychological impact on the trader as he has to bear a large number of losses and cover them with some positive high return operations.

The third is the series of consecutive trades with maximum loss. Consecutive loss can drastically affect an investor's decision to close the system. To better analyse this parameter, it is also useful to

observe the largest consecutive loss in monetary terms. There are traders who prefer to bear smaller but more numerous losses and traders who prefer to reduce the number of total losses but increase the average value of the single loss. It depends on the trading style, as the results may ultimately be the same. Suppose a system generates 15 consecutive losing trades with an average loss of $100, and a system that has only 3 consecutive losses with an average value of $5000, at the end in both systems the largest consecutive loss in monetary terms is $15000.

2.4.2 Technical parameters

The first set of parameters observed is that relating to the profits and losses generated by the strategy. Net Profit should be positive, but not necessarily as high as possible. It depends on the strategy used, if a strategy is applied that works only in certain months of the year included in a portfolio of strategies only to reduce the correlation. This strategy should not have the highest net profit, but it could be useful to enhance the overall profitability of the portfolio.

Periodic annual/monthly returns should be equally distributed across the test period. Outlier years/months, especially positive ones, should not be considered in the evaluation as it is very unlikely to consistently replicate these results. The assumption that higher past returns imply even higher future returns is not sustainable and, on average, leads to negative future returns.

The consistency and stability valuation can also be applied to DD analysis. The drawdowns should be harmonised across the test period, with convergence to a mean value to demonstrate the robustness of the strategy and to estimate the expected average DD of the strategy. The anomalous losses, in this case, may be due to a particular event, trend or changing structure of the market. A detailed analysis of this period is always suggested. Moreover, it is better to observe and evaluate the DD as a monetary value than as a percentage. This is because their evaluation in percentage terms is heavily affected by the time horizon and the position on the equity line in which they occurred. For example, suppose two DD of $500, one at the start beginning period of trading and one at the end, the initial capital of $2000 and the capital after five years of $10000. Even if the two drawdowns have the same monetary value, in percentage terms the first is equal to 25% and the second only to 5%. Finally, the relevance of returns and DD is higher in the last years than at the beginning of the test period, but it is also useful to consider the past and anomalous years, such as 2000 or 2008, to evaluate how the strategy performs under determinate market conditions. The equity line could be useful for having a graphical representation of these metrics. More in detail, the characteristics of the acceptable equity curve are that it must be growing and demonstrate consistency, with a large number of new highs and lower

and less significant drawdowns. Again, the most recent section of the equity line is more relevant than the beginning one.

The second technical metrics analysed are the those related to the evaluation of the strategy in terms of the risk adjusted return, so there is the observation of the profit generated for each additional risk unit. Below there is a table with the limit value that each ratio should have to justify the performance of the strategy in terms of risk assumed.

Ratio	Limit value
$\dfrac{Net\ Profit}{Max\ Strategy\ DD}$	≥ 7
Profit Factor	$\geq 1,5$
Annualised Sharpe Ratio	≥ 1
Rina Index	≥ 30

Note that it is very unlikely to build a strategy that meets all the requirement for the performance ratios. These requirements are reference values, not exclusive values. Of course, the closer the system performance ratios are to these values, the better.

The third set of parameters to evaluate is the total number of trades, the average trade and the average number of bars per trade. The total number of trades is essential to determine the statistical significance of the strategy. A strategy during the testing period should perform at least 100 trades, the higher the number of trades executed the higher the probability that the results of the backtest will repeat themselves in the out of sample period. Another metrics to evaluate the minimum number of trades are the trades executed per year, which should be at least equal to or higher than 12. The average trade should be high enough to cover all possible transaction costs incurred. An empirical rule states that the average trade should be around 6-7 times greater than the sum of all assumed operational costs. The lower the liquidity in the market, the higher the cost (in particular the slippage) and so, the higher the average trade should be. The average # bars parameter has inverse relationship with the total number of trades and positive with average trade. In other words, higher is the average # bars, the higher the average trade should be since the total number of trades is reduced. Moreover, longer is the period that a trade stays open, higher is the risk involved. Assuming we have 2 possible inputs generating an equal average trade, the one with the lowest average # bars should be selected.

Another parameter to observe in the trade area is the number of outliers. They can be considered as abnormal trade and their statistical results are less significant. Lower is the number of outliers, and the profit generated by the outliers, more reliable is the strategy performance.

The last parameters to be analysed in the trade are the MAE and the MFE. MAE is useful for investigating the trade drawdowns and for setting a reliable stop loss. The goal is to reduce loss-making trade as much as possible while preserving the profitable one. As in the graph above it is possible to see convergence areas of losing trade (red arrow) which can be drastically reduced with the application of the stop loss. MFE reveals trade price increases and helps find efficient profit targets and breakeven orders. In this case, the aim is to preserve the profit generated and eliminate the outliers for more reliable and stable results.

Example of MAE before and after setting a stop loss of $2500 on Hi-Lo Gold Breakout strategy.

It possible to see that the stoploss cut most the negative trades of the system, but there are still trades that has higher excursion that the SL value, this can be due to the market structure, gaps or other event that does not allow the strategy to close the position with stoploss.

2.4.3 Walk Forward Analysis (WFA)

This evaluation process is mainly based on the use of the WFA. This methodology is useful for retrieving more stable and reliable results which are more correlated to the possible live-trading results. More in detail, this evaluation is based on the analysis of the OOS results obtained by the WFO. The main tools used are the Walk Forward Optimisation Robustness to measure the stability and significance of the strategy returns and the Walk Forward Optimisation Matrix to evaluate the stability of the strategy with different numbers of runs and OOS%.

2.4.3.1 WFO Robustness

Let's start with the analysis of the WFO Robustness. The robustness of the strategy is an indication of how sporadic the backtesting results are. The more solid a strategy is, the more correlated the backtesting results and the real trading results are. Sometimes a strategy can show great results with just one profitable trade. Sometimes a strategy shows good results in backtesting but fails in real trading due to Curve Fitting. Exploring these situations allows you to determine why the strategy was profitable in backtesting but turned out to be a loser in real trading. The main criteria for evaluating the robustness of the system are the Overall Profitability, the Profit Factor, Walk-Forward Profitable Runs Count, Max Drawdown, Number of Trades and Walk Forward Efficiency (WFE).

Overall profitability is calculated as the average of the OOS net profit generated. The Profit Factor criteria is the average of the Profit Factor of the OOS segments. The Walk-Forward Profitable Runs Count is expressed as a percentage value and provides information on how many runs are generating positive returns compared to the total number of runs. The Max Drawdown represents the average drawdowns of the WFO runs in monetary terms. The Number of trades represents the average trade executed during the OOS periods. The WFE value compares the in-sample average profit with the out of-sample average profit and is expressed in percentage terms. Below is the value selected in this dissertation for validating the robustness of the strategies.

Robustness Setting	
Overall Profitability	Average Strategy Net Profit ≥ 0
Profit Factor	Average Profit Factor ≥ 1,30
WF Profitable Runs Count	Number of Profitable Runs ≥ 60%
Max Drawdown	Average Max DD ≤ 30.000
Number of Trades	Average Number of Trades ≥ 12
WFE	Average Efficiency ≥ 60%

2.4.3.2 WFO Matrix

The main pitfall of the WFO Robustness test is that the results largely depend on the setting of the WFO, the number of runs and OOS%. It is possible that following this test, traders will discharge a good and profitable strategy or accept a strategy that has performed well only thanks to these specific settings. The WFO Matrix could solve this issue.

WFO Matrix is used to determine the most optimal parameters for Regular Re-optimisation: how often and in what IS/OOS proportion will be used. This time, instead of running a single WFO, the

process executes multiple WFO clusters. The main settings are the starting value, the final value to reach, and the steps to proceed for both runs and OOS%.

In this example, the cluster analysis ran 9 different WFO. Each optimisation changes the values for the OOS% and walk-forward runs. In the first single WFA, 10 runs were evaluated using 10 percent OOS% to determine WFO fitness, in the second there is the evaluation with 10 runs and 20 percent of OOS%, and so on until all the possible combination are reached. Let's apply the WFO Matrix, with the robustness setting stated before, on the Hi-Lo Breakout strategy on gold futures.

Optimization Results

OoS \ Runs	10	15	20
10 %	FAIL	FAIL	PASS
20 %	PASS	PASS	PASS
30 %	PASS	PASS	FAIL

The strategy passes 6 tests over 9. To pass the single WFO test the strategy should be aligned with all the constrained set in the robustness test. In general, an acceptable rate in the WFO matrix is around 60%, so at least 6 WFO evaluation over 9 should have met the robustness criteria.

Markets and strategies are different. It is therefore necessary to test and evaluate them with different WFO settings and the walk-forward matrix allows the trader to evaluate multiple combinations of WFO settings at the same time. The WFO helps determine whether a trading algorithm needs to be retrained periodically and whether the algorithm proves robust enough to match to some extent the results derived during its training. More in detail, the right WFO allows you to establish which set of parameters must be used and modified, in how many days this set must be re-optimised, and to assess the soundness of the strategy. (Pruitt, G. (2016) Chapter 8: Genetic Optimisation, Walk Forward, and Monte Carlo Start Trade Analysis. [Online]. Hoboken, New Jersey , Wiley).

Based on those assumptions is possible to evaluate the best WFO setting for a particular strategy. The evaluation can be done observing the results of each WFO in terms of net profit, average trade and profit factor. After select the most efficient setting for the WFO, it is possible to individuate the length of the designed IS period on which perform the optimisation. Finally, the parameters selected from the last optimisation are applied in the designed OOS period. This process is done on each new OOS period. For example, suppose than the IS period has 3 years length for 1 year length OOS, so it will be used the IS from January 2017 to January 2020 to forecast the OOS period from January 2020 to January 2021, the next year the IS will be from 2018 to 2021 to forecast the OOS of 2022 and so on.

2.5 Practical Example: full development and analysis of a strategy

This is a practical example of the application of the theory and methodologies explained above. The example starts with the description of the main idea involved in the strategy and the analysis of the input and the tool used. After that, it proceeds with the optimisation of the inputs and the analysis of the performance changes in relation to the optimisation progress. The next step will be the evaluation the performance report of the IS results and applying the WF matrix to assess robustness. Finally, the example concludes with a brief analysis of the OOS results and the overall considerations over the performances and metrices of the strategy.

The main idea is the construction of High-Low Breakout strategy on the Dax Index in order to capture the actual market trend. More in detail, the long stop orders are executed when there is a breakout of the maximum of the day, and short stop orders are filled when the price falls below the minimum of the day. Both temporal and pattern filters are applied to limit false signals and reduce the number of unprofitable operations. The following table presents the main elements to know before proceeding with the development of the strategy and the initial code of the trading system.

Strategy	High-Low Breakout strategy
Instrument	DAX Futures Continuous Contract (EUREX)
Tick	Tick size of 0,5 for 12.5 Eur value
Session	8:00 -22:00 (UTC+1), Monday-Friday
Timeframe	60 minutes bar
Initial Capital	€100.000
Number of contracts	1
IS period	01/01/2008 - 01/01/2020
OOS period	01/01/2020 - 01/01/2022

```
Input: PatLY(41), PatSY(41), PatLN(42), PatSN(42);

Input: StartTrade(900), EndTrade(2100);

Input: NoLDay(0), NoSDay(0);

Input: SL(0), TP(0);


{entry condition}

If Time > StartTrade And time < EndTrade then begin

    If     PatternFilter(PatLY)    and    PatternFilter(PatLN)=False    and
dayofweek(date)<>NoLDay

        then buy next bar at Highd(0) stop;

    If     PatternFilter(PatSY)    and    PatternFilter(PatSN)=False    and
dayofweek(date)<>NoSDay

        then sellshort next bar at lowd(0) stop;

end;

{exit condition}

Setstopcontract;

If SL > 0 then setstoploss(SL);

If TP > 0 then setprofittarget(TP);

setexitonclose;
```

Let's start analysing the inputs of the strategy. The first couple of parameters refers to the time window in which the order can be sent to the market. This setting is fundamental because the high or low of the session is determined between the start of the session and the start of the operativity. The default settings are 9:00 for the start time to give at least 1 hour to the market to establish the high/low of the session, and 21:00 for end time to avoid the order exactly at the end of the session at 22:00. This time window is used as temporal filter and it is related to specific market bias. The second set of inputs is related to the pattern. There are 4 types of patterns, the ones that must be present and the ones to avoid in the trades' selection. More in detail, the PatLY is related to the pattern whose presence should have a positive impact on the return of the strategy, the PatLN refers to a configuration that should be avoided as it negatively effects the overall performance of the strategy. The same goes for short positions with the PtnSy and PtnSN. The default setting for PtnLY and PtnSY is pattern 41 (always true) and for PtnLN and PtnSN it is pattern 42 (always false). They are used as a technical filter since the pattern used are linked to indecision, directionality, or the strength of the market movement. The following inputs refer to an additional temporal filter, which establishes whether to avoid certain days of the week to increase the overall profitability of the system. NoLDay refers to which day the trader should be stopped the operative for the long positions and NoSDay is the same but for short trades. This filter removes one specific day from the operation to improve the performance. The choice of the day should be meaningful and usually speculate. Meaningful means selecting days in which there is usually macro news about EU or USA (highly correlated) that could distort market movements and effectiveness of the strategy. Finally, the last parameters are the stoploss (SL) and take profit (TP) used as an additional exit to the reverse of the positions. For the take profit, there is no limit to the setting, instead, stoploss for intraday positions a good starting point should be a stoploss between 1000 and 2500 euros per contract.

Now let's proceed with the analysis of the construction of the condition for the execution of orders. The code starts with selecting the best intervals to operate on. There is a time window to start and end the execution of orders. This condition is useful for determining the best interval in which movement can be captured and when to stop the entry order because the setup is already filled in. After that it is possible to see the filters related to the patterns and the other temporal filter, so the orders are executed only if the "yes" configuration is present and the "no" pattern is not checked, and the day of the week is different from that in which operations are not allowed. Pattern selection does not require secularity as the instrument used is an index with a long polarization consisting of long term and small movements and a different short bias with strong and quick negative price movements. If these previous conditions are met, now there is the core of strategy, which consists of placing a buy stop order at the high of the day (Highd(0)), and a sell stop order at the low of the day (Lowd(0)). The

High and Low used are the ones which has already occurred after the starting of the session and before the beginning of time window selected for the operativity. This condition is applied to check if the market has enough strength to break the high on the long side, or if it is weak enough to break the low of the day on the short side. Finally, there is the analysis of the exit conditions. There is the application of the stoploss and take profit parameters if they are set above zero. The stestopcontract command applies the SL and TP value to the single contract/share used, otherwise, SL and TP are applied as (SL or TP)/Total number of contracts. The setexitonclose command automatically closes the positions at the end of the session avoiding the overnight exposure, guaranteeing the intraday setting of the positions.

Let's start with the optimisation phase. The criteria selection applied in the optimisation is mainly based on the focus on net profit, average trade, profit factor, and max DD.

Next the initial performance of the strategy with the default setting are presented.

	All Trades	Long Trades	Short Trades
Net Profit	126 800,00 €	123 100,00 €	3 700,00 €
Max Strategy Drawdown	-80 200,00 €	-40 725,00 €	-87 575,00 €
Profit Factor	1,04	1,09	1,00
Annual Rate of Return	10,57%	10,27%	0,31%
Monthly Rate of Return	0,88%	0,86%	0,03%
Average Trade	28,75 €	55,80 €	1,68 €
Total # of Trades	4410	2206	2204

The starting point provides positive but not stable results. The main problems are the value of average trade which is too low to cover potential costs, the excessive drawdown, and the profit factor too close to 1. The main reason for these negative results can be identified in the performance differential between long and short trades.

Long trades provide quite stable and positive returns, especially in the second half of the testing period, indeed the short trades show an unstable and fluctuating detailed equity curve. Short orders are the ones that require the most focus on their improvements.

The first step is the optimisation of the time window of the operativity, the optimised and evaluated inputs are StartTrade and EndTrade.

StartTrade is optimised from 900 to 2100 with step=100 (1 hour).

	Net Profit	Total Trades	% Profitable	Avg Trade	Avg Bars in Winner	Max Intraday Drawdown	Profit Factor	StartTrade (A_trendF)
1	167.750,00	3.381	45,99 %	49,62	8	-59.200,00	1,08	1.100
2	128.775,00	3.773	45,19 %	34,13	9	-59.925,00	1,06	1.000
3	126.800,00	4.410	42,54 %	28,75	10	-80.200,00	1,05	900
4	115.525,00	3.132	46,17 %	36,89	7	-63.000,00	1,06	1.200
5	72.350,00	2.518	47,30 %	28,73	6	-55.300,00	1,06	1.400
6	68.025,00	2.102	47,19 %	32,36	5	-41.750,00	1,07	1.500
7	53.650,00	2.895	46,42 %	18,53	7	-70.950,00	1,03	1.300
8	33.175,00	521	46,64 %	63,68	2	-10.400,00	1,27	1.900
9	19.900,00	741	47,37 %	26,86	3	-18.025,00	1,09	1.800
10	4.325,00	1.461	47,23 %	2,96	4	-50.900,00	1,01	1.600
11	0,00	0	0,00 %	0,00	0	0,00	0,00	2.000
12	0,00	0	0,00 %	0,00	0	0,00	0,00	2.100
13	-4.775,00	982	47,15 %	-4,86	3	-31.825,00	0,99	1.700

The best value is to start the operativity at 11:00. It is possible to note that there is stability around this parameter as the second, third, and fourth results are 10:00, 9:00, and 12:00. Moreover, it is the best input also in terms of average trade and net profit, and there is also an improvement in the drawdown compared to default setting of 9:00. So 11:00 is selected as starting time.

EndTrade is optimised from 1100 to 2100 with step=100.

Net Profit	Total Trades	% Profitable	Avg Trade	Avg Bars in Winner	Max Intraday Drawdown	Profit Factor	EndTrade (A_trendF)
217.875,00	3.018	46,39 %	72,19	9	-56.850,00	1,12	1.700
195.700,00	1.186	50,00 %	165,01	10	-32.075,00	1,26	1.300
193.050,00	3.207	46,24 %	60,20	8	-47.100,00	1,10	1.800
191.950,00	2.607	46,99 %	73,63	9	-55.850,00	1,12	1.600
169.700,00	1.670	48,62 %	101,62	10	-37.025,00	1,15	1.400
167.750,00	3.381	45,99 %	49,62	8	-59.200,00	1,08	2.100
157.550,00	3.316	46,11 %	47,51	8	-65.475,00	1,08	2.000
157.000,00	3.266	46,05 %	48,07	8	-61.425,00	1,08	1.900
117.575,00	2.181	46,86 %	53,91	9	-59.450,00	1,08	1.500
0,00	0	0,00 %	0,00	0	0,00	0,00	1.100
0,00	0	0,00 %	0,00	0	0,00	0,00	1.200

It is possible to see that the best input in terms of average trade and profit factor should be 13:00. This parameter is not selected because it reduces the total number of trades too much and shows instability since the 14:00 and 12:00 inputs are too far and different. Instead, 17:00 is chosen as it provides a significant improvement in the net profit and average trade and does not drastically reduce the number of trades compared to the previous optimisation. Moreover, it is also possible to observe the stability of the parameter since 16:00 and 18:00 are in the third and fourth position.

With these inputs, it is possible to see an improvement on the detailed equity line, in particular in that short trades.

The second step is to optimise the inputs related to pattern. While there are no mirroring requirements for the selection of the patterns, usually, if the same pattern produces positive results on both sides of the orders, it has higher stability than other patterns.

PatLY is optimised from 1 to 41 with step=1.

Net Profit	Total Trades	% Profitable	Avg Trade	Avg Bars in Winner	Max Intraday Drawdown	Profit Factor	PatLY (A_trendF)
279.500,00	2.313	47,69 %	120,84	9	-62.725,00	1,20	1
236.450,00	2.273	46,90 %	104,03	9	-37.175,00	1,17	3
231.275,00	2.258	46,24 %	102,42	9	-53.950,00	1,17	14
226.500,00	2.241	46,99 %	101,07	8	-64.725,00	1,17	20
223.425,00	2.210	47,10 %	101,10	9	-51.575,00	1,16	23
217.875,00	3.018	46,39 %	72,19	9	-56.850,00	1,12	41

PatSY is optimised from 1 to 41 with step=1.

Net Profit	Total Trades	% Profitable	Avg Trade	Avg Bars in Winner	Max Intraday Drawdown	Profit Factor	PatSY (A_trendF)
235.325,00	2.346	48,38 %	100,31	9	-40.600,00	1,17	1
230.750,00	2.212	49,01 %	104,32	9	-44.850,00	1,17	23
228.200,00	2.645	47,79 %	86,28	8	-58.800,00	1,14	12
221.225,00	2.331	47,70 %	94,91	9	-46.800,00	1,17	17
217.875,00	3.018	46,39 %	72,19	9	-56.850,00	1,12	41

At first glance, it can be observed that the best pattern for both sides is pattern 1. For long orders is the best in terms of net profit, average trade, and profit factor, and for short orders is the best in terms of net profit, max DD, profit factor and the second best for the average trade. The base Pattern 1 is a pattern of volatility, therefore of indecision, based on yesterday's candle. It is determined with the following graphical configuration Body of yesterday <50% of Range of yesterday. This pattern is based on the idea that if, during the day, prices move up and down and eventually return to a position where the range (from open to close) is less than 50% of the total range, it means that there is no clear directional trend. The stop order should catch the direction of the market after this compression of the body.

Going deeper for more specific patterns, it is possible to observe for long order pattern 14 which could be meaningful considering that it is a directional up pattern, and for short side the pattern 23 since it is a directional down pattern. Pattern 14 observes the last 2 daily bars. It requires that there has been an up close yesterday, so yesterday's close must be greater than the previous day's close. This is a bullish directional pattern. The base pattern 23 takes into account the last 5 daily bars and compares the low of 5 days ago with the low of yesterday. If yesterday's low is less than 5 days ago, the pattern is true. Pattern 23 requires that there has been a downtrend in the past 5 days so that yesterday's low is lower than it was five days earlier. These two patterns are chosen because it is assumed that they should provide additional stability and reliability to the directional market movements.

The final choice for PatLY is the pattern 14 and for PatSY is pattern 23. Moreover, pattern 1 is also added on both sides by changing the code of the strategy as follows.

… If Time > StartTrade And time < EndTrade *and PatternFilter(1)* then begin …

The next step is the optimisation and individuation of patterns to avoid PatLN and PatSN. These patterns are cleaning filters, as the total number of trades is already reduced from 4410 to 785. These patterns should not be too selective to avoid excessive limitation in the operativity, but they should provide an improvement in the main matrices evaluated compared to those with a default set of 42.

PatLN is optimised from 1 to 42 with step=1.

Net Profit	Total Trades	% Profitable	Avg Trade	Avg Bars in Winner	Max Intraday Drawdown	Profit Factor	PatLN (A_trendF)
233.800,00	781	52,88 %	299,36	9	-28.825,00	1,54	31
231.275,00	785	52,74 %	294,62	9	-28.825,00	1,53	9
231.275,00	785	52,74 %	294,62	9	-28.825,00	1,53	15
231.275,00	785	52,74 %	294,62	9	-28.825,00	1,53	18
231.275,00	785	52,74 %	294,62	9	-28.825,00	1,53	29
231.275,00	785	52,74 %	294,62	9	-28.825,00	1,53	42
224.525,00	720	52,64 %	311,84	9	-27.475,00	1,55	38
220.150,00	701	52,21 %	314,05	9	-23.825,00	1,56	32
217.150,00	703	52,92 %	308,89	9	-30.325,00	1,55	7
214.825,00	701	53,07 %	306,46	9	-27.425,00	1,54	22
214.175,00	669	53,21 %	320,14	8	-24.575,00	1,55	13

The more meaningful pattern is the number 7 which is a directional down pattern. Compared to pattern 42 it cuts 82 trades and generates a higher average trade and profit factor even if the net profit is lower and there is an increase in the max DD. Selectively reducing the number of trades by improving or maintaining the same level of core performance could result in lower costs incurred and higher profit when charges are applied to the system. Pattern 7 looks for a bearish impulse and requires that the excursion between the open and today's low be greater than one and a half times the excursion that took place yesterday from opening to yesterday's low throughout the day. This pattern, therefore, looks for an obvious downside weakness in the market. It is applied on long orders to avoid possible bull trap configuration in the market.

PatSN is optimised from 1 to 42 with step=1.

Net Profit	Total Trades	% Profitable	Avg Trade	Avg Bars in Winner	Max Intraday Drawdown	Profit Factor	PatSN (A_trendF)
245.450,00	599	55,43 %	409,77	9	-14.975,00	1,82	2
229.100,00	627	55,02 %	365,39	9	-26.350,00	1,69	36
228.600,00	634	54,42 %	360,57	9	-19.675,00	1,69	32
225.650,00	682	53,52 %	330,87	9	-26.250,00	1,59	28
224.900,00	640	54,22 %	351,41	9	-21.950,00	1,63	13
223.100,00	679	53,31 %	328,57	9	-24.825,00	1,59	27
222.800,00	672	52,83 %	331,55	9	-32.175,00	1,60	31
222.350,00	587	54,68 %	378,79	9	-18.225,00	1,75	22
222.125,00	694	53,31 %	320,06	9	-25.025,00	1,57	8
221.975,00	651	54,07 %	340,98	9	-31.025,00	1,62	38
219.675,00	679	53,46 %	323,53	9	-29.575,00	1,58	24
217.150,00	703	52,92 %	308,89	9	-30.325,00	1,55	42

The more relevant pattern that takes into consideration only short orders is the number 28, which is a trend up pattern. Moreover, compared to 42, it reduces the drawdown, improves the net profit, the average trade, and the profit factor with a cut of only 19 trades. Base Pattern 28 takes into account the last three daily bars and today's open. Note that it is necessary to wait for the market to open for complete information on whether the pattern is true or false; therefore, the intraday bars are used. To be verified, pattern 28 requires that there are 2 consecutive increasing daily closes and that today's open is higher than yesterday's close. This pattern, therefore, looks for an uptrend in the market in the last period.

The third step is checking the specific day of the week when it is best to stop the trading system.

NoLDay and NoSDay are optimised starting from 0 to 5 with step=1

Net Profit	Total Trades	% Profitable	Avg Trade	Avg Bars in Winner	Max Intraday Drawdown	Profit Factor	NoLDay (A_trendF)	NoSDay (A_trendF)
292.575,00	717	54,53 %	408,05	9	-25.475,00	1,70	0	2
277.825,00	644	54,66 %	431,41	9	-28.125,00	1,74	2	2
274.300,00	637	54,95 %	430,61	9	-23.075,00	1,75	3	2
273.525,00	783	53,64 %	349,33	9	-26.250,00	1,57	0	0

It is possible to observe a recurrence of the number 2 which refers to Tuesday. In third position, there is the 2-2 combination which significantly improves the average trade, the profit factor with a quite worsening of the max DD compared to the 0-0 combination. After detailed analysis, it turns out that the recurring economic event on Tuesday is the ZEW survey of sentiment on the economy Performance report in Germany.

The ZEW Economic Sentiment Indicator is a sentiment indicator created by the monthly ZEW financial markets survey. The ZEW Financial Market Survey is an aggregation of the sentiments of around 350 economists and analysts about Germany's medium-term economic future. ZEW stands for Zentrum für Europäische Wirtschaftsforschung, which translates to Center for European Economic Research. In 2018, for example, the ZEW economic sentiment indicator went from a positive reading of 20.4 to minus 25 in seven months. During this period, German economic growth slowed from 2.2% in 2017 to 1.5% in 2018, so the ZEW economic sentiment indicator overestimated the severity of this slowdown, which is not unusual on the part of economic market sentiment indicators.

So, the combination 2-2 is chosen in order to improve the overall metrics of the system taking advantage of avoiding possible price excursions due to the release of these macro-economic data.

The fourth step is the optimisation of the SL and TP parameters.

For the SL the range in which to consider the optimisation is between 1000 and 2500, for additional confirmation let's take a look at the MAE.

In confirmation, most negative trades occur with an excursion higher than €2500 of drawdown. It is suggested to focus more on the SL value close to 2500 in order to not cut too profitable trades.

SL optmised from 1000 to 2500 with step=250 (20 ticks).

TP optmised from 0 to 4000 with step=500.

Net Profit	Total Trades	% Profitable	Avg Trade	Avg Bars in Winner	Max Intraday Drawdown	Profit Factor	SL (A_trendF)	TP (A_trendF)
234.025,00	639	56,96 %	366,24	6	-19.600,00	1,72	2.500	2.500
233.025,00	600	55,83 %	388,38	7	-16.700,00	1,73	2.500	3.500
231.025,00	615	56,42 %	375,65	7	-19.100,00	1,72	2.500	3.000
230.325,00	619	55,90 %	372,09	7	-16.225,00	1,72	2.000	3.000
230.275,00	619	56,06 %	372,01	7	-18.100,00	1,71	2.250	3.000
229.450,00	591	54,48 %	388,24	8	-16.025,00	1,73	2.250	4.000
229.350,00	587	54,86 %	390,72	8	-17.525,00	1,73	2.500	4.000
227.650,00	604	55,30 %	376,90	7	-15.700,00	1,71	2.250	3.500
227.100,00	592	54,22 %	383,61	8	-17.100,00	1,72	2.000	4.000
227.000,00	643	56,61 %	353,03	6	-18.600,00	1,69	2.250	2.500
224.725,00	604	54,97 %	372,06	7	-15.250,00	1,70	2.000	3.500
224.650,00	620	54,68 %	362,34	7	-16.075,00	1,70	1.750	3.000
224.175,00	593	53,12 %	378,04	8	-14.675,00	1,72	1.750	4.000
223.650,00	644	56,37 %	347,28	6	-16.725,00	1,67	2.000	2.500
220.975,00	645	55,19 %	342,60	6	-16.575,00	1,67	1.750	2.500
220.175,00	559	53,85 %	393,87	9	-20.050,00	1,73	2.500	0

The optimisation shows that there is convergence of the SL value between 2000 and 2500 as identified in the MAE. For the TP there is stability of values between 3000 and 4000. Considering the net profit, average trade, profit factor, and max DD combination, the choice is 2500 as SL and 3500 TP.

The final code of the strategy with the input is:

```
Input: PatLY(14), PatSY(23), PatLN(7), PatSN(28);

Input: StartTrade(1100), EndTrade(1700);

Input: NoLDay(2), NoSDay(2);

Input: SL(2500), TP(3500);


If Time > StartTrade And time < EndTrade and PatternFilter(1) then begin

    If PatternFilter(PatLY) and PatternFilter(PatLN)=False and

    dayofweek(date)<>NoLDay then buy next bar at Highd(0)stop;


    If PatternFilter(PatSY) and PatternFilter(PatSN)=False and

    dayofweek(date)<>NoSDay then sellshort next bar at lowd(0)stop;

end;

Setstopcontract;

If SL > 0 then setstoploss(SL);

If TP > 0 then setprofittarget(TP);

setexitonclose;
```

Next the validation phase begins. In this step, the strategy must pass 3 tests before it can be used for forward validation or in the real market. The first one is the analysis of the results of the fully optimised IS strategy, the second is the check of the robustness of the strategy using the WF matrix, and the final test is the valuation of the results in the OOS period with the inclusion of trading costs.

Test 1 IS valuation

	All Trades	Long Trades	Short Trades
Net Profit	233 025,00 €	88 800,00 €	144 225,00 €
Max Strategy Drawdown	-16 700,00 €	-15 475,00 €	-16 050,00 €
Annual Rate of Return	19,43%	7,40%	12,03%
Monthly Rate of Return	1,62%	0,62%	1,00%
Average Trade	388,38 €	298,99 €	475,99 €
Total # of Trades	600	297	303

From a comparison with the starting point, all the relevant metrics have improved. In particular, the symmetry between long and shorts trades has changed drastically, providing similar and excellent results from both factions. Moreover, the number of trades went from 4410 to 600, reducing the potential cost of the strategy by approximately 7 times. The number of trades equal to 600 implies static significance and reliability of the results. The results which have improved the most are the average trade and the max DD. The average trade now implies the full capacity of the strategy to bear the potential costs, and the drawdown is reduced by approximately 4 times. This implies a higher risk adjusted return, the confirmation of which is presented in the results from the performance ratios below.

Annualized Sharpe Ratio	0,94
RINA Index	6.564,11
Return on Max Strategy Drawdown	13,95
Profit Factor	1,73

The comparison of the ratios results with the limit values presented in the evaluation subchapter is optimal. The RINA Index of 6564,11 is largely greater than the limit value of 30, the Return on Max Strategy Drawdown of 13,95 is almost double the limit value of 7 and the Profit Factor of 1,73 is greater than 1,5. Only the Annualized Sharpe Ratio of 0,94 is lower than the limit value of 1, but being very close, this result can also be accepted.

Below is the analysis of the detailed equity line of the strategy including drawdown.

The equity line is growing and stable. The average drawdown in monetary terms is around €10.000. The main problem with the detailed equity curve is the flat periods between peaks, where the strategy does not generate any relevant profit for an average period of 1.5 years after the relevant maximum is reached.

Moreover, to check this behaviour, let's observe the equity curve close to close. As identified before, the strategy generates a large number of new peaks, but after these, there is a flattering period of about 100 trades.

This particularity of the outcomes can also be found in the Annual Period Analysis.

Period	Profit (€)	Profit (%)	Average Profit (€)	# Trades	% Profitable
2019	- 625,00 €	-0,19%	- 12,50 €	50	46,00%
2018	53 950,00 €	19,29%	884,43 €	61	67,21%
2017	4 275,00 €	1,55%	95,00 €	45	57,78%
2016	-5 175,00 €	-1,84%	- 136,18 €	38	39,47%
2015	46 075,00 €	19,65%	869,34 €	53	66,04%
2014	15 600,00 €	7,13%	318,37 €	49	53,06%
2013	-8 775,00 €	-3,85%	- 182,81 €	48	35,42%
2012	13 575,00 €	6,34%	357,24 €	38	55,26%
2011	60 600,00 €	39,47%	977,42 €	62	66,13%
2010	950,00 €	0,62%	23,75 €	40	60,00%
2009	25 650,00 €	20,21%	475,00 €	54	61,11%
2008	26 925,00 €	26,93%	434,27 €	62	53,23%

The strategy over an IS period of 12 years generates 9 years of profit and only 3 of these have negative returns. In five years out of twelve, so in 41% of cases, the performance generated is above the average. This apparently implies instability on returns. Moreover, it is possible to observe that higher returns usually imply lower returns over the next 1 or 2 years, as shown in the equity curves. This dynamic is quite stable over the test period, so it can be used as a confirmation of the stability of the return distributions. Considering the overall metrics, the IS test is passed. In the OOS, the strategy is expected to have a negative return in 2020 but have a large and positive return in 2021.

Test 2 WF matrix

This test consists of running the WF matrix and assessing if at least 60% of the selected combination passes the robustness test.

Overall Profitability	Average Strategy Net Profit ≥ 0
Profit Factor	Average Profit Factor ≥ 1,30
WF Profitable Runs Count	Number of Profitable Runs ≥ 60%
Max Drawdown	Average Max DD ≤ 30.000
Number of Trades	Average Number of Trades ≥ 12
WFE	Average Efficiency ≥ 60%

Setting Robustness parameters.

Run	From 10 to 20 with step=5
OOS%	From 10% to 30% with step=10%
Number of combinations	9

Setting Clustering WFO process.

SL	From 1000 to 2500 with step=500
TP	From 0 to 6000 with step=500

Setting the inputs optimisation.

For the selection of the inputs to be optimised, the choice are only SL and TP, because for the other inputs selection, discretionary techniques are used which differ from the selection of the best parameters based on the objective function. The other inputs are kept fixed.

Optimization Results

Runs / OoS	10	20	30
10 %	PASS	FAIL	PASS
20 %	PASS ⓥ	PASS	PASS
30 %	PASS	PASS	FAIL

The test is successful as 77% (7/9) of the WFOs pass the robustness test. This result implies a higher level of stability of the strategy and reliable results even in the OOS periods used in the process. Moreover, this is a confirmation of the inputs chosen to be optimised and the validity of those which are kept fixed. The second test has passed.

Test 3 OOS valuation

The first step is to identify the inputs to be used in the OOS period. This takes place through the selection of the best WFOs from the WF matrix, from this let's determine the length of the IS period and run an optimisation on that period, finally let's apply the inputs in the OOS period of references which length is determined by the WFO selected.

Following there are the results of net profit, average trade and profit factor of the different WFOs.

Optimization Results

Runs / OoS	10	20	30
10 %	9.940,00	5.483,75	4.250,83
20 %	16.252,50 ⓥ	6.717,50	4.268,33
30 %	14.180,00	6.538,75	5.095,83

Optimization Results

Runs / OoS	10	20	30
10 %	281,41	265,95	284,25
20 %	372,58 ⓥ	210,40	224,40
30 %	262,49	189,42	255,76

Optimization Results

Runs / OoS	10	20	30
10 %	1,52	1,88	2,18
20 %	1,88 ⓥ	1,72	1,75
30 %	1,60	1,60	1,78

The WFO with runs=10 and OOS%=20%, has the highest net profit, the largest average trade and the second-best profit factor. This combination provides the most stable and best results compared to the others, so this WFO setting is used to forecast inputs for the OOS period. With this WFO the average length of the IS period is 1250 days and for OOS period is 310 days, these results can be approximate into 3 years and 5 months for the IS and 1 year for the OOS period.

The cost applied are 2 tick per trade, so in this case is €25 per trade. Most economic theories have the too strong assumption of zero cost involved. In this dissertation to provide more reliable and real results, this assumption is removed, and potential costs are considered. Costs are applied only in the OOS period and not in the optimisation process of the strategy because they could have a negative impact on the process and stability of the input selection.

Following there is the results of the optimisation for the SL and TP from 01/07/2016 to 01/01/2020.

Net Profit	Total Trades	% Profitable	Avg Trade	Avg Bars in Winner	Max Intraday Drawdown	Profit Factor	SL (A_trendF_intra_Dax)	TP (A_trendF_intra_Dax)
60.275,00	208	62,02 %	289,78	5	-12.775,00	1,63	2.500	1.500
59.275,00	174	57,47 %	340,66	7	-13.625,00	1,62	2.500	3.000
56.100,00	185	48,11 %	303,24	7	-14.400,00	1,63	1.000	3.000
55.150,00	166	56,63 %	332,23	8	-12.400,00	1,63	2.500	3.500
55.100,00	181	56,35 %	304,42	6	-13.575,00	1,56	2.500	2.500

The inputs selected for the OOS period from 01/2020 to 01/2021 are 2500 for stoploss and 3000 for take profit. This combination is chosen because it generates the highest average trade with a small worsening in term of net profit and maximum drawdown. Following there are the results of the first OOS.

	All Trades	Long Trades	Short Trades
Net Profit	7 925,00 €	-1 387,50 €	9 312,50 €
Max Strategy Drawdown	-19 500,00 €	-11 800,00 €	-14 775,00 €
Avg Trade	152,40 €	- 63,07 €	310,42 €
% Profitable	53,85%	50,00%	56,67%
Slippage Paid	2 150,00 €	937,50 €	1 212,50 €
Annual Rate of Return	7,97%	-1,40%	9,37%
Monthly Rate of Return	0,66%	-0,12%	0,78%
Total # of Trades	52	22	30

Profit Factor	1,15
Annualized Sharpe Ratio	0,64
RINA Index	275,15

The strategy generates positive returns of 7,97%, in particular is possible to observe that the positive performance is due to the short trades which completely offset the losses generated by long trades. This asymmetry is due to the market structure of that period which was huge effected by the Covid shock. The system was able to catch the sharply and unexpected drawdown of the market, in particular on 11th March 2020. Following the graphical example of the position executed by the system in that date.

Regards the performance ratios, the only sufficient ratio is the Rina Index, the Annualised Sharpe ratio and the profit factor are below the predetermined level of 1 and 1,5. This represent that the return of the strategy are excessively due to risk exposure.

Let's repeat the process using as IS the period from 01/07/2017 to 01/01/2021, in order to select the input for the OOS related to the period from 01/01/2021 to 01/01/2022.

Net Profit	Total Trades	% Profitable	Avg Trade	Avg Bars in Winner	Max Intraday Drawdown	Profit Factor	SL (A_trendF_intra_Dax)	TP (A_trendF_intra_Dax)
74.825,00	185	57,84 %	404,46	7	-16.700,00	1,63	2.500	3.500
71.150,00	183	55,19 %	388,80	7	-16.525,00	1,59	2.500	4.000
68.850,00	212	46,70 %	324,76	6	-16.625,00	1,61	1.000	3.000
68.675,00	199	46,23 %	345,10	7	-13.200,00	1,64	1.000	3.500
67.875,00	197	57,87 %	344,54	6	-19.500,00	1,52	2.500	3.000

The best results observing the combination of net profit, average trade and profit factor is to use as SL 2500 and as TP 3500. Following are presented the results in the OOS period from 01/01/2021 to 01/01/2022.

	All Trades	Long Trades	Short Trades
Net Profit	9 200,00 €	14 700,00 €	-5 500,00 €
Max Strategy Drawdown	-13 375,00 €	-5 175,00 €	-10 125,00 €
Avg Trade (win & loss)	219,05 €	588,00 €	- 323,53 €
% Profitable	45,24%	52,00%	35,29%
Slippage Paid	1 975,00 €	1 150,00 €	825,00 €
Annual Rate of Return	9,33%	14,91%	-5,58%
Monthly Rate of Return	0,78%	1,24%	-0,46%
Total # of Trades	42	25	17

Profit Factor	1,32
Annualized Sharpe Ratio	0,67
RINA Index	250,29

The strategy generates positive returns of 9,33%, in particular thanks to the long trades which offset the short losing ones. This can be due to the strong recovery movement of the index after the difficulty occurred during the 2020. The performance ratios are aligned with the ones of 2021, so it demonstrates again a low risk adjusted return.

The last step is the comparison of the results with the buy and hold strategy.

Net Profit 2021	7 925,00 €		**Buy & Hold 2021**	3 987,17 €
Net Profit 2022	9 200,00 €		**Buy & Hold 2022**	15 281,01 €
Cumulated Net Profit	17 125,00 €		**Cumulate Buy & Hold**	19 268,18 €

During the 2021 the strategy outperforms the benchmark, but in the 2022 underperform it. Observing the cumulated return is possible to see the strategy generate slightly lower return that the classical buy and hold strategy but the strategy stays in the market only the 2.52% (18 days and 9 hours over 2 years horizon) and so the active strategy with this performance is highly more efficient than the passive one.

The strategy demonstrates quite high stability in the performance and input selection. It passes all three tests, so the possibility of overfitting is greatly reduced, and expectations of future returns should be aligned with the results obtained in the OOS period. This system has shown the ability to offset strong drawdowns such as that of March 2020 thus reducing the exposure of a potential portfolio to the black swan event if the strategy is included in a basket of system.

To recap, the first step in the process of building, evaluating and validating a strategy is the identification of the basic setting rules for the system operativity and the possible filters to be apply. The second step is the evaluation of the system with the basic rules in order to check if an improvement is possible and meaningful. The third step is the optimisation process. The optimisation of the inputs can be done using either ES or GA. Remember that the GA compared to ES, it is very influenced by the objective function. The first combination of inputs to be optimised is the time window with the start and end trades operativity. The second combination of parameters to evaluate is the configuration of the pattern, looking for meaningful patterns to avoid possible overfitting. The third inputs selection relates to additional temporal filters such as the days of the week in which the operativity stops. Finally, the fourth combination to choose is the SL and TP parameters. With the fully optimised system, the fourth step is the evaluation and validation of the system through the 3 main tests. The first test is related to the evaluation of the performance of the IS period, passing through the summary of the performance report, the performance ratios, the equity curve and the annual period analysis. The second test is referred to the walk forward matrix to assess the stability of the system with different combination of walk forward optimisation. The best WFO is used to determine setting to use to forecast inputs for the OOS period. The final test is the evaluation of the performance of the OOS period through the same process used in the evaluation of the IS period with the integration of potential costs and the comparison with the buy and hold strategy on the reference market. When all three tests have been passed, the strategy can be applied to live trading for forward validation.

Chapter 3

Risk Management & Position Sizing

This chapter is one of the most relevant to enhance the performance with focus on risk management. As state in the multiple examples, there is no return without exposure to risk, but an excessive exposure could imply the bankruptcy of the trading account. Moreover, note that the markets compensate traders only for non-diversifiable risk, so even if higher profits are usually implied by higher risk the opposite is not true. This chapter starts by providing a precise definition of risk, going forward there is a deepening in the single position management with definition and setting of stoploss, take profit and trailing stops. The next section is related to Money management and position sizing with focus on the main position sizing models that can be applied to single strategy or portfolio. Subsequently, there is the subchapter dedicated to the Montecarlo simulation with definition of the Method used and its properties and limits. Finally, this chapter ends with a practical example of Money Management application on trading system.

3.1 Definition of risk

Market risk is defined as a risk that should be monitored and managed on a regular (at least daily) basis because as market conditions change, market prices change, and thus profits and losses are generated. As a result, market risk is typically measured by the degree of price volatility, or in technical terms, the standard deviation of the price change (or return). To put it another way, the greater is the volatility (standard deviation), the greater is the risk. Market risk exists in all asset classes, but some are more easily monitored than others. Equities, for example, are traded frequently (many times per day), making market risk easier to compute and measure. Fixed income securities, such as swaps, are not frequently traded, so calculating market risk is difficult. As a result, scientific methods are required to estimate market risk.

3.2 Position management

Risk management is the branch of money management that deals with the management of the position and it is aimed at determining and containing the internal risk of the transaction, which must be determined at the same time as entering the market through a stop loss. Risk management, however, goes far beyond setting the initial stop. In fact, through trailing stop techniques it is possible to take full advantage of market movements, ensuring part of the profits made up to the achievement of the profit target (price target at which the transaction closes).

The simplest form of risk management within a single trading system is the control of the distance between entry and exit. This is the first step in risk management, and it involves incorporating the quantified risk values into your trading strategy. The main parameters that traders can use to manage

single position risk are listed below. These values refer to the stop loss, take profit, and trailing stop, and the methods listed below provide alternatives to using monetary or static values to set them.

3.2.1 Stop Loss

A stop-loss order allows you to manage risk on individual trades. It is a fundamental tool, which allows the trader to limit losses by liquidating a position when the operation turns out to be incorrect. It must be fixed at the same time as the opening of the position, in order to establish the risk inherent in the operation and the consequent loss from the beginning of the operativity. In other words, it is an order in the form of insurance against major losses, which is activated when the trend takes a direction contrary to our forecasts, making us exit the market with a predetermined and limited loss, to avoid finding ourselves in irrecoverable situations.

For long position, the stoploss consists in a sell stop order which is placed below the current price, it becomes a sell market order when the designed price is reached. Stops do not guarantee that you will be filled at the stop price because opening gaps, fast markets (especially after news events), and low volume can result in significant slippage. Despite these events, the stop loss is still a fundamental tool for risk management and extremely useful in the open market, which is why it must always be set at the same time as opening a position and respected. If the market opens lower than the sell stop, the order is filled at the market price. Tight stops (stops placed close to the current price) are frequently hit. The greater the distance between it and the target, the less likely it is to be hit. The pattern resembles random price movements. The number of times a stop is reached multiplied by the distance of the stop will always be constant when using random numbers. To be a good trading rule, using a stop must outperform a random event. A novice trader may decide that no trade should lose more than $500 and set a stop loss at that level. Some more experienced traders believe that a simple trade should never lose more than 3% of your total investment. Scaling your losses to the size of your investment makes sense, but stops are more sensible if they are related to the nature of the system, the timing of the trade, market volatility, or a chart pattern. Leverage should be reduced or increased depending on the magnitude of the risk.

According to Tushar Chande and Stanley Kroll (Tushar Chande and Stanley Kroll, The New Technical Trader (New York): John Wiley & Sons, 1994), there are various options for setting stops that change with market conditions, including:

- placing the initial stop at a previous support or resistance level;
- using a multiple of the current volatility, such as 3 times the 10-day ATR;
- advancing the stop by a percentage of the price change;
- using the recent swing high or low point, based on a percentage minimum swing;

- using the highest high or lowest low of the recent n periods.

Cynthia Kase delves deeper into how to set a stop loss based on volatility, using the standard deviation. She uses the following steps in her Der-stop to create stop-loss levels for both long and short positions (Cynthia Kase, "Redefining Volatility and Position Risk," Technical Analysis of Stocks & Commodities (October 1993)):

1. Determine the true range (TR) of the previous two trading days; the highest high and lowest low of the 2-day period or 2-bar period.

2. Using 30 bars for intraday charts and 20 days for daily charts, compute the rolling average true range (ATR) of TR (in step 1). It should be noted that each period consists of two days.

3. Using the same 20-day and 30-bar periods as in step 2, compute the standard deviations (STDEV) of the true ranges in step 1.

4. The stop-loss values are DDEV = ATR + (f STDEV), where f can be 1, 2.06 to 2.25, or 3.20 to 3.50, with the larger values of the pairs correcting for skew and allowing for greater risk.

5. For long positions, the der-stop is traded high - DDEV, and for short positions, the dev-stop is traded low+ DDEV. Trade high and trade low are the prices that correspond to the greatest profit in long and short trades, respectively.

Other traders use stop-loss orders that are not based on the price or volatility of the specific market traded. They usually take one of the three approaches listed below:

- a percentage of the initial margin, for example, 50% to 70% of the initial margin. This is related to long-term volatility, but it lags significantly. An estimate of long-term volatility might be a better option (Tushar Chande and Stanley Kroll, The New Technical Trader (New York: John Wiley & Sons, 1994)).

- A percentage of the portfolio's or total account's value, such as 1.0 percent to 2.5 percent. This concept of risk equalization across all markets is widely accepted. It is not sensitive to individual markets, and it imposes artificial overrides, as do many other stops. If one market's volatility rises or falls faster than others, this risk level must be tailored to each market; otherwise, the stop would be too close in some markets and too far away in others.

- The maximum negative excursion is determined by historical analysis. A stop is set just beyond the maximum negative excursion for each trade, or 2.5 percent of the price, whichever is less. (John Sweeney, Campaign Trading (New York: John Wiley & Sons, 1996)).

3.2.2 Take Profit

Profit targets are points at which the system captures a profit that is expected to be greater than the return at the end of the trade, or a windfall move, such as a positive reaction to an economic report. Profits are taken in mean-reversion trading when the relative value returns to normal or corrects by a predetermined amount. Profit-taking works best for both strategies, reverse and trend following, in noisy markets where prices are unlikely to continue in one direction. It also works best when based on price volatility, and it is commonly calculated for long positions as a positive move of f*ATR on any single day or combination of consecutive days, where f is a multiplication factor. In this case, it could happen on any day with enough volatility. This methodology assumes that any large move will reverse, even if it is a profitable move with a negative net trade.

It is also possible to scale Out of a trade by using different profit targets; however, it is recommended that three or more profit targets be used with this approach. Begin by constructing them with the "best" factor, say 3.0. Set two additional factors to 2.0 and 4.0, or 1.5 and 4.5, so that the average of the profit targets is the best choice. Your exposure is reduced if one of the targets is hit. If you reach two, it is unlikely that you will turn a profit into a loss. This method avoids the issue of a price that approaches the profit target but then reverses. Professional short-term traders frequently use it (CMT Level II 2016: Theory and Analysis, Market Technician's Association, John Wiley & Sons, 2015). It is important to say that the use of any target, regardless of the technique used to fix it, is penalizing, because you decide in advance the level at which to close the entire position or part of it, thus reducing the profits that we could have obtained. At the same time, however, it allows us to secure the profits made up to that point, avoiding the risk that excessive greed leads us to delay the timing of exit too much, to the point that a trend reversal could occur that transforms a profitable operation in a loss-making one.

3.2.3 Trailing stops

A trailing stop captures an increasing portion of profits as prices move in a positive direction. Some trailing stops advance, while others may retreat based on volatility and price changes. Trailing stops are typically built using a fixed percentage technique, volatility, or a lock-in profits approach.

In the Fixed percentage setting the trailing stop is set at 3% below the highest closing price during the trade. The position is exited if either the trend changes or prices fall by 3% from the high point of the trade, whichever comes first. This stop does not retreat.

The stop in the Volatility approach will be closer when there is less volatility and farther away when there is more volatility. It will also be positioned downward from a long position's best high or close.

A typical stop for a long position could be as follows:

$$Highest\ high\ (n) - x * ATR(10)$$

Where n is the period for which the maximum is calculated, x represents a certain number of points based on the instrument, and 10 is the period (days) for the Average True Range Calculation. Rather than using a stop all of the time, in the Locking-in Profits method, some traders will reposition the stop to the entry price once the trade has reached a certain level of profit. It adheres to the old maxim, "Don't let a profit turn into a loss." If you do it too soon, you may miss out on market noise.

In the following section, there is an example of using dynamic stoploss and take profit, as well as a comparison with static ones, on the HiLo breakout strategy on gold. In this case, the default inputs are modified because the time zone is used locally, based on Rome GMT +02:00, rather than using exchange time. Here's the updated code.

```
Input: StartTrade(1700), EndTrade(2100);
inputs: LX_bar(80), SX_bar(80);
var: timewindow(false);
timewindow=TW(StartTrade,EndTrade);

{entry}
If timewindow then begin
     buy next bar at Highd(0)stop;
     sellshort next bar at lowd(0)stop;
end;

{temporal exit}
if BarsSinceEntry = LX_bar then
     Sell ("LX") next bar at market;
if BarsSinceEntry = SX_bar then
     buytocover ("SX") next bar at market;

{stop and TP basic}
Input: SL(2500), TP(2500), trigger(0);
if trigger=0 then begin
     Setstopcontract;
     If SL > 0 then setstoploss(SL);
     If TP > 0 then setprofittarget(TP);
end;

{stop and TP dynamic}
input:length_atr(30),f(6),sd_length(30);
var:Diff(0),TP_din(0), SL_din(0), atr(0), mp(0), sd(0);

mp=marketposition;
atr=AvgTrueRange(length_atr);
sd=StdDev(atr,sd_length);
Diff=f*sd;

if trigger=1 then begin
     if mp>0 then begin
          TP_din=Highd(0)+ Diff;
          SL_din= Lowd(0) - Diff;
          sell ("TPle") next bar at TP_din limit;
          sell ("SLle") next bar at SL_din stop;
     end;
     if mp<0 then begin
          TP_din= Lowd(0) - Diff;
          SL_din= Highd(0) + Diff;
          buytocover ("TPse") next bar at TP_din limit;
          buytocover ("SLse") next bar at SL_din stop;
     end;
end;
```

The introduction of the input trigger is the primary difference in the system's structure. If the trigger is equal to 0, the stoploss and take profit are set using static monetary values of SL and TP, whereas if the trigger is equal to 1, the parameters are set using dynamic values that change with market movement.

The idea is to use the day's maximum (Highd(0)) and minimum (Lowd(0)) values, along with a shift value (Diff), as a dynamic level of stoploss and take profit. The shift value is calculated as the product of a factor(f) and the standard deviation of the n-period average true range. Because the strategy utilises intraday charts, the ATR period is set to 30 by default, as suggested by Cynthia Kase in "Redefining Volatility and Position Risk." The "marketposition" function returns one of two values: 1 if the system is in a long position and -1 if it is in a short position. The take profit for a long position is calculated as the high of the day plus the differential point, and it is executed as a sell limit order. The stoploss is calculated as the day's low minus the difference in value, and it is executed as a sell stop order. For short orders, symmetric values are used. The values of these parameters are defined as dynamic because they change in response to market volatility; the greater the volatility, the greater the distance and the values of the stoploss and take profit; the opposite is true for low volatility. This setting is based on the assumption that if there is a breakout combined with high volatility, the market's impulse will be higher than in a lower volatility environment, so the profit target reached should be higher as well as the stoploss in order to reduce the likelihood that this one is taken due to market noise. In the case of low volatility, both values are lower because the expected profitable breakout movement is more limited, and the length of the stoploss should be lower as well, because the noise in the market is reduced during the low volatility period, and the system does not require a large stoploss to catch false signals. The results with trigger values of 0 and 1 are shown below.

Static Parameters	
Net Profit	199.760,00
Max Strategy Drawdown	- 24.690,00
Annual Rate of Return	16,67%
Monthly Rate of Return	1,39%

Dynamic Paramenters	
Net Profit	163.210,00
Max Strategy Drawdown	- 14.470,00
Annual Rate of Return	13,62%
Monthly Rate of Return	1,13%

Return on Max Strategy Drawdown	8,09
Profit Factor	1,26
Annualized Sharpe Ratio	0,74
RINA Index	263,67

Return on Max Strategy Drawdown	11,28
Profit Factor	1,33
Annualized Sharpe Ratio	0,89
RINA Index	863,35

Based on these results, it is possible to conclude that the dynamic parameters reduce the system's overall profitability while increasing its efficiency. More in detail, the 41 percent reduction in the maximum DD from 24.690 to 14.470 implies an improvement in risk adjusted returns. The higher

performance ration indicates that the strategy obtains a higher profit for each unit of risk exposure when compared to the system with static stoploss and take profit.

Detailed equity curve Static P.

Detailed equity curve Dynamic P.

Going deeper into the DD analysis, the detailed equity line shows that the strategy's stability has increased as the average maximum DD decreases from 20.000 to 10.000 and the average DD tends from 10.000 to 5000. Furthermore, even though the equity line with dynamic parameters is very close to the one with static parameters, it has a higher upward slope.

Average profit by month Static P.

Average profit by month Dynamic P.

The average profit by month, which has a more stable distribution, also demonstrates the higher stability of the returns. The positive and negative outlier months in the system with static parameters, such as August and October, are no longer outliers in the strategy with dynamic parameters, and they are more aligned with the average monthly returns.

This example demonstrates the importance of risk management through position management, as well as how different stoploss and take profit levels can improve or degrade a strategy's overall performance.

3.3 Money Management and Position sizing

The trader Stanley Kroll argued that "It is better to have a mediocre system and a good money management strategy, rather than an excellent system and a poor money management strategy " (Kroll, Stanley, in Kroll on Futures Trading Strategy, published by Dow Jones-Irwin (1988)). In fact, an excellent trading strategy, without a good money management strategy, does not have sense, because incorrect money management sooner or later will lead to failure even the trader with the best operating techniques. Money Management is a set of rules that govern the efficient management of assets. Risk management and position sizing are two fundamental and inseparable aspects of money management. The first analyses the risk associated with the market position, while the second identifies the capital to invest in each single market operation open and the distribution of the capital among the various portfolio assets. Regardless of the trading system used, proper risk management has the sole goal of maximizing profit and minimizing losses.

Each money management strategy adheres to a basic logic that is comprised of several fundamental points (https://www.borsaitaliana.it/):

• Adequate capital for the financial instrument used;

• Risk limited to no more than 2-3% of the portfolio for each individual transaction;

• Define the portfolio's maximum risk (drawdown): if all of the stop-losses are triggered at the same time, the trader should keep a sufficient share of capital to continue operating on the market;

• Thorough knowledge of the market in which you intend to invest.

Using Money Management means calculating how much money to allocate to each position based on the strategy, operating technique, or system used, and then using a Money Management algorithm to determine which exposure to open the next trade with. The model chosen is determined by the type of market in which you intend to operate: if it is a share security, we must determine how much capital to use; if it is a future, we must determine how many contracts to work with; and if it is Forex, we must determine the number of batches or micro-batches. The three main models are presented in the following sections: the fixed fractional method, the fixed ratio, and the percent volatility.

3.3.1 Fixed Fractional Method

The fixed fractional method, also known as percent f, is unquestionably the most popular money management strategy in the trading world. In practice, the system's calculations are based on determining what percentage of your capital to risk with each trade: this percentage is known as the "fraction" or percent f. The basic method considers the system stop loss to be the loss that would be incurred if one contract is used. Having determined the amount of capital available, traders determine the fraction they intend to risk in order to determine the total amount that they are willing to lose, and thus provides for the division of the amount obtained by the amount of the stop loss, in order to calculate how many contracts can be taken.

To proceed, the Worst Case Scenario must be introduced. The Worst Case Scenario is associated with the worst-case scenario imaginable; a classic setting of this value, as previously mentioned, is the use of the stoploss. In addition to the stop loss, there are other values that can be taken, such as the worst day or the worst historical loss, which provide a more precise idea of the strategy's reality. It is true that the strategy has a stop of € 1,500, but if, but if it suffers a slippage of three or four times the stop, for example, because the operation was influenced by the release of macro data or because the market opened in a gap, that loss will undoubtedly be more relevant to the operational reliability of the system. It is also possible to take the average of the last N worst trades. To obtain this parameter, take the list of trades and select the five worst ones, for example, calculate the average, and that is the Worst Case Scenario. In the case of the WSC setting as Worst Time Performance, it can be daily or weekly.   In fact, if a fund has a weekly NAV, it is possible to refer to the worst week, or the worst NAV, and use this value as a Worst Case Scenario, thus adjusting its entire model and market exposure correctly on the limitation of the impact of a Worst Case Scenario that should recur. The historical drawdown, or an average of the five worst drawdowns, is another unit of measurement that can be used.

For the calculation of the WCS, several possibilities must be considered, in fact, being closely linked to the stop loss can be somewhat misleading. Let us not forget that there are strategies that do not have a fixed stop, i.e., strategies that are always on the market, such as reverse entry. In these cases, the possible reverse position and stops are only known at the start of the trade, and this level varies over time. In such cases, the fixed stop clearly loses its dependability.

The formula for calculating the number of contracts with the percentage f is shown below:

$$Contracts = INT\left(\frac{E \times \%f}{WCS}\right)$$

The number of contracts used in the following position is the integer obtained by dividing E, which is the equity (capital available), times percent f, which is the percent of capital to risk, by WCS, which is the worst case scenario.

A practical example of how the fixed fractional method works in progression is provided below. Assume we examine ten trades from a trading system with a percent f=3%, a WCS set equal to a stoploss of €250, and an initial equity of €50.000.

Trades	Equity	Risk (%f=3%)	Contract	P%L per contract	P%L
1	50.000,00 €	1.500,00 €	6	700,00 €	4.200,00 €
2	54.200,00 €	1.626,00 €	6	900,00 €	5.400,00 €
3	59.600,00 €	1.788,00 €	7	500,00 €	3.500,00 €
4	63.100,00 €	1.893,00 €	7	-250,00 €	-1.750,00 €
5	61.350,00 €	1.840,50 €	7	-250,00 €	-1.750,00 €
6	59.600,00 €	1.788,00 €	7	-250,00 €	-1.750,00 €
7	57.850,00 €	1.735,50 €	6	500,00 €	3.000,00 €
8	60.850,00 €	1.825,50 €	7	300,00 €	2.100,00 €
9	62.950,00 €	1.888,50 €	7	1.000,00 €	7.000,00 €
10	69.950,00 €	2.098,50 €	8	-250,00 €	-2.000,00 €

The formula indicates that the initial number of contracts to be used is six. The series of profitable trades implies an increase in the portfolio's equity, and as a result, the number of contracts used rises to seven. Following a string of losses, the equity decreases, as does the number of contracts to be used in the next trade, which falls to six. Finally, with the last series of positive trades, the number of trades to use has increased to eight.

Trades	Equity	Risk (%f=3%)	Contract	P%L per contract	P%L
1	50.000,00 €	1.000,00 €	1	500,00 €	500,00 €
2	50.500,00 €	1.010,00 €	1	2.000,00 €	2.000,00 €
3	52.500,00 €	1.050,00 €	1	- 1.000,00 €	-1.000,00 €
4	51.500,00 €	1.030,00 €	1	- 1.000,00 €	-1.000,00 €
5	50.500,00 €	1.010,00 €	1	- 1.000,00 €	-1.000,00 €
6	49.500,00 €	990,00 €	0	2.000,00 €	- €
7	49.500,00 €	990,00 €	0	5.000,00 €	- €
8	49.500,00 €	990,00 €	0	3.000,00 €	- €
9	49.500,00 €	990,00 €	0	2000,00 €	- €
10	49.500,00 €	990,00 €	0	- 1.000,00 €	- €

In this example, the WCS is €1.000, the risk percentage is 2%, and the initial equity is €50.000. It is possible to see that the strategy ceases to operate from trade 6 onwards due to capital constraints. Even if the next trades are profitable, the money management method used prevents operability because the capital at risk is less than the worst-case scenario set.

Clearly, the percentage of a loss initially established is subjective, it depends on the capitalization and risk appetite of the individual operator, in fact, this is a method that is based on the investor's psychology, making him choose how much he is willing to lose, so there are no better percentages of others or universally valid.

3.3.2 Fixed ratio

Ryan Jones introduced the Fixed Ratio model as an alternative to the Fixed Fractional Method in The Trading Game (The Trading Game: Playing by the Numbers to Make Millions – April 15, 1999, Wiley). He criticizes the Fixed Fractional method because the increase in each contract takes place too slowly at the beginning of the operations, then at some point, to develop an increase in contracts so fast to make the levels of derived Drawdown unacceptable. This method, unlike Percent f, is based on increasing contracts when each contract currently in use generates a certain level of profit called delta. Each contract must earn this delta before moving on to the next; the smaller the delta, the faster the increase in the number of contracts will be, and thus the strategy's aggressiveness.

With this approach, you can select the number of contracts, to begin with. Generally, traders begin with a contract, but theoretically, they can choose any number they want, regardless of the capital at their disposal. Unlike percent f, where it became impossible to use the strategy due to undercapitalization, this model allows you to manage the number of contracts as desired by establishing a minimum number.

It is important to note that before another contract can be added, each contract must make an equivalent contribution to capital growth. For this model, it is critical to consider the equity of contribution of each contract. While it is true that this model could begin more aggressively, there are no lower bounds. The margin is the only theoretical limit; you must have enough margin to trade with that minimum number of contracts.

Moving forward in the construction of the equity line, it implies a scenario that generally exposes the system to less pronounced drawdowns, simply because the increase in contracts becomes much more prudent in this model. If with the Percent f the increase reaches fixed steps, such as when 50 contracts are used in a single operation, the next step is easily reached because that necessary step in equity increasing is covered by the contribution of 50 contracts. In the Fixed Ratio, each of the 50 contracts must bring the delta as a contribution, so it will take much longer. In this manner, we will have a much more stable increase in the steps, to the benefit of greater control of the equity, because the more violently the contracts increase, the more accentuated the control, including the drawdown phases. Clearly, in the Fixed Ratio, whenever you go back for losses, falling below one of the trigger levels of the contract increase, you return to decreasing a contract by passing to the previous point.

The formula for calculating the number of contracts with a fixed ratio is shown below:

$$Contracts = INT\left(\frac{1 + \sqrt{1 + 8 \times \dfrac{(E - E_i)}{Delta}}}{2}\right)$$

Where E is the current equity, E_i is the initial equity and Delta is the gain/loss per contract. The integer past of the ratios described determines the number of contracts used in the next position.

A practical progressive example using this method is provided below.

Assume the initial equity is €50.000, the Delta is €1000, so 2% of the initial capital, and the minimum number of contracts is 1.

Trades	Equity	Contract	P%L per contract	P%L
1	50.000,00 €	1	700,00 €	700,00 €
2	50.700,00 €	1	900,00 €	900,00 €
3	51.600,00 €	2	500,00 €	1.000,00 €
4	52.600,00 €	2	-250,00 €	- 500,00 €
5	52.100,00 €	2	-250,00 €	- 500,00 €
6	51.600,00 €	2	-250,00 €	- 500,00 €
7	51.100,00 €	2	500,00 €	1.000,00 €
8	52.100,00 €	2	300,00 €	600,00 €
9	52.700,00 €	2	1.000,00 €	2.000,00 €
10	54.700,00 €	3	-250,00 €	- 750,00 €

It is possible to see that the number of contracts grows as the profits from the strategies imply a higher equity value. More specifically, the number of contracts increases from one to two when the capital increases by more than approximately one delta value, and it increases to three when equity exceeds the initial capital plus approximately two delta values.

The same series of trades that stops the system's operation with the percent f model is presented in the following example, but this time the fixed ratio model is used.

Trades	Equity	Contract	P%L per contract	P%L
1	50.000,00 €	1	500,00 €	500,00 €
2	50.500,00 €	1	2.000,00 €	2.000,00 €
3	52.500,00 €	2	-1.000,00 €	- 2.000,00 €
4	50.500,00 €	1	-1.000,00 €	- 1.000,00 €
5	49.500,00 €	1	-1.000,00 €	- 1.000,00 €
6	48.500,00 €	1	2.000,00 €	2.000,00 €
7	50.500,00 €	1	5.000,00 €	5.000,00 €
8	55.500,00 €	3	3.000,00 €	9.000,00 €
9	64.500,00 €	5	2.000,00 €	10.000,00 €
10	74.500,00 €	7	-1.000,00 €	- 7.000,00 €

It is possible to see that, whereas previously the system was stopped from trade 6 onwards, in this case, the system continues to operate because the minimum number of contracts is set to 1. When the step value is met again, the number of contracts begins to rise again until it reaches 7.

There are schools of thought that weighed the behaviour of the fixed ratio underwent, because it risks more when you have less and risks less when you have accumulated a higher capital. Others, on the other hand, claim that this behaviour of the fixed ratio is the only feasible for low capital and guarantees a stable earnings curve once arrived at the accumulation of a good capital. The final choice once again is up to the trader, who after the appropriate tests in relation to the available capital and maximum loss, will choose what is closer to his risk tolerance.

3.3.3 Percent Volatility

Van Tharp introduced this money management model in the book Trade your way to financial freedom (McGraw-Hill, 1998), and it is based on market fluctuations and the maximum fluctuation you want to keep for your capital. A measure of volatility is used to measure the fluctuations of the instrument on which one intends to trade. The daily excursions between maximum and minimum are measured and averaged over a set number of days, in this regard. In general, fewer days are counted for systems that do not stay in place for an extended period of time, and a longer period is counted for larger systems. Assume that it is reasonable to average 4-5 days for relatively fast systems (positions ranging from 2 days to a week) and 20 days for systems that ride a trend for a longer period of time (positions from 10 days to a month).

The described average is calculated as the average of the period's ranges. It is more convenient to consider the Average true range (ATR) to account for any gaps. The difference between range and True Range is determined by the position of the previous close in relation to the range of the bar where the measurement will be taken. In practice, if the close is within the range, the range and True Range are equivalent; however, if the close is outside the range, range and True Range are distinct, because the True Range starts by measuring the furthest distance from the close. This difference is due to the fact that if we have overnight positions, we may find ourselves at the time of the closing of the markets measuring our portfolio against the end of the day. The next day, however, the portfolio's true situation, i.e. the True Range, will be measured starting not from the opening, but from the previous day's close. The graphical examples of the difference and the calculation for the range and true range are shown below.

The first step is to compute ATR for N bars, where N is the number of bars that must be compatible with the system's average length of positions. The ATR is then multiplied by the Big Point Value to yield the Average Money Range, which represents the average monetary fluctuation of the last N bars. Finally, divide the percentage of capital you do not want to exceed in terms of fluctuation by the Average Money Range to get the number of contracts.

While the Percent f does not permit operation when the available capital is insufficient for the type of strategy employed (value less than 1), the Percent Volatility presents a different situation, because in this formula the %Vol and the BPV are fixed, but the ATR varies according to market volatility. This means that just because the formula returns a value less than one today does not mean that in 10 or 15 days the ATR will not be reduced to the point where the formula returns a value greater than one, and thus it is permissible to enter the market with one or more contracts depending on the circumstances. The difference between Percent Volatility and Percent f is that while in Percent f the result is fixed, in this case the result of the equation can change depending on market conditions. So even if we are unable to operate with the system today due to capital constraints, it is not certain that we will not be able to operate again in periods of lower volatility.

The formula for the calculation of the number of contracts with the % volatility is presented below:

$$Contracts = INT\left(\frac{E \times \%Vol}{ATR \times BPV}\right)$$

Where E is the equity, %Vol is the fluctuation of the desired capital, ATR is the average true range, and BPV is the big point value. The integer past of the ratios described determines the number of contracts used in the next position. The following is a practical example of the percent volatility method. The first step is to compute the ATR, which is done by using the market's movement over the previous five days.

Day	High	Low	Close	True Range
1	48,21	44,95	47,68	3,26
2	50,21	46,15	49,27	4,06
3	48,05	44,55	45,23	4,72
4	47,05	43,25	44,03	3,8
5	51,07	44,5	50,04	7,04

The ATR is 4,576 points, calculated as the average of the five true ranges. Assume that the equity is €250.000, the percent volatility is 3%, and the BPV of the instrument is 500. Using the percent volatility formula, the results show that three contracts should be used in the following trades.

This method arouses a certain interest, because it is not linked to the worst loss suffered, and this allows it to differentiate itself from the fixed fraction, to stop in conditions of volatility considered excessive, and then to start following the signals again once the conditions of acceptable volatility. In the Fixed Fractional, on the other hand, once an insufficient capital level is reached to face the maximum admissible loss, the system stops definitively. Here instead the method can stop and then leave when the volatility conditions allow it. A reduction in volatility increases the number of contracts (because it is the denominator of the formula), furthermore at low volatility conditions can occur that allow you to make a trade even with little capital because if there is low volatility, you risk less, consequently, in the presence of lower risk, it can be operated with low capital.

3.3.4 Comparison of models

The worst case scenario setting has a significant impact on the fixed fractional model. It can be set in a static manner using the stoploss or in a more dynamic manner using the system's worst loss to date, or the average of the last 5 negative trades; the higher the WCS, the fewer contracts are available for the next trade. Based on the level of percent f and WCS in this model, it is possible that the operation is halted due to capital constraints. This model produces better results when the standard deviation of the trades is low, i.e. when there is low dispersion of the trades around the mean.

The fixed ratio model is mainly affected by the delta value setting, so approximately the monetary gain/loss generated per contract used in order to determine the next step of contracts. Operativity is always permitted in this model with the minimum number of contracts set by the traders, if the margin requirement allows it. This model produces better results when the average trade and the delta are close to each other; the greater the difference between these values, the longer it will take to increase/decrease the number of contracts used in the positions.

The percent volatility model is influenced by market volatility as measured by the ATR; the higher the volatility, the fewer contracts should be used in trades. This method ensures that the position sizing used is appropriate for the market conditions. The percent volatility model may halt operations during periods of unusual volatility, but it may resume operations once the market conditions have stabilized. Instead of a single strategy, this model is primarily used in portfolio applications.

3.4 Montecarlo Simulation

MonteCarlo simulation is a mathematical technique used to estimate the possible outcomes of an uncertain event. It is also known as the Monte Carlo method or multiple probability simulation. Monte Carlo simulation models possible outcomes for any variable with inherent uncertainty by utilizing a probability distribution, such as a uniform or normal distribution. It then recalculates the results several times, each time using a different set of random numbers ranging from the minimum to the maximum value (https://www.ibm.com/).

This is the most sensible and realistic method to use for risk analysis. Mose Arye Milevsky, a finance professor at York University in Toronto, predicted in 2001 that "in five years, all financial planning will be Monte Carlo," because it is a much more realistic measure of financial risk and return than any other traditional financial planning method (www.bloomberg.com/)

The Montecarlo simulation entails carrying out the following steps:

- Risk factor-related scenario simulation. The scenarios are defined by the probability distribution chosen and the parameters that describe the distribution. Parameters are calculated based on the historical data that has been gathered. This phase is distinguished by a high level of calculation intensity as a large number of scenarios are generated using the Monte Carlo method.
- Reversal of the portfolio's simulated scenarios. As a result, there are as many possible outcomes as there are simulated scenarios.
- Use a histogram to visualize the distribution of profits and losses.

3.4.1 Selection without replacement Method

According to this simulation, the new positions of existing trades are determined at random. In a system, for example, trade 1 is now in position 842, trade 2 is in position 66, trade 1051 is in position 980, and so on. The important point is that every trade still exists like before, no trade is deleted, and no trade is added. This method of permutation is known as "selection without replacement" (Jaekle, U. & Tomasini, E. (2019) Trading Systems 2nd Edition. Harriman House).

Selection with replacement is another permutation method. A selection without replacement has the advantage of replicating the input sequence's probability distribution, whereas a selection with replacement may not. The disadvantage of selection without replacement is that the number of trades in the randomly sampled trade sequences is limited to the number of trades in the input sequence. As a result, if the sequence of trades is short (less than 50 trades), the accuracy of the calculations may be limited. The first method is similar to random selection with replacement, but the final list of trades has the same statistical properties as the original list. The second method adds more randomness to the trade sequence, which may be preferable if the expected trades in the future differ from those in the original sequence. The final outcome of all trades must remain constant, regardless of the new order in which the trades are placed. Because the sum of the trades remains constant, all new equity curves must end up with the same amount using a fixed number of contracts. Because the trades are now in a different order, the shape of the new equity lines and, in particular, the occurring drawdowns change.

The original trade sequence (thick green line) and 1000 permuted trade sequences (thin grey lines) are depicted in this figure. Two additional thick lines can be seen, one blue representing the simulation with the smallest drawdown and one red representing the simulation with the highest drawdown. Because no trades are added or removed, but only in the order in which they appear, all permutated equity curves have the same starting and ending points. The change in trade orders has the effect of causing large variations between the equity curves, with different drawdown phases occurring at different times.

3.4.2 Properties and limitations

The estimation of expected drawdowns is the most important aspect of Montecarlo analysis. The Monte Carlo analysis is a tool for identifying potential worst-case scenarios. It searches for the worst drawdowns that can occur during the trading system's lifetime. Because this method is based on the assumption of normal distribution, statistical rules can be used to retrieve information about the probability and size of drawdown based on standard deviation measures.

$$P(\mu - 1\sigma \leq X \leq \mu + 1\sigma) \approx 68.27\%$$
$$P(\mu - 2\sigma \leq X \leq \mu + 2\sigma) \approx 95.45\%$$
$$P(\mu - 3\sigma \leq X \leq \mu + 3\sigma) \approx 99.73\%$$

Where P() denotes the probability function, X denotes an observation from a normally distributed random variable, μ (mu) denotes the distribution's mean, and σ (sigma) denotes its standard deviation. The drawdown based on one σ implies that approximately 68 percent of the possible drawdown scenarios should be lower than that drawdown, with two σ trades, lower DD should be expected in approximately 95 percent of the cases, and with three σ trades, there is approximately a 1% probability that the maximum DD is greater than the result obtained.

Monte Carlo analysis is the right method for estimating the real risks that are hidden beneath the results of your performance table, but when concluding Monte Carlo calculations, it is necessary to take into account the assumptions on which they are based and their limitations. The risk is that Montecarlo analysis uses trades from system backtests, which sometimes come from overfitted strategies, and the simulation does not solve or identify the overfitting problems. Because it only takes the system's trades, it usually produces excellent results if the back-test is highly profitable. On the other hand, it only displays negative results if the back-test does not produce proficient results. Montecarlo analysis is only useful when used correctly, and it should not be used on over-fitted trading systems.

"And some events are beyond the model's ability to predict them. The brainy sorts at Long-Term Capital Management, the hedge fund that imploded in 1998, employed sophisticated probability models. But those models failed dramatically during a financial calamity that was triggered by a default in Russia. That's a warning that this high-tech planning is not foolproof. My concern is that people are using Monte Carlo as a certainty test. It isn't. It's a probability test. " (A Better Way to Size Up Your Nest Egg: 'Monte Carlo models simulate all kinds of scenarios', Christopher Farrell, BusinessWeek (2001)).

3.5 Practical Example: Money Management Model Application on Dax

The following section presents a practical example of applying money management models. The strategy used is the intraday trend following strategy on Dax already presented in the previous chapter. The first step is analysing the new code and strategy IS results without position sizing. The second step is to apply money management models and compare their results. The third step is to select the model to be applied in the OOS and perform a re-optimisation of the IS inputs. Finally, there is the OOS analysis and final considerations.

The previous chapter's settings, operability, and triggers are retained, with the only difference being the selection of the IS and OOS period chosen. To increase the meaning of this example, the IS period goes from 01/01/2008 to 01/01/2018 and the OOS period runs from 01/01/2018 to 01/01/2022. These periods are applied to see the real effect of position sizing models, which is more relevant over multiple years than one or two. Below is the modified code with the integration of money management models.

```
{money management models}
input: MM_model(0), MM0_Base(1), MM1_delta(10000), MM1_BaseContracts(1);
input: MM2_PercentF(4), MM3_PercentVol(3), Equity0(100000), len_ATR(7);
Input: SL(2000), TP(0);
var: MySize(1), ATRValue(1),wcs(0);

wcs=SL;

if MM_model=0 then MySize = MM0_Base

else if MM_model=1 then MySize =
intportion((MM1_BaseContracts+SquareRoot(1+8*(maxlist(1,netprofit)/MM1_delta)))/2)
else if MM_model=2 then MySize = intportion(((Equity0+netprofit)*MM2_PercentF*0.01)/(wcs))
else if MM_model=3 then begin
     ATRValue = averagetruerange(len_ATR);
     MySize = intportion(((Equity0+netprofit)*MM3_PercentVol*0.01)/(ATRValue*bigpointvalue));
end;

{max contract on dax =30}
if Mysize>30 then Mysize=30;

{strategy}
Input: PatLY(14), PatSY(23), PatLN(7), PatSN(28);
Input: StartTrade(1100), EndTrade(1700);
Input: NoLDay(2), NoSDay(2);

If Time > StartTrade And time < EndTrade and PatternFilter(1) then begin
     If PatternFilter(PatLY) and PatternFilter(PatLN)=False and dayofweek(date)<>NoLDay
          then buy mysize contracts next bar at Highd(0)stop;
     If PatternFilter(PatSY) and PatternFilter(PatSN)=False and dayofweek(date)<>NoSDay
          then sellshort mysize contracts next bar at lowd(0)stop;
end;

Setstopcontract;
If SL > 0 then setstoploss(SL);
If TP > 0 then setprofittarget(TP);
setexitonclose;
```

In the code it is possible to notice that there is a constraint on maximum contracts used by the strategy, in particular, this detail is useful to have more reliable results. This value for the Dax should be set equal to 30 or, more generally, this value should be aligned with the number of contracts that should

not have high impact on the market. High impact means this number should be limited to cover one or at maximum two level of the of the order book, otherwise, the strategy results could be adversely affected by slippage and delayed execution due to large orders being used. Another detail to pay attention to is the length of the ATR used in the percent volatility model; to have more reliable results from this parameter, it should be set close to the average number of bars on a trade. Since the average of the bars on trade is 7.2, the ATR is calculated on the last 7 bars. Also, since the strategy is already optimised, the money management models test should be done taking into account the possible costs. The cost is set at 2 ticks per contract, therefore €25 per contract.

The IS results are presented below without applying the position sizing model (MM_mode = 0).

	All Trades	Long Trades	Short Trades
Net Profit	158 350,00 €	63 500,00 €	94 850,00 €
Max Strategy Drawdown (%)	-14,69%	-11,58%	-12,35%
Slippage Paid	23 000,00 €	11 500,00 €	11 500,00 €
Return on Initial Capital	158,35%	63,50%	94,85%
Annual Rate of Return	15,85%	6,36%	9,49%
% Profitable	52,61%	53,04%	52,17%
Max # Contracts Held	1	1	1

Return on Max Strategy Drawdown	7,81
Profit Factor	1,63
Annualized Sharpe Ratio	0,78
RINA Index	3.295,67

It is possible to notice that the strategy generates a positive return with 158 350,00 € of net profit and a total return of 158,35% obtained from an average annual return of 15,85%. All performance ratios are above the limit value except for the Sharpe Ration which is slightly below 1. The maximum strategy Drawdown is -14,96%, and from the detailed equity curve, it is possible to observe that the

expected average DD is close to 6%. In analysing the application of the Money Management Model, traders should focus on the percentage drawdown rather than the monetary drawdown, the latter more relevant only in the strategy construction. In the strategy without money management, the number of contracts is fixed at 1 regardless of all other variables in the system.

Period	Profit (€)	Profit (%)
2017	-4 450,00 €	-1,69%
2016	-8 700,00 €	-3,20%
2015	34 775,00 €	14,69%
2014	14 975,00 €	6,75%
2013	-13 500,00 €	-5,74%
2012	11 950,00 €	5,35%
2011	66 400,00 €	42,32%
2010	500,00 €	0,32%
2009	20 150,00 €	14,79%
2008	36 250,00 €	36,25%

The annual period analysis shows that the strategy provides significant positive returns over six out of ten years, with the highest in 2011 with a return of 42.32% and the lowest in 2013 with a negative return of -5.74%.

Let's start with the second step, analysing the position sizing models. The analysis starts with a comparison of the models using the standard metrics provided by the performance report. The second phase consists in performing different scenarios through Montecarlo Analysis to quantify the expected drawdowns in percentage terms and observe the distribution of drawdowns and returns. Here the choice of the model is based on the stability of the distributions, and on lower drawdowns. Finally, there is the choice of the best model to apply. To add fairness to the comparison, the default inputs of the money management models are chosen to provide a similar net profit.

The first model to analyse is the fixed ratio method (MM_model = 1). The selected default inputs are the delta equal to 10 000€ and the minimum number of contracts equal to 1.

The results of the performance report are presented below.

	All Trades	Long Trades	Short Trades
Net Profit	1144 125,00 €	637 075,00 €	507 050,00 €
Max Strategy Drawdown (%)	-22,20%	-32,19%	-36,65%
Slippage Paid	225 000,00 €	116 350,00 €	108 650,00 €
Return on Initial Capital	1144,13%	637,08%	507,05%
Annual Rate of Return	114,52%	63,77%	50,75%
% Profitable	52,61%	53,04%	52,17%
Max # Contracts Held	17	17	17

Return on Max Strategy Drawdown	3,52
Profit Factor	1,44
Annualized Sharpe Ratio	0,80
RINA Index	2.383,44

The result compared to IS one has completely changed. The net profit increase to 1,14M with a total return of 1144,13% and an average annual return of 114,52%. In most economic theories additional return is implied by higher risk exposure and also in this case they are confirmed as the maximum drawdown increase from 14,69% to 22,20%, with an expected average drawdown close to 15% compared to the previous 6%. The ratio shows that there is a decline in the efficiency of the risk-return trade-off. The Return on Max Strategy Drawdown is lower than the established limit value, while the profit factor and the annualised Sharpe ratio are close to those predetermined levels. The Rina Index is largely positive. The maximum number of contracts used by the strategy reaches 17 in a single trade.

Period	Profit (€)	Profit (%)
2017	-72 800,00 €	-5,53%
2016	-147 525,00 €	-10,07%
2015	499 925,00 €	51,83%
2014	183 200,00 €	23,45%
2013	-168 675,00 €	-17,76%
2012	148 250,00 €	18,49%
2011	553 850,00 €	223,42%
2010	-4 425,00 €	-1,75%
2009	88 800,00 €	54,30%
2008	63 525,00 €	63,53%

The strategy still generates positive returns over six years out of nine and, as anticipated above, it is possible to observe that the application of this money management model enhances both losses and profits but not in a linear way. This can be demonstrated by the comparison of the best year, 2011,

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where the return without money management was 42,32% and is now 223,42% so close to 6x. The most negative return is still obtained in 2013 with -17,76% which is close to 4x compared with the negative outcome of the strategy without money management equal to -5,74%.

The second model analysed is the fixed fractional, so with the trigger MM_mode=2. The default inputs are set as %f equal to 4% and the worst case scenario equal to the stoploss of 2 000€.

The results of the performance report are presented below.

	All Trades	Long Trades	Short Trades
Net Profit	1020 050,00 €	653 775,00 €	366 275,00 €
Max Strategy Drawdown (%)	-33,74%	-44,62%	-50,06%
Slippage Paid	273 950,00 €	141 000,00 €	132 950,00 €
Return on Initial Capital	1020,05%	653,78%	366,28%
Annual Rate of Return	102,10%	65,44%	36,66%
% Profitable	52,61%	53,04%	52,17%
Max # Contracts Held	30	30	30

Return on Max Strategy Drawdown		1,88
Profit Factor		1,30
Annualized Sharpe Ratio		0,78
RINA Index		998,22

Compared to the previous model it is possible to observe that the fixed fractional has lower stability as the drawdown has increased without implying additional returns reaching a maximum drawdown of -33,74% with an expected average drawdown close to 20%. This is also demonstrated by the worse performance ratios, which also implied higher inefficiency in terms of risk-return trade-off. Moreover, it is possible to observe an increase in slippage paid due to the greater number of contracts

used by the strategy, and an increase in the asymmetry between long and short position, where the long position counts for the 64% of the total return and the short position represents only the 36%. In particular, with this method of money management, the strategy reaches the maximum number of contracts set, so 30 contracts per trade.

Period	Profit (€)	Profit (%)
2017	-130 425,00 €	-10,43%
2016	-259 500,00 €	-17,19%
2015	707 600,00 €	88,19%
2014	187 325,00 €	30,46%
2013	-189 500,00 €	-23,55%
2012	158 775,00 €	24,59%
2011	444 525,00 €	220,88%
2010	-1 175,00 €	-0,58%
2009	54 150,00 €	36,52%
2008	48 275,00 €	48,28%

From the annual period report, it is possible to observe that from the 2012 to 2017 there is an enhancement of both profits and losses, this is due to the higher exposure of the strategy and the faster increase in the contracts used. Compared to previous model the ratio of profit generates per unit of losses is lower, as shown by performance ratios analysis.

The last model is the percent volatility with the trigger MM_model=3. The default inputs are %vol=3% and the length of ATR equal to 7 since the average number of bars per trade is equal to 7,2. Following the performance reports results.

	All Trades	Long Trades	Short Trades
Net Profit	1148 350,00 €	847 775,00 €	300 575,00 €
Max Strategy Drawdown (%)	-49,01%	-78,99%	-77,86%
Slippage Paid	435 150,00 €	237 850,00 €	197 300,00 €
Return on Initial Capital	1148,35%	847,78%	300,58%
Annual Rate of Return	114,94%	84,86%	30,09%
% Profitable	52,61%	53,04%	52,17%
Max # Contracts Held	30	30	30

Return on Max Strategy Drawdown	1,79
Profit Factor	1,23
Annualized Sharpe Ratio	0,79
RINA Index	1.057,86

The percent volatility shows an even higher aggressivity in setting the position sizing with an increase in the maximum drawdown to 49,10% and an expected average drawdown close to 30% compared to the two previous models. The performance ratios are aligned with the percent f model but worse than the fixed ratio. The aggressivity of the model can be seen in the paid slippage which increases significantly due to the greater number of contracts used. Also in this case, the strategy reaches the maximum number of contracts per trade allowed and, considering the high cost incurred, the escalation of the number of contracts is faster than the two previous methods which demonstrates the greater risk exposure of the approach. As identified in the percent f model, in this case, the asymmetry between long and short position is more pronounced.

Period	Profit (€)	Profit (%)
2017	-127 250,00 €	-9,25%
2016	-338 325,00 €	-19,74%
2015	931 725,00 €	119,12%
2014	134 925,00 €	20,85%
2013	-362 200,00 €	-35,88%
2012	331 725,00 €	48,95%
2011	420 700,00 €	163,66%
2010	-32 075,00 €	-11,09%
2009	129 425,00 €	81,04%
2008	59 700,00 €	59,70%

From annual period analysis is possible to notice a greater instability of the returns generated by the strategy. This riskier approach enhances both profits and losses but generates a very high level of exposure to a large drawdown compared to the previous two models. The enhancement of negative returns is due to the strategy's cost of slippage.

Looking at the metrics of the performance report, the most efficient money management system for this strategy and instrument is the fixed ratio. Now let's see if the results of the Montecarlo analysis are aligned with the first consideration made.

The simulation results for Fixed Ratio are presented below, starting from the analysis of the drawdown scenario and subsequently from the analysis of the return scenario.

Max DD	604.225,00 €	
Max DD%	66,30%	

Average DD	25,45%	
-/+1 SD	19,22%	33,71%
-/+2 SD	14,51%	44,65%
-/+3 SD	10,95%	59,15%

DD distribution

The first model shows that within 1000 simulations the maximum drawdown obtained is 66,30% compared to the 22,20% of the performance report, this value is found at the end of the right tail of the distribution of DD distribution. The average drawdown observed is 25,45%, moreover in 68% of cases the drawdown should be between 19,22% and 33,71%. Focusing on the worst scenario only, this money management model applied to the basic strategy in 95% of cases should generate a DD of less than 44,65%, and there is a 1% probability that the maximum drawdown will be higher than 59,15%.

Max Equity	4.464.350,00 €	4364,35%
Min Equity	105.275,00 €	5,28%

Average Equity	1.090.834,62 €	
-/+1 SD	611.539,50 €	1.945.778,12 €
-/+2 SD	342.838,92 €	3.470.785,02 €
-/+3 SD	192.201,03 €	6.191.018,68 €

Return distribution

Looking at the distribution of the 1000 simulation returns, in 99,6% of the scenario the strategy generates a return of more than 200%. More in detail, in 55,7% of cases, the strategy provides returns higher than 1000% and in 29% of the outcomes the returns are between 500 and 1000 percent. The average net profit obtained is 1,01M euros, with the maximum return equal to 4364,35% and the

minimum of 5,28% (this result corresponds to a probability of 0,2%). From the normal distribution assumption, there is a 32% chance that returns are less than 611%, 5% that they are less than 342% and only 1% that they are less than 192% over 10 years of trading.

Now, let's proceed with the Montecarlo analysis on the Fixed fractional method.

Max DD	896.625,00 €	
Max DD%	52,03%	

Average DD	25,86%	
-/+1 SD	20,14%	33,19%
-/+2 SD	15,69%	42,60%
-/+3 SD	12,23%	54,68%

Compared to the fixed ratio model, the percent f simulations generate a lower maximum drawdown in percentage terms but higher in monetary terms. The average drawdown is very close, with a slight improvement in results considering one, two and three standard deviations from the average.

Max Equity	5.643.700,00 €	5543,70%
Min Equity	143.975,00 €	43,98%

Average Equity	1.198.953,02 €	
-/+1 SD	585.883,53 €	2.453.539,43 €
-/+2 SD	286.299,38 €	5.020.927,14 €
-/+3 SD	139.903,81 €	10.274.833,59 €

The metrics of possible performance outcomes also improved, in particular in the worst possible scenario which generates 43.98% (with 0.1% probability) compared to the previous 5.28%. In this case, the strategy generated a return of over 200% 96.5% of the time.

Let's now proceed with the results obtained from the application of the percent volatility model.

Max DD	846.025,00 €	
Max DD%	86,97%	

Average DD	43,44%	
-/+1 SD	32,99%	57,20%
-/+2 SD	25,06%	75,31%
-/+3 SD	19,03%	99,16%

The outcomes with this model are highly unstable compared to the previous two models as also anticipated from the performance report. The maximum DD registered is 86,97%, going deeper into the analysis there is a 32% probability that the DD is higher than 57,20%, a 5% probability of losing more than 75,31% and the 1% chance that the negative returns are greater than 99,16%, so almost all the initial capital.

Max Equity	5.026.550,00 €	4926,55%
Min Equity	20.950,00 €	-79,05%

Average Equity	658.772,17 €	
-/+1 SD	224.209,68 €	1.935.602,28 €
-/+2 SD	76.308,60 €	5.687.180,42 €
-/+3 SD	25.971,24 €	16.710.055,29 €

In this case, the worst case scenario is to lose 79,05% of the initial capital, while with the other strategy all the 1000 simulations were able to generate positive returns. There is a 13,2% probability that the strategy generates negative outcomes, which is also shown by the average return of 65,87% lower than the two previous models and the fatter left tail in distribution.

From the Montecarlo analysis, it seems that the two best models in terms of stability and risk-return trade-off are the fixed ratio and the fixed fractional method. Since these are quite similar results, the choice of the model is mainly based on the analysis of the performance report metrics. Thanks to the

lower exposure to costs and the more stable change in the number of contracts used, the fixed ratio is chosen.

The last step is the optimisation of inputs of the strategy with selected money management model applied (MM1 strategy), and the observation of the OOS results with a comparison between the single contract based strategy (MM0 strategy) and the buy and passive hold approach. From ES optimisation for MM1 strategy the best inputs for SL and TP are 2500 and 3500, for MM0 strategy they are 2500 and 0.

Let's start from the MM0 OOS results.

	All Trades	Long Trades	Short Trades
Net Profit	61 350,00 €	23 675,00 €	37 675,00 €
Max Strategy Drawdown (%)	-11,76%	-15,20%	-11,67%
Slippage Paid	23 000,00 €	11 500,00 €	11 500,00 €
Return on Initial Capital	61,35%	23,68%	37,68%
Annual Rate of Return	15,37%	5,93%	9,44%
% Profitable	51,10%	55,32%	46,59%
Max # Contracts Held	1	1	1

Return on Max Strategy Drawdown	3,17
Profit Factor	1,46
Annualized Sharpe Ratio	0,93
RINA Index	1.017,04

At first glance, it is possible to observe that the strategy generates a positive return of 61,35% with an average annual rate of return of 15,37%. Observing the DD and the return it is possible to notice a slight asymmetry between long and short position. In the 4 years of OOS the short position generates higher profits and lower drawdowns than to long one. The ratios are quite satisfactory, with the Rina index largely positive, and the annualised Sharpe ratio and the profit factor close to 1 and 1,5. This ensures a quite efficient risk adjusted return.

Period	Profit (€)	Profit (%)
2021	7 325,00 €	4,76%
2020	23 600,00 €	18,09%
2019	-4 850,00 €	-3,59%
2018	35 275,00 €	35,28%

The strategy generates positive cost adjusted return in 3 out of 4 years with the 2018 as best year with 35,28% performance, and the worst is the 2019 with -3,59%. From the IS results, it is expected that the strategy with the fixed ratio applied could enhance both losses and profits, in particular a more severe drawdown is expected in 2018.

Now let's observe the results from the MM1 strategy.

	All Trades	Long Trades	Short Trades
Net Profit	257 875,00 €	100 775,00 €	157 100,00 €
Max Strategy Drawdown (%)	-30,69%	-50,03%	-28,42%
Slippage Paid	46 050,00 €	24 575,00 €	21 475,00 €
Return on Initial Capital	257,88%	100,78%	157,10%
Annual Rate of Return	64,60%	25,24%	39,35%
% Profitable	54,50%	56,00%	53,00%
Max # Contracts Held	8	8	8

Return on Max Strategy Drawdown	2,43
Profit Factor	1,34
Annualized Sharpe Ratio	1,06
RINA Index	1.243,25

Period	Profit (€)	Profit (%)
2021	58 875,00 €	19,69%
2020	95 050,00 €	46,60%
2019	-21 125,00 €	-9,39%
2018	125 075,00 €	125,08%

These results confirm the IS evidence. The strategy with money management highly enhances profit but also losses. In particular, the strategy now generates a return of 257,88% compared to the previous 61,35%. The additional profit is implied by additional risk found in the maximum DD of 30,69%,

approximately 3x with respect to the previous value of 11,76%. The maximum number of contracts reaches 8 per trade, which again implies an increase in the paid slippage by almost 2x. The asymmetry identified in MM0 is still present with more evident negative results in terms of drawdown for long positions. It is possible to observe contrasting results in terms of performance ratios. There is a worsening of the return of max strategy drawdown and of profit factor, but an improvement of the annualised Sharpe ratio and of Rina index. Again, the strategy demonstrates sufficient risk adjusted performance. A comparison of the annual report analysis showed that the increase in profits and losses is not linear with an improvement in positive returns greater than the negative ones.

Now to observe if these profits are sufficient to outperform the benchmark index let's compare with the buy and hold passive strategy.

The total return of the buy and hold strategy is 21 443,36 € which is lower than MM1 strategy return of 257 875,00 €, so active exposure outperforms the market more than ten times. Moreover, is possible to observe that the results are more stable and growing with a moderate drawdown compared to the index. The higher efficiency is also demonstrated by the time on the market of MM1 strategy which is only 3,30% of the time. Recall that the longer the time in the market the greater the possibility of being exposed to unforecastable events and to noise of the market, both of which have a negative impact on the stability and return of the strategy used.

To recap, the effective control of the strategy risk starts from the determination of the single trade risk with the different setting of stoploss, take profit, and trailing stops. They can be set dynamically or statically (point, monetary), in order to allow traders to limit losses and enhance profits. Even if the use of the trailing stops and take profit is not mandatory, a stoploss level should always be set in order to protect the capital in the event of high volatility of the market or not predictable events (black swan).

The second step is the evaluation of money management model to apply to the strategy. The first analysis can be done using the strategy valuation method presented in the previous chapter through

the performance report metrics. The second evaluation can be done through the Montecarlo simulation. With this method is possible to avoid overfitting results and increase the range of possible scenarios through 1000 or more simulations. The main outputs to watch out for are the drawdown analysis and the return analysis. These analyses return information on the probability and on the statistical measure of possible outcomes of the strategy in order to have a more reliable expectation of both positive and negative results.

An important note is that it is suggested to always take into consideration the possible costs in the valuation of the money management models because, as shown in the example, they could drastically change the possible outcomes of strategies. These models imply an escalation of the number of contracts used and consequently the cost of the strategy.

The choice and the setting of the models' inputs are heavily affected by risk aversion and trader preferences. Some very risk-averse traders may still prefer to use the fixed contract method as it generates the lowest drawdown or use models with less aggressive parameters than the one presented in the example. In the opposite case, if traders are risk lover, they would use models with inputs that generate a higher level of risk exposure as they are more focused on the potential profit than the potential loss. For these traders it is always useful remember that the results obtained from the evaluation of the models during the test could differ from the real trading results, and that the higher exposure also implies the worsening emotivity management by operators who could end up in stop and start the system multiple times influencing the strategy as a discretionary rather than a systematic trader.

Position sizing models are very useful to enhance profit and mid/long term return of the strategy, but traders should always be aware of their loss aversion and should adopt a risk management approach that focuses on potential loss rather than potential profit.

Chapter 4

Portfolio Construction

The fourth and final chapter is related to the main aims of this dissertation, the "portfolio construction". It starts with the introduction of the evolution of portfolio theory, from Markowitz to Post Modern Portfolio Theory. The next section is related to Pearson's Linear correlation coefficient, which is fundamental to understanding the subchapter related to diversification both in terms of asset selection and strategies. Subsequently, different types of portfolios are presented. The following subchapter is related to the position sizing with the introduction of capital allocation and position sizing models for portfolios. Next, there is the section dedicated to the portfolio management with focus on how to filter, select, and stop the strategies inside a fully diversified portfolio. Finally, also this chapter ends with a practical example of the application of concepts mentioned in the chapter.

4.1 Evolution of portfolio theory

Modern Portfolio Theory (abbreviated as MPT), also known as Markowitz Portfolio Theory or simply Portfolio Theory, is a theory developed by Harry Markowitz and published in the Journal of Finance in 1952. Prior to this brilliant theory, investors used empirical techniques to build their portfolios, attempting to intuitively evaluate the values for the risk and return of their investment, instrument by instrument; in fact, they focused their research on those tools that could offer the best prospect of profit while also posing the lowest risk.

This evaluation was deemed sufficient to include an asset in one's portfolio, but the investment strategy leads to the selection of highly correlated instruments, resulting in the portfolio's long-term failure. In fact, by selecting all securities with similar performance in the short term, instruments whose return is dependent on the same causes are included in the investment: when these lose their effects and prices collapse, the entire portfolio is at risk. Markowitz's intuition was a shift in perspective: he emphasized how the portfolio, rather than individual instruments, should present an adequate risk/reward ratio. Unlike in the past, he believed that risk and return analysis should be performed on the entire portfolio, rather than title by title. Markowitz was able to formalize his approach by describing the theory of diversification using a comprehensive mathematical model. Without going into too much detail, keep in mind that the model treats profits as a random variable to which you can assign expected values, calculate the standard deviation, and then calculate the correlation. For each portfolio constructed according to this rule, volatility and expected returns become a representation of risk and return, respectively. Within all possible portfolios, those that optimize the balance between risk and return make up the efficient frontier. As a result, the investor should select a portfolio that is as close to the border as possible, and ideally, the portfolio should be on it.

This theory's key findings imply that portfolio volatility is less than the weighted average invested volatility for each component. The efficient frontier curve represents all infinite portfolios that maximize returns for a given level of risk or minimize risk for a given level of returns. Mean-Variance Optimisation (MVO) is the algorithm used to generate the curve because what is optimized is the return relative to the standard deviation or the variance relative to the average of the returns. Although this theory is widely used in textbooks to describe risk/reward theory, Markowitz himself believed that a normal distribution of variance was an inadequate measure of risk. Models that use asymmetric and fat-tailed distributions to describe risk were then proposed: all of the proposals born as observations or criticisms of Markowitz's theory comprise what is known as Post-Modern Portfolio Theory (PMPT).

The combination of advances in portfolio theory and the increasing computing capacity provided by constant technological evolution has resulted in the Post-Modern Portfolio Theory supplanting the previous theory in quality, which simply becomes, within the revised model, a specific case characterized by a symmetrical distribution (Brian M. Rom and Kathleen W. Ferguson in Post-Modern Portfolio Theory Comes of age, The Journal of Investing, 2 (4) 27-33, (Winter 1993))

There is no significant exponent of the Post-Modern Portfolio Theory (PMPT) because it emerges as a multilateral response from various academic circles to the now-discussed Markowitz theory. As a result, there is no unambiguous definition of this theory that collects different sources. This term refers to both the formal model of asset allocation theories that use risk measures other than the MVO and any improvement or extension to the Markowitz theory. Because both models describe how rational investors should use diversification to optimize their investment portfolio, it is frequently defined as an extension of the traditional Modern Portfolio Theory. The primary distinction between PMPT and Markowitz and Sharpe's Modern Portfolio Theory (MPT) is the different asset allocation strategy employed. According to its supporters, PMPT advances investment science by incorporating behavioural finance and other innovations that result in higher long-term returns.

The PMPT is used in this dissertation to select different active strategies in different markets. Diversification among strategies, filters to select the best strategies to incorporate into the diversified portfolio, and position sizing techniques to implement capital allocation efficiency improve the overall performance of the portfolio.

4.2 Pearson's Linear correlation coefficient

The linear correlation, which yields a value called the correlation coefficient r, expresses the strength of the relationship between the data on a scale from +1 to -1. When two price series have a negative

correlation, it means that when one rises, the other falls. There is a perfect positive correlation when $r = +1$, no correlation when $r = 0$, and a perfect negative correlation when $r = -1$.

To calculate the correlation coefficient, r, for the most recent n days, where t is today, it is used the Pearson's Product-Momentum Correlation (named after Karl Pearson who formulated the correlation coefficient from a related idea by Francis Galton in the 1880s):

$$r = \frac{1}{N} \sum_{I=T-N+1}^{T} \left| \left(\frac{x_i - \bar{x}}{\sigma_x} \right) \left(\frac{y_i - \bar{y}}{\sigma_y} \right) \right|$$

Where σ_x and σ_y are the standard deviation of x and y, and $\bar{x}$ and $\bar{y}$ are the averages. Following there is a graphical representation of the possible results.

Perfect Positive Correlation	Highly Positive Correlation	Low Positive Correlation	No Correlation	Low Negative Correlation	Highly Negative Correlation	Perfect Negative Correlation
r =1	r =0.8	r =0.3	r =0	r =-0.3	r =-0.8	r =-1
(a)	(b)	(c)	(d)	(e)	(f)	(g)

When r equals one, it denotes a perfect positive linear correlation. The data points are along a straight line going upward to the right (a). For every upward move in x, there is a corresponding upward move in y. When $+1 > r > 0$, the scattered points become more uniformly distributed about a positive approximation line since the value of r becomes closer to +1 (b-c). There is no linear correlation when r is equal to 0 (d). When $-1 < r < 0$, the scattered points become more uniformly distributed about a negative approximation line since the value of r becomes closer to -1 (e-f). Finally, when r is equal to -1, there is a perfect negative linear correlation, and the line goes downward to the right. Every upward movement in x corresponds to a downward movement in y (g).

Most price analyses employ two-time series, and a strong trend can exaggerate correlations by overshadowing the smaller movements. Correlations should be fed returns or price changes rather than actual prices. It is preferable if these changes are expressed in percentages, but for back-adjusted futures data, price differences should be used.

4.3 Diversification

Diversification means spreading risk across multiple markets to reduce portfolio risk exposure. To reduce risk, we must distinguish between systematic risk, which can be reduced through diversification, and market risk, which cannot be eliminated (Kaufman Perry J., Trading System and Methods, six ed, Wiley Trading Series, (2013).

When the markets traded have different price movements and the methods of making trading decisions are unrelated, the benefits of diversification are greatest. Fixed income, equities, real estate, art, and various investment philosophies are common components of typical investment portfolios. These all work together to provide different rates of return with different patterns, ensuring that they do not suffer losses at the same time. Market risk, including price shocks and catastrophic risk, is unpredictable and can catch even the most seasoned investors off guard. The subprime mortgage crisis of 2008 demonstrated that diversification can vanish under pressure. Even in a random scenario of up or down, the prices of two independent markets will move in the same direction 50% of the time.

Practical diversification can begin with a broad range of markets and a single tactical approach, a variety of trading strategies for a single product, or a combination of multiple systems and many markets. Diversification can be accomplished through two main processes: the selection of individual assets from unrelated groups, as well as the application of multiple strategies.

4.3.1 Asset selection

The risk is reduced in the first process by spreading trading across markets that have as little relationship to one another as possible. This can be measured as a low covariance or low correlation. Limiting the assets to exchange-traded stocks, futures, and funds, market groups can be roughly classified, in order of liquidity, like fixed income, currencies, equities and equity index, energy, industrial and precious metals, grains, livestock, foods, and miscellaneous. The final category includes wood and other products.

Equities are divided into several industrial sectors, including technology, health care, and utilities. Because most of those groups tend to react to the same broad economic conditions, the degree of diversification among them is limited. Financials is a broader category that includes fixed income, currencies, and index markets. While these sectors can move independently in the short term, they are known to have strong fundamental interdependence. When an economic report is released, the relative direction of all financial markets follows a predictable pattern. For example, a stronger-than-expected GDP announcement in the United States will first cause Treasury prices to fall (yields to

rise because a strong economy eventually causes inflation), then the US dollar to strengthen (people buy dollars to invest in the United States), and the stock market will rise. If a portfolio allocation is to provide the best solution, it must be able to exploit these relationships. Aside from financial markets, other commodities are affected by changes in interest rates and the US dollar. Oil, gold, and grain prices rise as the US dollar weakens. These products have international value because they are traded on active global markets. Although we recall news coverage that causes high volatility and correlated movement between groups, there are long periods when commodity prices are not influenced by news or financial markets. Agricultural markets have little to do with metals during those periods, and each asset class moves according to its fundamentals.

It is possible to see that increasing the number of assets in the portfolio reduces total risk. This diversification only eliminates unsystematic risk, not systematic risk. It should be noted that the reduction in the risk exposure to the portfolio is relevant when the assets included change from 1 to 20, but as more assets are added (from 20 to 1000), the improvement due to diversification diminishes and becomes less meaningful.

4.3.2 Multiple Strategies

Given the higher degree of correlation between markets under stress, employing a variety of strategies should provide better diversification during times of uncertainty. Although some techniques appear to be different, they may be highly related. It is best to choose strategies with different functional

attributes for system diversification. The following methods are less likely to be correlated with one another:

- Trend-following (moving averages, point-and-figure, breakout)
- Countertrend or mean-reverting (stochastic, contrary opinion, Hilbert)
- Spreading (pairs trading, sector neutral, arbitrage, product)
- Fundamental (value, supply and demand, P/E ratio)
- Carry programs, convenience yield, and implied yield
- Patterns (divergence, charting formations)

Each of the six techniques is conceptually distinct. Trend-following strategies attempt to take positions in the direction of the major price movement, whereas mean-reverting strategies aim for short holding periods and the opposite position. Spreads are typically directionally neutral and benefit only from the relative movement of two markets, whereas fundamentals use value and various other statistics to take a long-term position without the benefit of timing. Carry programs and yield extraction target price components, and patterns can take any formation. These various strategies can hold conflicting positions in the same market at the same time, lowering overall risk.

4.4 Type of portfolio

It is possible to achieve a higher risk-adjusted return by utilizing diversification. As previously stated, different asset classes and strategies can be used to achieve this improvement in return efficiency. It is possible to obtain the various types of portfolios by employing the technique described above. Three major possible combinations are investigated. The first portfolio can be built with a single strategy applied with different inputs on different markets, the second on different strategies on a single instrument, and the third, which should be the most diversified, on the application of different strategies in different markets.

Let's start with the first portfolio based on a single strategy. This operativity aims to use a unique strategy with different inputs on different markets. It is related to the first principle of diversification in that increasing the number of asset classes reduces overall portfolio risk if these assets are not highly positively correlated. The main disadvantage of this approach is the difficulty in identifying a strategy that generates positive returns on different instruments. Most instruments and markets have intrinsic characteristics that respond better to different trading approaches; for example, a strategy that generates a high return on gold does not necessarily imply a high return on silver.

The portfolio in the following example is based on a strategy applied to different markets, with different inputs used in each market and specific settings for each market. The strategy is applied to a basket of currency futures in this case, but it could also be applied to other markets, and it is based on the false breakout principle. A false breakout occurs when a price re-entry occurs following a breakout, i.e. the price movement moves in the opposite direction to the breakout.

```
input: size(1);
input: strartT(1700), endT(1600);
input: SL(0.01),TP(0);
vars:timew(false);

timew=tw(strartT,endT);

if timew and (HighD(1)-lowD(1))<(highD(2)-lowD(2)) then begin
    if Close crosses over lowD(1) then buy("LE") size contracts next bar market;
    if Close crosses under highD(1) then sellshort("SE") size contracts next bar market;
end;

setstopcontract;
if SL>0 then setstoploss(SL*bigpointvalue);
if TP>0 then setprofittarget(TP*bigpointvalue);
```

The strategy is based on a single contract per trade. It employs a temporal filter to determine the best time window for trading, as well as a volatility filter based on range. More specifically, the range from yesterday must be lower than the range from two days ago, which represents a congestion pattern. Long trades occur when the close crosses from below the level of the low of yesterday, and short trades are places when the close crosses from above the high of yesterday. The inputs chosen from the optimisation process for each instrument are shown below.

Currency	startT	endT	SL	TP
AD (Australian Dollar)	300	1900	0,01	0
BP (British Pound)	1400	1600	0,02	0,015
EC (Euro Currency)	2200	1200	0,015	0
CD (Canadian Dollar)	300	1200	0,01	0,02
JY (Japanese Yen)	1300	0	0,02	0,02

It should be noted that with the different time windows used, the strategy operates on different currencies at different intervals, improving the portfolio's diversification. The main results for the individual instruments are presented below.

Market	Net Profit	Max. Equity Draw Down(%)	Annualized Sharpe Ratio	Profit factor
@AD	77.260,00	-11,40%	0,47	1,37
@BP	20.968,75	-4,75%	- 0,13	1,36
@EC	124.812,50	-12,55%	0,71	1,39
@CD	30.360,00	-20,36%	0,07	1,29
@JY	99.643,75	-10,84%	0,68	1,57

	Profit (%)				
	AD	**BP**	**CD**	**EC**	**JY**
2021	**-1,48%**	0,12%	0,25%	8,92%	**-1,12%**
2020	8,32%	2,16%	7,56%	**-1,34%**	0,28%
2019	0,63%	2,14%	**-2,55%**	**-1,58%**	1,07%
2018	8,76%	**-0,53%**	4,07%	**-4,04%**	**-0,98%**
2017	**-2,85%**	2,84%	15,03%	1,86%	1,48%
2016	13,85%	**-2,61%**	5,78%	10,34%	5,98%
2015	**-5,82%**	6,87%	9,54%	14,46%	12,20%
2014	**-2,48%**	0,75%	**-2,14%**	**-2,35%**	14,34%
2013	7,84%	1,63%	3,69%	-3,81%	10,58%
2012	**-5,94%**	**-1,48%**	3,08%	6,52%	7,75%
2011	16,07%	1,47%	**-9,30%**	24,95%	15,59%
2010	26,70%	6,24%	**-5,72%**	38,15%	5,01%

All strategies generated positive returns with the maximum provided by the Euro Currency of 124.812,50. The maximum drawdown occurred with the Canadian Dollar currency at -20,36%. The Annualized Sharpe Ratios for individual currencies are not sufficient, the highest one is for the Euro Currency at 0,71 while the lowest and negative one is that of the British Pound. The profit factor values are quite efficient with the Japanese yen high being 1,57. The annual report for the period shows that on average the individual instruments generate 4 years with a negative return compared to the 12 examined. Note that these negative returns occur in different years, this should imply a negative correlation between currencies.

The annual correlation coefficient results are shown below.

	@AD	**@BP**	**@EC**	**@CD**	**@JY**
@AD	1,00	- 0,03	0,31	- 0,38	- 0,14
@BP	- 0,03	1,00	0,31	0,03	0,16
@EC	0,31	0,31	1,00	- 0,39	0,24
@CD	- 0,38	0,03	- 0,39	1,00	- 0,20
@JY	- 0,14	0,16	0,24	- 0,20	1,00

According to this table, the Canadian Dollar provides the most diversification because it is negatively correlated with three currencies out of four, and the fourth one has approximately zero correlation. Another improvement in the diversification is added by the Japanese Yen which is negatively correlated with the Australian Dollar. With these results, it is expected that the portfolio's overall and average drawdown will be lower than those shown above. With lower DD also the performance ratios are expected to be improved as the overall performance of the system.

The results for the overall portfolio are shown below.

Net Profit	353.045,00
Max Portfolio Drawdown (%)	-11,63%
Annualized Sharpe Ratio	1,11
Profit Factor	1,41

Period	Net Profit	% Gain	Average Profit
2021	14.035,00	3,21%	83,54
2020	23.228,75	5,60%	155,90
2019	- 898,75	-0,22%	- 6,91
2018	6.575,00	1,61%	45,03
2017	21.328,75	5,50%	143,15
2016	53.147,50	15,89%	359,10
2015	52.678,75	18,70%	365,82
2014	11.740,00	4,35%	86,96
2013	22.668,75	9,17%	160,77
2012	12.952,50	5,53%	74,44
2011	64.002,50	37,56%	392,65
2010	70.380,00	70,38%	406,82

The overall portfolio's return is positive; more specifically, it is the sum of all individual profits from a single instrument since they are all applied to the same capital. However, even if the profit is the sum of the individual returns, the drawdown due to diversification is less than the individual sum. More specifically, the maximum DD is only 11,63%, as opposed to the previous -20%. The average percentage drawdown is close to 5%, and the monetary drawdown is close to 15.000, with peaks approaching 20.000. The performance ratios have been improved, the profit factor is higher than the average for single currencies, and the Annualised Sharpe Ratio is more efficient because it is greater than 1 with a value of 1,11. The equity line is stable and growing, indicating overall portfolio stability.

The annual period analysis reveals only one negative year with a performance of -0.22% in 2019. This result is very close to the break-even point and is significantly lower than the worst years in individual currencies (2011 – CD) of -9.30%.

The second portfolio is based on a single instrument and employs various strategies to maximize diversification. More specifically, this approach is the starting point for constructing a fully diversified portfolio (the third one), because the procedure applied to the single instrument can be replicated with other instruments to retrieve a multimarket or sectorial diversified portfolio. The minimum number of strategies that should be used to build a portfolio on a single instrument is 3, and these strategies can be trend following, reversal, bias, or a combination of them. Diversification can also be done with the strategy's timing and duration.

In the following example, a portfolio on Dax futures is built using three strategies. The first strategy is the intraday trend, which is similar to the strategy discussed in the previous chapter, the second is Andrea Unger's Dax first hour which is presented in the bias strategy example, and the third is another bias strategy that captures the overnight movement of the Dax.

```
input: startT(1800), endT(2155), exitT(0900);
input: Size(1), SL(3000);

if Time>=startT and Time<endT then buy("LE") Size contracts next bar market;
if marketposition=1 and Time>=exitT and Time<startT then sell("LX") next bar market;

setstopcontract;
```

This is a simple strategy for capturing the movement of the Dax throughout an overnight period. It operates within a 5-minute timeframe, opening a long position at 18:05 and closing the position at 9:05 exchange time if the position is still open and the stop loss has not yet been taken. Because it operates in different time windows than the other two strategies, this strategy should provide a significant improvement in portfolio diversification.

The results for single strategies are shown below.

Strategy	Net Profit	Max. Equity Drawdown(%)	Annualized Sharpe Ratio	Profit factor
Intra_trendF	213.350,00	-9,25%	0,77	1,64
First_Hour	163.700,00	-14,59%	0,84	1,38
Night_Dax	326.075,00	-19,98%	1,12	1,20

	Profit (%)		
	Intra_trendF	First_Hour	Night_Dax
2021	3,70%	3,24%	12,14%
2020	7,43%	22,99%	5,30%
2019	-0,12%	4,45%	4,58%
2018	24,00%	-6,33%	5,87%
2017	1,92%	-2,56%	15,66%
2016	-2,27%	3,39%	2,97%
2015	25,32%	13,99%	18,81%
2014	9,38%	14,16%	19,25%
2013	-5,01%	5,90%	16,48%
2012	8,40%	14,19%	16,21%
2011	60,03%	23,57%	0,64%
2010	0,95%	8,35%	41,28%

The strategies, particularly the overnight Dax strategy, generate positive and relevant profit. The overnight Dax has a maximum drawdown of -19,98%, most likely due to the exposure to gaps. The Annualized Sharpe Ratios for the single strategies represent adequate efficiency in the return generated by risk exposure, with the overnight Dax having the highest at 1.12. The profit factor values are quite efficient, with the intraday trend following strategy having the highest of 1,64. According to the annual period report, the intraday trend following strategy generates three years of losses, the first-hour strategy generates two years of negative returns, and the overnight Dax generates all positive returns over the 12 years under consideration.

The annual correlation coefficient results are shown below.

	Intra_trendF	First_Hour	Night_Dax
Intra_trendF	1,00	0,16	- 0,24
First_Hour	0,16	1,00	- 0,16
Night_Dax	- 0,24	- 0,16	1,00

As evidenced by the previous results, the overnight Dax strategy can provide the greatest diversification benefit to the portfolio. It has a negative correlation with both the other strategies. Furthermore, the first-hour strategy has a low correlation with the intraday trend following system.

The portfolio results are shown below.

Net Profit	703.125,00
Max Portfolio Drawdown (%)	-10,27%
Annualized Sharpe Ratio	1,60
Profit Factor	1,29

Period	Net Profit	% Gain	Average Profit
2021	65.437,50	8,89%	169,09
2020	87.687,50	13,52%	221,99
2019	24.250,00	3,88%	60,47
2018	60.150,00	10,66%	155,03
2017	42.662,50	8,18%	115,30
2016	10.062,50	1,97%	25,60
2015	115.112,50	29,05%	294,41
2014	75.575,00	23,56%	201,53
2013	27.475,00	9,37%	70,09
2012	55.625,00	23,41%	151,57
2011	87.037,50	57,80%	222,60
2010	50.575,00	50,58%	140,88

As with the previous portfolio, the maximum drawdown of the strategy is reduced in this case, while performance and return stability are improved. More in detail, the Annualised Sharpe Ratio is 1,6, implying a very high risk-adjusted return level. The average drawdown is close to 5%, with peaks of

10%, such as in March 2020. These peaks demonstrate the strategy's high level of stability, as the Dax drops by around 30% during the same month in March 2020. The portfolio's diversification allows it to provide all positive and consistent returns.

The third type of portfolio is a hybrid of the previous two approaches. It is built by combining diversification across asset classes with ad hoc strategy diversification for each market. When combining different instruments, it is important to look for synergy between instruments with similar "weights," rather than combining a system on the Silver (SI) with a system on the Cocoa (CC), which, while it may be an excellent combination, is difficult to evaluate unless the number of contracts of the lightest system is increased sufficiently. The instruments' weights can be determined by computing the dollar value ATR of the last 45 days. The reference weights for the majority of traded futures are shown below. These data are obtained by calculating the ATR*big point value of the instrument with 45 days average. The count of the days starts backward from 01/01/2022.

Index	ATR	Treasury	ATR	Commodity	ATR	Currency	ATR	Others	ATR
FDAX	5070	US	1460	GC	2220	CD	500	OJ	625
FESX	615	TY	630	SI	2720	BP	560	CC	570
NQ	5750	FGBL	836	HG	2530	AD	620	FC	1180
ES	3015			NG	3250	EC	1070	W	1115
YM	2165			CL	3025	JY	670	S	1160

Note that these values change over time, so during periods of high volatility, the weights for certain assets are higher than their average. These values are not absolute and should be recalculated on a regular basis for more meaningful references. The basic principle for constructing this portfolio is to try to mix very different markets, different entry logics, strategies with entrances at different times of day, and a focus on market characteristics.

The table below shows the annual correlation coefficient among the futures mentioned above on a passive buy and hold strategy. The time horizon of the calculation starts from 01/01/2010 to 01/01/2022.

	@FDAX	@FESX	@NQ	@ES	@YM	@US	@TY	@FGBL	@GC	@SI	@HG	@NG	@CL	@CD	@BP	@AD	@EC	@JY	@OJ	@CC	@FC	@W	@S
@FDAX	1,00	0,92	0,47	0,74	0,77	-0,26	-0,31	-0,46	-0,04	0,08	0,59	0,08	0,46	0,41	0,40	0,11	0,25	-0,35	-0,26	0,15	-0,19	0,30	0,45
@FESX	0,92	1,00	0,46	0,79	0,79	-0,42	-0,52	-0,53	-0,25	-0,16	0,44	0,34	0,52	0,23	0,33	-0,18	0,06	-0,51	-0,39	0,28	-0,16	0,28	0,23
@NQ	0,47	0,46	1,00	0,85	0,65	0,10	-0,00	-0,36	0,23	0,18	0,54	0,12	0,27	0,31	0,38	0,09	0,32	-0,04	-0,13	0,18	-0,13	0,41	0,29
@ES	0,74	0,79	0,85	1,00	0,92	-0,12	-0,26	-0,46	0,02	-0,02	0,60	0,30	0,59	0,41	0,36	-0,00	0,22	-0,28	-0,18	0,07	-0,03	0,34	0,27
@YM	0,77	0,79	0,65	0,92	1,00	-0,13	-0,31	-0,45	-0,01	-0,07	0,59	0,22	0,69	0,52	0,37	0,05	0,35	-0,22	-0,23	-0,11	0,05	0,16	0,17
@US	-0,26	-0,42	0,10	-0,12	-0,13	1,00	0,95	0,79	0,69	0,36	-0,12	-0,71	-0,35	0,23	0,11	0,51	-0,00	0,46	-0,02	-0,38	0,38	-0,05	-0,14
@TY	-0,31	-0,52	-0,00	-0,26	-0,31	0,95	1,00	0,74	0,68	0,41	-0,18	-0,79	-0,37	0,17	0,14	0,55	0,01	0,52	0,11	-0,37	0,21	-0,08	-0,05
@FGBL	-0,46	-0,53	-0,36	-0,46	-0,45	0,79	0,74	1,00	0,38	0,12	-0,43	-0,40	-0,54	-0,06	-0,31	0,19	-0,35	0,20	0,09	-0,35	0,41	-0,21	-0,24
@GC	-0,04	-0,25	0,23	0,02	-0,01	0,69	0,68	0,38	1,00	0,87	0,46	-0,61	0,01	0,66	0,10	0,87	0,16	0,74	-0,09	-0,40	0,05	0,50	0,28
@SI	0,08	-0,16	0,18	-0,02	-0,07	0,36	0,41	0,12	0,87	1,00	0,65	-0,48	0,04	0,64	0,02	0,87	0,15	0,70	0,05	-0,21	-0,07	0,69	0,59
@HG	0,59	0,44	0,54	0,60	0,59	-0,12	-0,18	-0,43	0,46	0,65	1,00	0,03	0,50	0,78	0,21	0,61	0,37	0,20	-0,01	-0,10	-0,01	0,73	0,73
@NG	0,08	0,34	0,12	0,30	0,22	-0,71	-0,79	-0,40	-0,61	-0,48	0,03	1,00	0,29	-0,22	-0,38	-0,66	-0,19	-0,59	0,13	0,23	-0,16	0,04	0,05
@CL	0,46	0,52	0,27	0,59	0,69	-0,35	-0,37	-0,54	0,01	0,04	0,50	0,29	1,00	0,57	0,16	0,15	0,21	0,05	0,04	-0,37	-0,18	0,17	0,20
@CD	0,41	0,23	0,31	0,41	0,52	0,23	0,17	-0,06	0,66	0,64	0,78	-0,22	0,57	1,00	0,34	0,79	0,51	0,32	-0,12	-0,43	0,09	0,50	0,56
@BP	0,40	0,33	0,38	0,36	0,37	0,11	0,14	-0,31	0,10	0,02	0,21	-0,38	0,16	0,34	1,00	0,26	0,63	-0,19	-0,54	0,30	0,10	0,15	0,15
@AD	0,11	-0,18	0,09	-0,00	0,05	0,51	0,55	0,19	0,87	0,87	0,61	-0,66	0,15	0,79	0,26	1,00	0,36	0,65	0,05	-0,46	0,11	0,46	0,51
@EC	0,25	0,06	0,32	0,22	0,35	-0,00	0,01	-0,35	0,16	0,15	0,37	-0,19	0,21	0,51	0,63	0,36	1,00	0,02	-0,10	-0,07	-0,15	-0,05	0,34
@JY	-0,35	-0,51	-0,04	-0,28	-0,22	0,46	0,52	0,20	0,74	0,70	0,20	-0,59	0,05	0,32	-0,19	0,65	0,02	1,00	0,21	-0,51	-0,09	0,16	-0,02
@OJ	-0,26	-0,39	-0,13	-0,18	-0,23	-0,02	0,11	0,09	-0,09	0,05	-0,01	0,13	0,04	-0,12	-0,54	0,05	-0,10	0,21	1,00	-0,48	-0,18	-0,29	0,27
@CC	0,15	0,28	0,18	0,07	-0,11	-0,38	-0,37	-0,35	-0,40	-0,21	-0,10	0,23	-0,37	-0,43	0,30	-0,46	-0,07	-0,51	-0,48	1,00	0,02	0,31	0,09
@FC	-0,19	-0,16	-0,13	-0,03	0,05	0,38	0,21	0,41	0,05	-0,07	-0,01	-0,16	-0,18	0,09	0,10	0,11	-0,15	-0,09	-0,18	0,02	1,00	0,08	-0,13
@W	0,30	0,28	0,41	0,34	0,16	-0,05	-0,08	-0,21	0,50	0,69	0,73	0,04	0,17	0,50	0,15	0,46	-0,05	0,16	-0,29	0,31	0,08	1,00	0,62
@S	0,45	0,23	0,29	0,27	0,17	-0,14	-0,05	-0,24	0,28	0,59	0,73	0,05	0,20	0,56	0,15	0,51	0,34	-0,02	0,27	0,09	-0,13	0,62	1,00

For example, the main indexes have negative correlations with treasury markets, with the Dax and EuroStoxx50 having coefficients of -0,46 and -0.53 with the Bund future, respectively. Another interesting example is that both the 30-year US Treasury Bonds, the 10-year US Treasury Notes, and the Bund have a high negative correlation with Natural Gas and Crude Oil, and Natural Gas has a negative correlation with Gold and Silver of -0,61 and -0.48, respectively, and so on. This table can serve as a starting point for determining which markets are naturally uncorrelated or negatively correlated. It is important to note that these correlation coefficients are only useful as a starting point because the meaningful ones are provided by the combination of active strategies in each market, which can differ from buy and hold.

4.5 Position Sizing

4.5.1 Capital allocation

Capital allocation entails distributing resources in a way that maximizes portfolio efficiency and profits. When using Position Sizing on single strategies, the entire available capital is taken and used in the algorithm formula that indicated the number of contracts to be used on the entire capital. There are two approaches to capital allocation at the portfolio level: fractioning the capital based on the strategies used and the single reference method, in which all active strategies are applied to a single total capital without splitting.

4.5.1.1 Fractioned Capital

The first technique involves dividing the capital by all of the available strategies, giving each a sum of money to refer to. This method can be further subdivided into two sub-categories: fixed capital and fixed fraction.

In the fixed capital approach, the capital is divided into sub-accounts. This method involves making an initial allocation and fixing an initial capital for each strategy. In general, all strategies start with the same amount of money and then generate profits or losses that are considered settling. Each strategy's losses and gains are thus computed within the fraction of capital allotted to it. If strategy 1 wins and strategy 2 loses, strategy 2 will have less capital in the second trade than in the first, whereas strategy 1 will have more. With this approach, we tend to concentrate on winning strategies while limiting the less-effective systems.

In the fixed fraction approach, the fair distribution is recalculated from time to time usually on a monthly basis. If there are winning and losing strategies in the fixed fraction system, they will have an equal distribution of the total capital at the time of the split regardless of the returns generated. As a result, even the losing strategies will benefit from the increased capital, as new starting capital will be allocated to them, favouring the balance of the various strategies. In summary, operations are divided into numerous virtual sub-accounts, with a fraction allotted to each strategy.

Both approaches are theoretically sound. The former seeks to keep the various strategies separate, whereas the latter is more committed to the portfolio concept. The first method with fixed capital is more difficult to implement because it necessitates individual accounting for each system, so it can only be optimal for a limited number of systems. Furthermore, there is a risk of overexposure when using the fixed capital method. In fact, there is a risk that similar strategies, gaining and losing at similar times, will either increase or decrease their portion of capital to the point where operations

are no longer possible. Due to the momentary momentum of a specific type of system, we may unknowingly generate an overexposure to a specific sector or approach in this case.

The fixed fraction system, on the other hand, has two advantages: the first is its ease of use, as total capital is divided directly between the various systems, and the second is that it emphasizes the alleged portfolio synergies. In fact, by focusing on collaboration between different strategies without underweighting any of them and always maintaining a fair division, the synergy between them is always maintained at the same level. Working at a fixed fraction has its drawbacks as well. With this approach, it is in fact possible to incur a generalized limitation of capital. If the losses from the losing systems exceed the profits from the winning systems, the total capital decreases, and thus less money is allocated to the winning strategies.

4.5.1.2 Single Reference Capital

Single Reference Capital is the second capital allocation model, in which capital is managed as a single entity and each strategy refers to the total capital. Because it considers the group of strategies as a whole, this approach best fits the concept of a portfolio. The diagram below summarizes three different schools of thought concerning the determination of the reference capital.

The first refers to the current equity with profit and loss in place. This method is the simplest because all that is required is a simple calculation of your available capital, which includes all profits and losses from open positions.

The second approach involves an equity net of open position margins. If the capital is € 100,000, but there is an open position on the DAX and each contract on the DAX requires a margin of € 23,000, you must subtract the € 23,000 from the equity available to you, because such capital is not considered available. Margin requirements are linked to open positions in this approach, and thus cannot be taken into account in the calculation of equity. This method clearly represents a conservative approach.

The third approach considers the available equity not only stripped of the margins of open positions but also of potential losses. The potential losses are considered as the capital that could be lost if all open positions always close in the worst possible scenario, and the money that they could lose are deducted from the equity. This potential loss is marked as a stop loss on existing positions.

Assume to have a capital of € 100,000 and open a short position on the DAX with a margin of around €23,000. Suppose that this strategy has a stop of 100 points, which corresponds to €2,500 in value, given that a DAX point is worth €25. The next day, position overnight, assume that the position is still open and that it has a profit at that moment of €4,000. So right now, in the morning, the position is profitable by €4,000.

CAPITAL

1. 100.000 + 4.000 = 104.000

2. 100.000 – 23.000 = 77.0000

3. 100.000 – 23.000 – 2.500 = 74.500

In the first model, we take the capital and add or subtract the profit and loss of the open positions, resulting in € 100.000 plus € 4.000, because we are earning € 4.000 from our only open position. This means we have € 104.000 available because there is only one open position earning € 4.000, which we add to the initial € 100.000.

The second model disregards profits and losses in favor of margins. If you have an open position on the DAX with a margin of € 23.000, you must deduct € 23.000 from your total capital because they are not available as they are dedicated to the instrument's margin. In this case, the available capital is therefore € 100.000 minus € 23.000, or € 77.000.

In addition to subtracting the margins, the third method also subtracts the potential loss in the worst-case scenario. As a result, the calculation is as follows: € 100.000 in initial capital minus the € 23.000 margin and minus € 2.500, which is the set stop loss level, from which we get € 74.500. This model ignores the fact that, in reality, the position is currently profitable by € 4.000 and thus € 6.500 above that level (profit plus stop loss).

4.5.2 Position Sizing Model

The rules learned in the previous chapter for Position Sizing still apply because the techniques used within a portfolio are derived from them. In theory, we could treat each system as a separate entity, employing a different Position Sizing model for each, or we could use a single money management model for the entire portfolio to homologize the process.

The first method takes more time as the number of systems in the portfolio grows, but it may yield better results because the money management model is calibrated for each system. The second method is certainly more efficient and may yield a more homogeneous result from a portfolio standpoint.

In this brief explanation, we look at the choice of the money management model with the currencies portfolio. The settings are chosen to achieve the same net profit for more comparable results. The inputs are a delta of 8000, a percent f of 4%, percent volatility of 0.5 percent, and an ATR length of 90 because this is the average number of bars in trade for each system.

Period	Perc Vol	Perc f	Fixed Ratio
2021	7,56%	4,46%	18,68%
2020	36,46%	16,34%	1,65%
2019	-14,09%	-7,79%	-5,49%
2018	-8,32%	-4,56%	-14,34%
2017	17,48%	3,23%	1,17%
2016	36,60%	47,28%	41,34%
2015	63,08%	34,01%	61,81%
2014	-27,92%	-19,78%	-18,21%
2013	15,13%	3,51%	-10,39%
2012	-8,94%	-15,77%	1,57%
2011	47,56%	89,71%	100,08%
2010	96,59%	164,16%	79,45%

	Perc Vol	Perc f	Fixed Ratio
Net Profit	575.685,00	666.176,25	506.715,00
Max Portfolio Drawdown (%)	-48,01%	-42,51%	-45,95%
Slippage Paid	558.480,00	596.100,00	447.810,00
Annualized Sharpe Ratio	0,67	0,67	0,63

The models generate very similar results from the annual period analysis and other performance measures. In the selection of the position sizing models for the portfolio, it is also useful to observe

the distribution of returns and drawdowns for the strategies and check the most stable and uniform ones. The distribution results are presented below.

Net Profit with Percent f

	@AD	@BP	@EC	@CD	@JY
Net Profit	164350	47976,25	292455	56880	104515

DD with Percent f

	@AD	@BP	@EC	@CD	@JY
DD	-0,68	-0,17	-0,5	-0,57	-0,16

Net Profit with Percent Vol

	@AD	@BP	@EC	@CD	@JY
Net Profit	83.310,	18.533,	139.428	159.305	175.107

DD with Percent Vol

	@AD	@BP	@EC	@CD	@JY
DD	(0,5	(0,2	(0,6	(0,3	(0,4

Net Profit with Fixed Ratio

	@AD	@BP	@EC	@CD	@JY
Net Profit	75570	3971,25	306417,5	18135	102621,25

DD with Fixed Ratio

	@AD	@BP	@EC	@CD	@JY
DD	-0,48	-0,12	-0,51	-0,23	-0,31

Based on these results, it is clear that the percent volatility method produces a more homogeneous net profit and drawdown, so this model should be used. Because the maximum drawdown may be deemed excessive, it is now possible to reduce the risk of the percent volatility model and apply scenario analysis for more reliable results and to stress the system.

4.6 Portfolio Management

The use of filtering techniques to achieve portfolio composition is implied by active portfolio management. Averaging or dynamic model selection can be used to accomplish this. This procedure should take into account the risk associated with each position about the expected return. Individual risks are typically calculated about asset volatility, and a correlation matrix aggregates those individual risks into a global portfolio risk. It should be noted that, instead of considering the correlation of assets, one can also consider the correlation of each strategy Wagman (Wagman L., Stock portfolio evaluation: An application of genetic programming based technical analysis. Working Paper, Stanford University, California (1999)) presented a simple framework based on Genetic Programming (GP) that attempts to find an optimal portfolio based on a simple technical analysis indicator, the moving average (MA). The approach begins by generating a set of random portfolios, and the GP algorithm attempts to converge into an optimal portfolio by using an evaluation function that takes into account the weight of each asset in the portfolio as well as the respective degree of satisfaction against the MA indicator while employing different period parameters. Likewise, Yan (Yan W., Profitable, return enhancing portfolio adjustments: An application of genetic programming with constrained syntactic structure. MSc Computer Science Project 2002/2003, University College London, UK (2003)) and Yan et al. (Yan W., Clack C.D., Evolving robust GP solutions for hedge fund stock selection in emerging markets. Working Paper, University College London, UK (2005)) used a GP approach to find the best model for categorizing stocks in the market. Top stocks take long positions, while bottom stocks take short positions. Their model is based on the use of Fundamental Analysis, which entails studying the underlying forces of the economy in order to forecast the market development.

In this dissertation, filters based on performance, drawdown, and correlation are used to select the best portfolio composition from a collection of active strategies on futures with various underlings.

4.6.1 Parametric Filters

Using traditional validation methods to decide when to stop, select, or discard a system from a portfolio perspective necessitates an excessive workload and may be too complex, given the system-by-system approach that should be expected. Indeed, the more complex the portfolio, the more difficult it is to manage using traditional methods.

The most efficient way to manage a large number of systems is to treat them "parametrically," that is, to apply filters that are the same for all systems to each system. The procedure consists in using system data for evaluation based on data parameters, and based on the results of the tests, it will be

determined systematically whether the system in question should be kept active or not. The individual strategies' daily profits and losses will be used as system data.

The first step is to identify the performance indicators, followed by the addition of other conditions to improve the analysis's accuracy. Taking the time horizon of the strategy in question, two sub-horizons can be identified: one long-term and one short-term. In the long term, a period greater than or equal to one year can be considered, whereas, in the short term, it refers to a period that can be monthly or quarterly. These two factors will be used to calculate the filters that will be applied to the system. The various filtering methods are discussed below.

Based on basic conditions it is possible to have:

- Long Term Profit > 0 & Short Term Profit > 0

In this case, we want a positive performance in both the long and short term.

- Average profit (Short Term) > Average Profit (Long Term)

In this case, the short-term profit average (in this scenario monthly, but it can also be weekly) must be greater than the long-term profit average.

- Periods > 0 in Short Term Profit > x%

This condition necessitates the establishment of a percentage threshold and that at least N periods in the short term are positive. For example, if 6 months were designated as short term and a 50% threshold was set, the condition would be met if at least three of the six months were positive. This filter, unlike the first two, seeks greater stability. Assume the strategy generates 5 months of losses and an abnormal return in the sixth month that is significantly greater than the accumulated losses in recent months over a 6-month time horizon. It might pass the test for the first two filters, but it would almost certainly fail the third because homogeneity in the returns is desired.

- The equity line is above its moving average based on the N number of period

Profits are greater than the N-period average.

- Average profit of last N period > X*average DD of last N period

In this case, the average of the profits generated in the last N periods (e.g. 3 years) must be greater than X times (e.g. 3) the average drawdown observed in the last N periods. This allows us to verify that the strategy still has a risk/return ratio higher than a certain threshold.

Note that the filters can be applied separately or combined for a more restrictive approach.

Working on a monthly basis, I usually use the previous year, which is 12 months, as the Long Period. As a Short Period, I generally put 4 months. Then I add the condition that they are both positive, that is, that the Long Period and Short Period are both greater than 0. I usually only use this condition because it is the most immediate and easily assessable because adding up the months is sufficient. Concerning the condition of the gain in relation to the drawdown and the exposure in general, I will only promote strategies that have shown an average gain greater than twice the maximum drawdown seen in those three years. So, I take the top three years ordered by highest return and divide them by three to find the average, look at the maximum drawdown, and reject the strategy if the average is not at least double the maximum drawdown. I also use filtering, with a positive threshold of 40% and a complementary negative threshold of 60%. If my filters give me correct indications more than 40% of the time, I use them quietly; if they give me incorrect indications more than 60% of the time (so they get it right less than 40% of the time), I do the opposite. As a Position Sizing model, I use a Percent f of 1.25 percent, and as a Worst Case, I use the Worst Day, which is also quite logical when working with daily data. I then impose an additional condition that the drawdown of the single strategy does not exceed 4% of the capital invested, which is a further constraint.

4.6.2 Filters evaluation

Given the evidence that there are no universally applicable rules, much depends on the market in question. For example, a classic breakout entry can produce huge profits in one market but fail in another, possibly because the latter has mean-reverting characteristics and thus the breakout entries are weak, whereas it would be more convenient to buy with limits orders and do it on retracements or so on. Filters can suffer the same fate. If the strategy, which has now become the market, had an equity line with mean-reverting characteristics, it could be discarded as frequently as it should be chosen, and vice versa. As a result, the filter's success ratio in generating positive synergies was determined. This ratio is calculated by comparing the results of the strategy's continuous application vs the system's application based on the metrics established by the filter. In general, the filter should apply the strategy when it generates profits and limit its execution before it generates a series of consecutive and significant losses. As a result, the result will be greater than the inhibited losses.

The filter's evaluation is determined by a certain threshold of positivity or negativity. If the filtering was advantageous and thus greater than the positivity threshold, it will be used; if the result was worse than the positivity threshold but not worse than the negativity threshold, it will not be used; and if the ratio is worse than the negativity threshold, it will be used with opposite metrics.

Surmise we set the positivity threshold to 50%, the negativity threshold to 60%, and my filtering is 63 percent positive; in this case, the filter is used because it works better than 50% of the time. If, on the other hand, the filtering has a pay-out ratio of 45 percent of the time and is thus negative 55 percent of the time, it is not used because it is worse than the designated 50 percent threshold. However, 55 percent is insufficient to exceed the negativity threshold of 60 percent, so the reverse is not applied. If, on the other hand, the filter has a positive ratio of 34% of the time and thus makes a mistake 66% of the time, the filter's opposite is applied, because not only has it not obtained a satisfactory result, but this result is even worse than the limit of acceptability of the negative.

Complementary percentages to 1 are commonly used (for example, 50% and 50%), but it is also possible to set a higher step for the negativity threshold, as in the case mentioned.

4.6.3. Portfolio periodic rebalancing

The recommended data analysis window is monthly. Improvements can be obtained by working on a weekly basis, but there will be a higher incidence of what are the losses from the gap over the week. For example, suppose that a strategy may no longer be suitable to be at work in the portfolio the following week and this consideration is done on Friday evening. Assuming that this strategy has open positions, they can only be closed when the markets reopen on Monday, so there may be a gap in the results generated by the strategy from Friday evening to Monday. When the assessment is performed on a monthly basis, the negative impact of potential gaps is significantly reduced because it can occur once a month as opposed to four times with a weekly rebalancing.

The following month, I will go over all of the strategies again. Obviously, I'll also take the ones we've discarded and go calculate how much they would have done during that month: that will be the parameter I'll need to evaluate the Long Term, Short Term, and so on. If one of these had a great month, it will almost certainly come back into play the following month, so with this method, you never completely discard a strategy, unless it is always bad and thus never promoted. As a result, it is an automatic and linear process.

4.7 Practical Example: Fully diversified portfolio

The example below depicts a fully diversified portfolio in terms of both instruments and strategies. It begins with a description of the reference benchmark, followed by an analysis of the IS results of the proprietary portfolio in the example. The IS results with money management models are presented in the following step. The fourth step is to analyze the OOS results and compare them to the benchmark results. First are compared the OOS results of the proprietary portfolio without the integration of the money management models versus the benchmark, secondly, the comparison occurs also with the application of money management models to the proprietary portfolio.

To avoid discrepancies among instruments since they refer to different exchanges, all portfolio strategies are developed with the local time zone (Italy). The IS period lasts from January 1, 2010 to January 1, 2018 (8 years), while the OOS period lasts from 2018 to January 1, 2022 (4 years). The initial capital is set to 1M in order to avoid margin issues with the integration of the various strategies. The base strategy is used with a single fixed contract. To enhance the portfolio effect, the capital allocation used is the single reference capital. Because there are a limited number of strategies in the portfolio, the money management models used are calibrated and applied differently on each instrument. All analyses related to the optimisation process, money management model selection, and strategy construction adhere to the rules and methodologies presented in previous chapters. The potential costs are calculated as two ticks per contract and added to the slippage section.

The instruments chosen are a way to partially replicate the asset allocation of Ray Dalio's All-Weather Portfolio using futures instead of ETFs. The All-Weather Portfolio is designed to withstand all economic environments by utilizing various asset types that perform differently during those various "seasons" (Ray Dalio, Bridgewater, The All Weather Portfolio Strategy Portfolio, Blurb Inc. (2019)).

Appropriately, it is also known as the "All Seasons Portfolio". During periods of market turmoil, the All-Weather Portfolio becomes especially appealing, particularly for investors with low risk tolerance and/or who are primarily concerned with capital preservation. The All-Weather Portfolio seemingly maximizes diversification using a variety of asset classes. The inherent uncorrelation of these assets provides this diversification benefit. The holdings and allocations correspond to Dalio's perspective on economic "seasons".

According to Dalio, the following four factors influence asset value:

- Inflation;
- Deflation;
- Rising economic growth;
- Declining economic growth.

Based on these, Dalio predicts four economic "seasons":

- Inflation is higher than expected.
- Inflation is lower than expected.
- Economic growth is higher than expected.
- Economic growth is lower than expected.

Dalio selected asset classes that performed well during each of these seasons, with the goal of diversification that allows for consistent growth and small drawdowns. To reduce volatility, the portfolio invests primarily in bonds and only 30% in stocks.

The asset allocation for the All-Weather Portfolio is as follows:

- 30% of US stocks
- 40% long-term treasuries
- 15% intermediate-term treasuries
- 7.5% commodities diversified
- 7.5% gold

Five ETFs can be chosen to replicate this asset allocation at the lowest possible cost:

- 30% VTI
- 40% VGLT
- 15% VGIT
- 8% IAU
- 7% PDBC

VTI (Vanguard Total Stock Market) ETF is a passively managed fund that tracks the CRSP US Total Market index. Its strategy is thus based on the performance of the entire US investable market, and it includes small-cap positions as a result (https://investor.vanguard.com/etf/profile/VTI).

VGLT (Vanguard Long-Term Treasury) is a Vanguard passive ETF that tracks the investment performance of the Barclays U.S. Long Government Float Adjusted Index (https://investor.vanguard.com/etf/profile/VGLT).

VGIT (Vanguard Intermediate-Term Treasury) is a passive ETF by Vanguard that tracks the investment results of the Barclays U.S. 3-10 Year Government Float Adjusted Index (https://investor.vanguard.com/etf/profile/VGIT).

IAU (iShares Gold Trust) from BlackRock provides exposure to one of the world's most famous metals, gold. The IAU was created to track the spot price of gold bullion by storing them in a secure vault. While it isn't the most liquid way to gain gold exposure, it does have one of the lowest expense ratios, making it a good choice for budget-conscious investors (https://www.blackrock.com/us/individual/products/239561/ishares-gold-trust-fund).

PDBC (Invesco DB Optimum Yield Diversified Commodity Strategy # K-1) ETF is a diversified way that provides investors with exposure to booming commodities (https://www.invesco.com/us/financial-products/etfs).

The rebalancing will be semi-annual to maintain the portfolio's initial allocation. This portfolio will be used as a benchmark for the proprietary portfolio in the example during the OOS period.

Let us now present the proprietary portfolio developed for this dissertation. The first step is to choose the asset allocation, which, as previously stated, is based on the replication of asset classes in the All-Weather Portfolio. So, for US stocks, the mini SP500 future (ES) is chosen, for bonds, the US 30 year treasury bond future (US), for gold exposure, the Gold Future (GC), and for diversified commodities, the Crude Oil Future (CL) and Natural Gas Future (NG) are selected. The strategy is chosen based on the intrinsic characteristics of each instrument: for the ES, a reverse strategy based on Bollinger bands is used, for the GC and NG, a temporal bias strategy is used, for the US, a reversal strategy based on false breakout is used, and for the CL, a trend following strategy is used. The IS results are shown below.

Net Profit	447.396,00
Max Portfolio Drawdown (%)	-1,79%
Max Portfolio Close To Close Drawdown (%)	-1,54%
Slippage Paid	105.549,00
Annual Rate of Return	5,62%

Return on Max Portfolio Drawdown	20,17
Profit Factor	1,52
Annualized Sharpe Ratio	1,36

Period	Net Profit	% Gain
2017	**- 8.047,50**	**-0,55%**
2016	48.472,00	3,44%
2015	14.325,25	1,03%
2014	53.783,50	4,01%
2013	63.046,75	4,93%
2012	86.687,75	7,27%
2011	85.637,25	7,73%
2010	107.288,50	10,73%

The portfolio with a fixed contract strategy (1 contract) generated a cost-adjusted return of 44,73% with an average annual return of 5,62%. The maximum DD is 1,79%, and this result allows to provide a Return on Max Portfolio Drawdown of 20,17. The other performance ratios are optimal with a Profit Factor of 1,52 and an Annualized Sharpe Ratio of 1,36. From the annual period report, it is possible to observe that the portfolio generates positive cost-adjusted returns in 7 years over eight with stable and uniform profits.

Net Profit	@GC	@CL	@ES	@US	@NG
Net Profit	118.23	176.64	54.700	41.016	56.810

Drawdown	@GC	@CL	@ES	@US	@NG
DD	-1,11%	-2,32%	-1,49%	-1,17%	-0,58%

According to the individual strategy analysis, the returns provided by ES, US, and NG are quite similar around 50.000, while the outperformance is primarily due to the crude oil strategy with a

176.640 profit over the 8 period in analysis. The drawdown analysis shows that the distribution for individual strategies is quite stable; the outlier can be identified in the CL as a demonstration that higher profits usually imply higher risk involved.

The following step is to introduce the various money management models that are used. The metrics and valuation discussed in the previous chapter are used to make the decision. A resume table for the method and parameters used on each strategy follows.

Market	Model	Parameter	Max Contract
GC	Percent f	3%	10
CL	Percent f	3,5%	20
ES	Fixed Ratio	8000	25
US	Percent Vol	1%	25
NG	Percent Vol	1%	10

The parameters of the maximum number of contracts are fundamental for the reliability of results; if more contracts are used for a single position, the orders may not be executed correctly, resulting in higher slippage risk.

The results with money management models applied are shown below.

Net Profit	6.126.610,00
Max Portfolio Drawdown (%)	-10,14%
Max Portfolio Close To Close Drawdown (%)	-7,34%
Slippage Paid	1.414.270,00
Annual Rate of Return	76,94%

Return on Max Portfolio Drawdown	13,97
Profit Factor	1,52
Annualized Sharpe Ratio	1,65

Period	Net Profit	% Gain
2017	**- 145.037,50**	**-2,00%**
2016	976.425,00	15,54%
2015	144.781,25	2,36%
2014	675.150,00	12,35%
2013	693.493,75	14,53%
2012	1.217.031,25	34,24%
2011	1.180.618,75	49,74%
2010	1.373.672,50	137,37%

The use of Money Management models has significantly increased the portfolio's return but also its drawdown. Note that the improvement of the profit is higher than the worsening of drawdown, the net profit increased more than 13x reaching 612% with an average annual return of 76%, while the drawdown has increased by approximately 5x reaching 10,14% with an average drawdown around 5%. In terms of performance ratios, the Return on Max Portfolio Drawdown decreases to 13,97, the profit factor remains at 1,52, while there is an increase in the Annualized Sharpe ratio to 1,65. From the annual period report, it is possible to see that the strategy still generates positive returns with only one negative year in 2017.

Market	Net Profit MM	Net Profit base	Change in Net profit	Max. Draw Down MM	Max. Draw Down Base
@GC	1.182.300,00	118.230,00	10,00	-6,50%	-1,11%
@CL	3.201.760,00	176.640,00	18,13	-14,46%	-2,32%
@ES	149.050,00	54.700,00	2,72	-8,87%	-1,49%
@US	1.025.400,00	41.016,00	25,00	-17,40%	-1,17%
@NG	568.100,00	56.810,00	10,00	-4,30%	-0,58%

This table summarizes the net profit and drawdown for each strategy. The effect of money management can be seen for each strategy, where the lowest increase is in the ES with 2x in the net profit, while the largest is observed in the US with 25x the base net profit. For the drawdown side, all of the maximum drawdowns have increased, with the one related to the US future worsening the most due to the higher exposure and risk involved in the strategy with the money management.

	@GC	@CL	@ES	@US	@NG
@GC	**1,00**	0,18	0,44	0,65	0,52
@CL	0,18	**1,00**	- **0,21**	0,10	0,37
@ES	0,44	- **0,21**	**1,00**	- **0,18**	0,18
@US	0,65	0,10	- **0,18**	**1,00**	0,57
@NG	0,52	0,37	0,18	0,57	**1,00**

According to the annual correlation analysis, the ES is the instrument that improves diversification the most. It has a negative correlation with both CL and US with -0,21 and -0,18 values, respectively. The CL with GC and the CL with the US are two other low-correlated instruments. The highest correlation is found in the United States, with a GC of 0.65. Overall, the portfolio is quite balanced and diverse, given that the instrument that contributes the most to the return (CL) has a correlation close to 0 with the second and third instruments in terms of contribution (GC, US).

The following step is to examine the OOS results. Let's start with the comparison of the proprietary portfolio results without money management versus the benchmark. Secondly, there is the same comparison but with the money management model applied to the proprietary portfolio.

	Portfolio	Benchmark
Net Profit	285.349,25	316.653,39
Max Portfolio Drawdown (%)	-2,58%	-14,64%
Max Portfolio Close To Close Drawdown (%)	-2,05%	-2,14%
Annual Rate of Return	7,18%	8,09%

	Portfolio	Benchmark
Return on Max Portfolio Drawdown	9,91	1,75
Profit Factor	1,50	3,44
Annualized Sharpe Ratio	1,38	0,70

Period	Net Profit PTF	% Gain PTF	Net Profit Benchmark	% Gain Benchmark
2021	62.308,50	5,09%	42.740,21	3,40%
2020	124.627,50	11,35%	161.898,15	14,79%
2019	56.544,00	5,43%	145.005,79	15,27%
2018	41.956,75	4,20%	- **50.247,49**	**-5,02%**

From a first comparison, the portfolio appears to underperform the benchmark because the total portfolio profit is 28,53 % with an annual return of 7,18 % compared to the benchmark's 31,66 % with an annual return of 8,09 %. The max drawdown in the portfolio is significantly lower at 2.58 % versus 14.64 %. Instead, when comparing the maximum DD close-to-close, the portfolio outperforms the benchmark by only 0.09 %. According to the performance ratio analysis, the portfolio is more efficient than the benchmark, with a higher and significant Annualized Sharpe Ratio and Return on Max Portfolio Drawdown of 1,38 and 9,91, respectively. The profit factor is also acceptable, but it is lower than the benchmark due to the differences in position structure and number. According to the annual period report, the portfolio generates all positive returns, whereas the benchmark generates 4 years over 5 of profit with a loss of -5,02 % in 2018. Because the rebalancing occurs between 2018 and 2019, the loss of -5,02 % is greater than the maximum DD close-to-close, and this loss is calculated even if the positions are still open.

Let us now examine the contribution of each instrument to the portfolios as well as the monthly correlation to assess the diversification effect.

Market	Net Profit	Contribution	Max. Equity Draw Down(%)
@GC	37.610,00	13,18%	-1,31%
@CL	23.000,00	8,06%	-2,88%
@ES	173.325,00	60,74%	-1,63%
@US	28.634,25	10,03%	-0,83%
@NG	22.780,00	7,98%	-0,94%

Market	Net Profit	Contribution	Max. Equity Draw Down(%)
VTI	174.202,94	55,01%	-12,30%
VGLT	82.227,45	25,97%	-12,20%
VGIT	13.071,02	4,13%	-1,22%
IAU	27.767,60	8,77%	-1,97%
PDBC	19.384,38	6,12%	-4,17%

	@GC	@CL	@ES	@US	@NG
@GC	1,00	- 0,03	0,10	0,11	0,04
@CL	- 0,03	1,00	- 0,03	0,14	- 0,05
@ES	0,10	- 0,03	1,00	- 0,09	- 0,12
@US	0,11	0,14	- 0,09	1,00	0,10
@NG	0,04	- 0,05	- 0,12	0,10	1,00

	VTI	VGLT	VGIT	IAU	PDBC
VTI	1,00	- 0,29	- 0,43	0,12	0,41
VGLT	- 0,29	1,00	0,89	0,31	- 0,24
VGIT	- 0,43	0,89	1,00	0,30	- 0,24
IAU	0,12	0,31	0,30	1,00	- 0,11
PDBC	0,41	- 0,24	- 0,24	- 0,11	1,00

In both strategies, exposure to US markets contributes the most to return generation; however, the drawdown distribution in the proprietary portfolio is much more stable than in the benchmark; this may be due to more efficient active management rather than simple rebalancing. According to the monthly correlation analysis, both portfolios are quite well diversified; in the proprietary one, all correlations are close to zero; in the All-Weather Portfolio, the lowest correlation is -0,43 with the pair VTI (US stock market) and VGIT (10 years treasury bond market).

Let us now examine the OOS results using the money management models.

	Portfolio
Net Profit	2.783.205,75
Max Portfolio Drawdown (%)	-15,21%
Max Portfolio Close To Close Drawdown (%)	-11,91%
Slippage Paid	728.528,00
Annual Rate of Return	70,05%

Return on Max Portfolio Drawdown	8,92
Profit Factor	1,41
Annualized Sharpe Ratio	1,83

Period	Net Profit	% Gain
2021	908.715,00	31,66%
2020	1.214.356,50	73,33%
2019	254.545,00	18,16%
2018	401.564,25	40,16%

Over the four OOS years, the strategy generates an outstanding performance of 278 %, with the highest drawdown of -15,15 %. The average expected drawdown peaks are around 10%, which is higher than the benchmark, but outperformance can justify this increase in risk exposure. The profit Factor and Return on Max Portfolio Drawdown are very similar to the portfolio without money management; however, the Annualized Sharpe Ratio is 1,83. The annual period analysis reveals that, as previously stated, the portfolio was able to generate positive returns each year. Let us examine each instrument's contribution to better understand which strategies are most important in terms of profit generation.

Market	Net Profit	Contribution	Max. Equity Draw Down(%)
@GC	376.100,00	14%	-11,45%
@CL	168.240,00	6,04%	-29,00%
@ES	1.312.187,50	47,15%	-10,06%
@US	707.488,25	25,42%	-14,78%
@NG	219.190,00	7,88%	-8,13%

	@GC	@CL	@ES	@US	@NG
@GC	1	-0,01	0,094	0,102	0,046
@CL	-0,01	1	-0,21	0,159	-0,05
@ES	0,094	-0,21	1	-0,24	-0,14
@US	0,102	0,159	-0,24	1	0,092
@NG	0,046	-0,05	-0,14	0,092	1

The reversal strategy on ES accounts for 47.15 percent of the performance, while the US accounts for 25.42 percent of the performance. The returns are more evenly distributed than without money management, reducing the contribution of the outlier and at advantage of the other strategies. Crude oil provides the highest individual drawdown, which may be due to the instrument's changing structure in 2020 and 2021. Monthly correlation analysis reveals that the use of position sizing models enhances the negative correlations and the diversification of the portfolio's return. In particular, the ES has a negative monthly correlation with the CL, US, and NG.

With the use of money management models, this proprietary portfolio outperforms the All-weather portfolio by more than 8x. It offers a higher level of risk exposure, with an average drawdown of around 10% compared to the benchmark's 2%. The all-weather portfolio, while requiring only

semiannual or annual rebalancing, is less expensive and pursues passive strategy management, but it demonstrates its limitations in terms of abnormal return generation. The active management of a portfolio with systematic strategies has a higher risk exposure and requires more frequent monitoring to ensure the effectiveness of the various strategies and margin maintenance, but it has been able to generate profits of more than 30% per year on average in OOS periods.

Conclusion

The purpose of this dissertation is to provide a step-by-step guide on the processes and methodologies used to construct an effective fully diversified portfolio of trading systems. It begins with the environment that must be set before beginning coding and progresses with the structure of the strategy scripts. Following that, the dissertation moves on to an introduction to different trading system typologies, pattern individuation, metrics for performing a meaningful backtest, and the performance report to understand and evaluate the results obtained from the strategies' application. The next step is the optimisation process, which can be done using Exhaustive Search Optimisation (ES), which analyzes every possible combination, or through Genetic Algorithm Optimisation (GA), which selects only a small number of possible combinations that are the closest to the optimum of the objective function. This is the most important process because excessive optimisation may result in overfitting, which produces optimal results during the test period, but the strategy does not match the out-of-sample data, resulting in exponential losses. The next step is the evaluation of the trading system performance and robustness to check the system's consistency and stability and determine whether a strategy is overoptimized. The main tools used for these tests are the analysis of the Performance Report and the use of Walk Forward Analysis to maximize the number of OOS periods and stress tests on the system. After learning how to build a solid foundation for a trading system, it is critical to learn how to manage risk for a single position, a single strategy, and an entire portfolio. This section explains the various money management models that can significantly increase the system's profitability. Since the additional return in most financial theories can only be justified by additional risk, the application of these position sizing models increases the size of the average and maximum drawdown of strategies and portfolios. As a result, it is critical to perform scenarios analysis through Montecarlo Simulation to retrieve 1000s of possible scenarios and evaluate the distribution and probability of both returns and drawdown for each money management model. The final step is portfolio construction, which takes into account all of the previous steps. Portfolio construction is the combination of various instruments and strategies in order to increase their synergies through the benefit of diversification. In the construction of the portfolio, when the number of strategies begins to grow exponentially, it is possible to use different valuation metrics to select

the best performing strategy and avoid losses due to one's whit worsening or flat performance. This process makes the portfolio more dynamic and is typically performed on a monthly or semi-annual basis.

There are descriptive and detailed examples in each chapter, along with codes, considerations, and the application of evaluation methodologies. The majority of the examples consider potential costs, which can reduce the profit generated by the strategy by up to 50% in some cases. More specifically, each example includes a reference benchmark to provide a higher level of significance and stability in the results obtained through the processes described. Furthermore, each example valuation is divided into IS and OOS periods in order to obtain more realistic and non-overfitted results. The goal of each strategy and portfolio analyzed is to provide the highest level of risk-adjusted return by maximizing net profit while keeping the level of drawdowns under control involved in the systems. Another important focus is on average trade, which is necessary to cover potential higher-than-expected costs.

To summarize, it is critical to focus on the potential risk that may occur when the systems are applied to the real market via the broker account. Overfitting and costs are the two major issues that could imply in higher unexpected losses. As previously explained, overfitting may result in abnormal returns during the test period but drastic negative returns during real trading. To overcome these issues, stress tests using Montecarlo analysis and Walk Forward Analysis should be performed to observe the potential behaviour of the strategy or portfolio with a small change in the optimized inputs, the length of IS-OOS periods, or the order of trades. Slippage is the most important cost to consider. It can be identified as the ticks that can be lost due to the volatility of the market, shortage of liquidity, or a black swan event. To overcome higher potential slippage, use limits orders instead of market orders and try to increase the average trade of each strategy.

Finally, because the market's structure, efficiency, and correlation among instruments and strategies change over time, it is critical to rebalance the portfolio using the techniques described in the previous chapter and to perform periodic re-optimisation of strategies to assess their effectiveness in the new market environment.

The most important advice is to perform all processes objectively. Do not be afraid to remove a historical strategy from the portfolio if it is not performing as well as it has in the past and try to disrupt the trading systems during the robustness evaluation process, in other words, try to not cheat yourself with "ad-hock constructed" results, because the experience in the real market with overfitted systems can be very dangerous and unprofitable.

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Abstract

Finance has been my greatest passion for several years, I devote to this sector the majority of my resources, study, and time. I started this long journey by learning about discretionary trading. Through active short-term strategies, I've been looking for a way to outperform the market using technical analysis, first in forex and then in equities. Because of my university career, I was able to deepening asset management theories through the use of more advanced portfolio management and risk management techniques. So, rather than focusing solely on stock-picking approach, I transitioned from an active short-term operation to one more focused on medium-long term asset allocation through the use of instruments that ensure greater diversification, such as funds and ETFs. With this thesis, I decided to return to my initial path, which brought me closer to this world in the first place, but to improve on it by making it systematic and combining it with the most advanced portfolio and management theories learned during my studies.

A financial portfolio is a collection of financial assets known as securities or investments such as stocks, bonds, futures contracts, or exchange-traded funds (ETFs). Building a financial portfolio is a well-known issue in financial markets that requires extensive research to identify the most profitable assets. Portfolio development consists of two interconnected tasks. The first is an asset allocation task, in which the investor must decide how to divide his or her wealth between risk-free securities and a set of N risky securities. The second refers to the development of a risky portfolio in order to determine how to allocate wealth and risk among the N risky securities.

As a result, in order to construct a portfolio, investment objectives must be defined in terms of the acceptable level of risk for a given return. Portfolio management is the process of determining which assets should be included in a portfolio, how much capital should be allocated to each type of security, and when a specific investment should be removed from a holding portfolio while keeping the investor's preferences in mind.

There are two types of management: passive management and active management. Passive management is when an investor's goal is to track a market index. This is related to the notion that it is impossible to outperform the market index. A passive strategy seeks only to build a well-diversified portfolio, not to find under or overvalued stocks. Active management is a strategy in which the primary goal of the investor is to outperform an investment benchmark index. (Maginn J.L., Managing investment portfolios: A dynamic process. 3rd ed, ed. C.I.I. Series, Wiley (2007)).

As previously stated, a standard equity portfolio is constructed and managed in relation to an underlying benchmark. An indexed equity portfolio is a passive management style that seeks to track

a benchmark while limiting residual risk to near zero. While an indexed equity portfolio may underperform the benchmark after expenses, enhanced indexed portfolios are designed to provide index-like performance plus some excess return after expenses. The latter may relax the residual risk constraint by slightly overweighting securities that are expected to perform well and slightly underweighting securities that are expected to perform poorly (Jacobs B., Levy K., Enhanced active equity strategies. Journal of Portfolio Management, 32, pp 45–55 (2006)). Active equity management seeks portfolios with a natural level of risk that corresponds to the investor's risk tolerance and is based on the available return opportunities. The majority of active equity portfolios aim to generate appealing risk-adjusted returns (or alpha).

The purpose of this thesis is to provide a step-by-step practical guide to developing trading strategies, risk management, and portfolio construction through a balanced and systematic approach. It is aimed at both newcomers to the trading world and more experienced readers who want to learn more about traditional portfolio management from a different angle and diversify their capital allocation. This dissertation will look at how to construct a diverse portfolio of active strategies. Unlike traditional asset allocation portfolios, the final portfolio, in this case, will be based not only on diverse asset classes and markets but also on diverse active strategies applied to these markets.

I'll go over how to identify trading signals, develop quantitative strategies, estimate expected returns, measure and score strategies, and allocate portfolios. This is done with the help of various articles cited throughout this thesis, as well as financial and economic textbooks.

The procedure begins by defining what a trading system is. There is no superior system, but a good system fits the trader's goals, timing, starting capital, and even personality. The trading system infrastructure follows, and it provides a solid foundation for the systematic trading environment through the main resources to be considered for its development, namely Data Feed Providers, Platforms, and Brokers. TradeStation is used as a data feed provider, MultiCharts as a trading platform, and PowerLanguage as a coding language for all processes, data, tools, codes, and examples in this thesis.

The second chapter intends to provide all of the steps and tools required to construct a trading system. It starts with the "trading system essentials," which include the structure of scripts and strategies, the main classification of strategies, an introduction to patterns, how to perform a meaningful backtest, and the test generators for determining the different time windows and periods to be used as In Sample (IS) and Out Of Sample (OOS). The chapter goes on explaining the strategy performance report in detail, including the strategy, trade, and periodical analysis. Following that, the optimisation process is introduced, beginning with standard optimisation via Exhaustive Search (ES) and Genetic

Algorithms (GA) methodologies and progressing to periodic re-optimisation via Walk Forward Optimisation (WFO). This section concludes with a focus on overfitting, which is commonly caused by optimization processes. The final subsection focuses on trading system evaluation, with a focus on psychological and technical metrics from the performance report, as well as robustness analysis using the Walk Forward Analysis (WFA). Finally, there is a detailed example that demonstrates how to apply all of the concepts and methodologies presented.

The third chapter is one of the most important for improving performance, with a focus on risk management. As stated in the numerous examples, there is no return without risk, but the excessive risk may result in the trading account's bankruptcy. Furthermore, keep in mind that markets only compensate traders for non-diversifiable risk, so even if higher profits are implied by higher risk the opposite is not true. This chapter begins with a precise definition of risk before delving deeper into single position management with the definition and setting of stoploss, take profit, and trailing stops. The following section is about money management and position sizing, with an emphasis on the main position sizing models that can be applied to a single strategy or portfolio. Following that, there is a subchapter dedicated to Montecarlo simulation, with a definition of the Method used, as well as its properties and limits. Finally, this chapter concludes with a practical application of Money Management on a trading system.

The fourth and final chapter is concerned with the dissertation's main goal, "portfolio construction." It begins with an overview of portfolio theory evolution, from Markowitz to Postmodern Portfolio Theory. The following section is about Pearson's Linear Correlation Coefficient, which is important for understanding the subchapter about diversification in terms of asset selection and strategies. Following that, various portfolio types are presented. The following subchapter is related to the position sizing with the introduction of capital allocation and position sizing models for portfolios. Next there is a section on portfolio management, with a focus on how to filter, select, and stop strategies within a fully diversified portfolio. Finally, this chapter concludes with a practical application of the discussed concepts.

Every chapter concludes with a practical example of how the theories presented can be used to improve understanding of the processes described. The numerous examples are intended to lend this dissertation a more practical rather than theoretical perspective, allowing traders to test and replicate the results and concepts presented in the most user-friendly manner possible.

Following that, an example of a fully diversified portfolio of active strategies is presented. This example is the final outcome of all techniques discussed in the various chapters. To summarize, the section that follows is more concerned with the analysis the results generated. Please see the main

dissertation for a detailed explanation of the methodology used in parameter selection, optimization, validation, and money management model evaluation.

In terms of both instruments and strategies, the example below depicts a fully diversified portfolio. It begins with a description of the reference benchmark, followed by an examination of the IS results of the example proprietary portfolio. In the following step, the IS results with money management models are presented. The fourth step is to compare the OOS results to the benchmark results. The OOS results of the proprietary portfolio without the integration of money management models are compared to the benchmark first, and then the comparison occurs with the application of money management models to the proprietary portfolio.

All portfolio strategies are developed with the local time zone (Italy) in mind to avoid discrepancies between instruments because they refer to different exchanges. The IS period lasts eight years, from January 1, 2010 to January 1, 2018, while the OOS period lasts from 2018 to January 1, 2022 (4 years). To avoid margin issues with the integration of the various strategies, the initial capital is set at 1 M. The base strategy is used in conjunction with a single fixed contract. The capital allocation used to enchant the portfolio effect is the single reference capital. Because the portfolio contains a limited number of strategies, the money management models used are calibrated and applied differently on each instrument. All analyses related to the optimization process, money management model selection, and strategy development follow the rules and methodologies outlined in previous chapters. The potential costs are calculated by adding two ticks per contract to the slippage section.

The instruments chosen are a way to partially replicate Ray Dalio's All-Weather Portfolio's asset allocation by using futures instead of ETFs. The All-Weather Portfolio is intended to withstand all economic environments by utilizing a variety of asset types that perform differently during those various "seasons." It is also referred to as the "All Seasons Portfolio." During market downturns, the All-Weather Portfolio becomes especially appealing, especially for investors with low risk tolerance and/or who are primarily concerned with capital preservation. The All-Weather Portfolio appears to maximize diversification by utilizing a wide range of asset classes. This diversification benefit is provided by the inherent uncorrelation of these assets. The holdings and allocations reflect Dalio's view of economic "seasons".

According to Dalio, four factors influence asset value: inflation, deflation, rising economic growth, and declining economic growth.

Dalio forecasts four economic "seasons" based on these:

- Inflation is higher than anticipated.
- Inflation is lower than anticipated.
- Economic growth exceeds expectations.
- Economic growth falls short of expectations.

Dalio chose asset classes that performed well during each of these seasons in order to achieve diversification that allows for consistent growth and small drawdowns. To reduce volatility, the portfolio primarily invests in bonds and only 30% in stocks.

The All-Weather Portfolio's asset allocation is as follows: 30% US stocks; 40% long-term treasuries; 15% intermediate-term treasuries; 7.5 % commodities diversified; 7.5 % gold.

To replicate this asset allocation at the lowest possible cost, five ETFs can be chosen: 30 % VTI, 40 % VGLT, 15 % VGIT, 8% IAU, and 7% PDBC.

The Vanguard Total Stock Market ETF (VTI) is a passively managed fund that replicates the CRSP US Total Market index. As a result, its strategy is based on the performance of the entire US investable market, and it includes small-cap positions. The Vanguard Long-Term Treasury ETF (VGLT) tracks the investment performance of the Barclays U.S. Long Government Float Adjusted Index. Vanguard Intermediate-Term Treasury (VGIT) is a Vanguard passive ETF that tracks the investment results of the Barclays U.S. 3-10 Year Government Float Adjusted Index. BlackRock's IAU (iShares Gold Trust) provides exposure to one of the world's most famous metals, gold. The IAU was established to track gold bullion spot prices by storing it in a secure vault. While it isn't the most liquid way to get exposure to gold, it does have one of the lowest expense ratios, making it a good choice for budget-conscious investors. The PDBC (Invesco DB Optimum Yield Diversified Commodity Strategy # K-1) ETF is a well-diversified way to gain exposure to booming commodities.

To maintain the portfolio's initial allocation, rebalancing will be done semi-annually. During the OOS period, this portfolio will be used as a benchmark for the proprietary portfolio in the example.

Let us now present the proprietary portfolio created for this dissertation. The first step is to select the asset allocation, which, as previously stated, is based on asset class replication in the All-Weather Portfolio. So the mini SP500 future (ES) is chosen for US stocks, the US 30 year treasury bond future (US) for bonds, the Gold Future (GC) for gold exposure, and the Crude Oil Future (CL) and Natural

Gas Future (NG) for diversified commodities. The strategy is chosen based on the intrinsic characteristics of each instrument: for the ES, a reverse strategy based on Bollinger bands is used, for the GC and NG, a temporal bias strategy is used, for the US, a reversal strategy based on false breakout is used, and for the CL, a trend following strategy is used. The IS outcomes are shown below.

Net Profit	447.396,00
Max Portfolio Drawdown (%)	-1,79%
Max Portfolio Close To Close Drawdown (%)	-1,54%
Slippage Paid	105.549,00
Annual Rate of Return	5,62%

Return on Max Portfolio Drawdown	20,17
Profit Factor	1,52
Annualized Sharpe Ratio	1,36

Period	Net Profit	% Gain
2017	- 8.047,50	-0,55%
2016	48.472,00	3,44%
2015	14.325,25	1,03%
2014	53.783,50	4,01%
2013	63.046,75	4,93%
2012	86.687,75	7,27%
2011	85.637,25	7,73%
2010	107.288,50	10,73%

The portfolio with a fixed contract strategy (1 contract) generated a cost-adjusted return of 44,73% with an average annual return of 5,62%. The maximum DD is 1,79%, and this result allows us to provide a Return on Max Portfolio Drawdown of 20,17. The other performance ratios are optimal with a Profit Factor of 1,52 and an Annualized Sharpe Ratio of 1,36. According to the annual period

report, the portfolio generates positive cost-adjusted returns in 7 out of 8 years with stable and uniform profits.

Individual strategy analysis shows that the returns provided by ES, US, and NG are quite similar around 50.000, with the crude oil strategy outperforming the others with a 176.640 profit over the 8-period analysis. The drawdown analysis reveals that the distribution for individual strategies is quite stable; the outlier can be identified in the CL as evidence that higher profits usually imply higher risk. The next step is to explain the various money management models that are used. The decision is based on the metrics and valuation discussed in the previous chapter. The method and parameters used for each strategy are summarized in the table below.

Market	Model	Parameter	Max Contract
GC	Percent f	3%	10
CL	Percent f	3,5%	20
ES	Fixed Ratio	8000	25
US	Percent Vol	1%	25
NG	Percent Vol	1%	10

The maximum number of contracts used for a single position is critical for the reliability of results; if more contracts are used for a single position, the orders may not be executed correctly, resulting in higher slippage risk.

The outcomes with money management models are shown below.

Net Profit	6.126.610,00
Max Portfolio Drawdown (%)	-10,14%
Max Portfolio Close To Close Drawdown (%)	-7,34%
Slippage Paid	1.414.270,00
Annual Rate of Return	76,94%

Return on Max Portfolio Drawdown	13,97
Profit Factor	1,52
Annualized Sharpe Ratio	1,65

Period	Net Profit	% Gain
2017	**- 145.037,50**	**-2,00%**
2016	976.425,00	15,54%
2015	144.781,25	2,36%
2014	675.150,00	12,35%
2013	693.493,75	14,53%
2012	1.217.031,25	34,24%
2011	1.180.618,75	49,74%
2010	1.373.672,50	137,37%

The use of Money Management models has increased the portfolio's return while also increasing its drawdown. It is worth noting that the profit has increased more than 13x, reaching 612 % with an average annual return of 76 %, while the drawdown has increased approximately 5x, reaching 10,14% with an average drawdown around 5%. In terms of performance ratios, the Return on Max Portfolio Drawdown falls to 13,97, the profit factor remains at 1,52, and the Annualized Sharpe ratio rises to 1,65. According to the annual period report, the strategy continues to generate positive returns, with only one negative year in 2017.

Market	Net Profit MM	Net Profit base	Change in Net profit	Max. Draw Down MM	Max. Draw Down Base
@GC	1.182.300,00	118.230,00	10,00	-6,50%	-1,11%
@CL	3.201.760,00	176.640,00	18,13	-14,46%	-2,32%
@ES	149.050,00	54.700,00	2,72	-8,87%	-1,49%
@US	1.025.400,00	41.016,00	25,00	-17,40%	-1,17%
@NG	568.100,00	56.810,00	10,00	-4,30%	-0,58%

The net profit and drawdown for each strategy are summarized in this table. The effect of money management can be seen for each strategy, with the ES showing the smallest increase with 2x in the net profit, and the US showing the largest with 25x the base net profit. All of the maximum drawdowns have increased, with the one related to the US future worsening the most due to the higher exposure and risk involved in the strategy with the money management.

	@GC	@CL	@ES	@US	@NG
@GC	1,00	0,18	0,44	0,65	0,52
@CL	0,18	1,00	- 0,21	0,10	0,37
@ES	0,44	- 0,21	1,00	- 0,18	0,18
@US	0,65	0,10	- 0,18	1,00	0,57
@NG	0,52	0,37	0,18	0,57	1,00

The ES is the instrument that improves diversification the most, according to the annual correlation analysis. It has a negative correlation with CL and US, with values of -0,21 and -0,18, respectively. Two other low-correlated instruments are the CL with GC and the CL with the US. The United States has the highest correlation, with a GC of 0.65. Overall, the portfolio is quite balanced and diverse, given that the instrument that contributes the most to the return (CL) has a correlation close to 0 in terms of contribution with the second and third instruments (GC, US).

The next step is to look over the OOS results. Let us begin by comparing the proprietary portfolio results without money management to the benchmark. Second, the same comparison is made, but with the money management model applied to the proprietary portfolio.

	Portfolio	Benchmark
Net Profit	285.349,25	316.653,39
Max Portfolio Drawdown (%)	-2,58%	-14,64%
Max Portfolio Close To Close Drawdown (%)	-2,05%	-2,14%
Annual Rate of Return	7,18%	8,09%

	Portfolio	Benchmark
Return on Max Portfolio Drawdown	9,91	1,75
Profit Factor	1,50	3,44
Annualized Sharpe Ratio	1,38	0,70

Period	Net Profit PTF	% Gain PTF	Net Profit Benchmark	% Gain Benchmark
2021	62.308,50	5,09%	42.740,21	3,40%
2020	124.627,50	11,35%	161.898,15	14,79%
2019	56.544,00	5,43%	145.005,79	15,27%
2018	41.956,75	4,20%	- 50.247,49	-5,02%

At first glance, the portfolio appears to underperform the benchmark because the total portfolio profit is 28,53% with an annual return of 7,18% versus the benchmark's 31,66% with an annual return of 8,09%. The portfolio's max drawdown is significantly lower, at 2.58% versus 14.64%. Instead, when the maximum DD close-to-close is compared, the portfolio outperforms the benchmark by only 0.09%. The portfolio is more efficient than the benchmark, according to the performance ratio analysis, with a higher and significant Annualized Sharpe Ratio and Return on Max Portfolio Drawdown of 1,38 and 9,91, respectively. The profit factor is also acceptable, but it is lower than the benchmark due to the differences in position structure and number. The portfolio generates all positive returns, according to the annual period report, whereas the benchmark generates 4 years over 5 of profit with a loss of -5,02% in 2018. Because the rebalancing takes place between 2018 and 2019, the loss of -5,02% is greater than the maximum DD close-to-close, and this loss is calculated even if the positions are still open.

Let us now examine each instrument's contribution to the portfolios as well as the monthly correlation to evaluate the diversification effect.

Market	Net Profit	Contribution	Max. Equity Draw Down(%)
@GC	37.610,00	13,18%	-1,31%
@CL	23.000,00	8,06%	-2,88%
@ES	173.325,00	60,74%	-1,63%
@US	28.634,25	10,03%	-0,83%
@NG	22.780,00	7,98%	-0,94%

Market	Net Profit	Contribution	Max. Equity Draw Down(%)
VTI	174.202,94	55,01%	-12,30%
VGLT	82.227,45	25,97%	-12,20%
VGIT	13.071,02	4,13%	-1,22%
IAU	27.767,60	8,77%	-1,97%
PDBC	19.384,38	6,12%	-4,17%

	@GC	@CL	@ES	@US	@NG
@GC	1,00	- 0,03	0,10	0,11	0,04
@CL	- 0,03	1,00	- 0,03	0,14	- 0,05
@ES	0,10	- 0,03	1,00	- 0,09	- 0,12
@US	0,11	0,14	- 0,09	1,00	0,10
@NG	0,04	- 0,05	- 0,12	0,10	1,00

	VTI	VGLT	VGIT	IAU	PDBC
VTI	1,00	- 0,29	- 0,43	0,12	0,41
VGLT	- 0,29	1,00	0,89	0,31	- 0,24
VGIT	- 0,43	0,89	1,00	0,30	- 0,24
IAU	0,12	0,31	0,30	1,00	- 0,11
PDBC	0,41	- 0,24	- 0,24	- 0,11	1,00

Exposure to US markets contributes the most to return generation in both strategies; however, the drawdown distribution in the proprietary portfolio is much more stable than in the benchmark; this could be due to more efficient active management rather than simple rebalancing. According to the monthly correlation analysis, both portfolios are quite well diversified; all correlations in the proprietary portfolio are close to zero; the lowest correlation in the All-Weather Portfolio is -0,43 with the pair VTI (US stock market) and VGIT (10 years treasury bond market).

Let's examine the OOS results using the money management models now.

	Portfolio
Net Profit	2.783.205,75
Max Portfolio Drawdown (%)	-15,21%
Max Portfolio Close To Close Drawdown (%)	-11,91%
Slippage Paid	728.528,00
Annual Rate of Return	70,05%

Return on Max Portfolio Drawdown	8,92
Profit Factor	1,41
Annualized Sharpe Ratio	1,83

Period	Net Profit	% Gain
2021	908.715,00	31,66%
2020	1.214.356,50	73,33%
2019	254.545,00	18,16%
2018	401.564,25	40,16%

The strategy generates an outstanding performance of 278% over the four OOS years, with the highest drawdown of -15,15%. The average expected drawdown peaks are typically around 10%, which is higher than the benchmark, but outperformance can justify this increase in risk exposure. The profit Factor and Return on Max Portfolio Drawdown are both very similar to the portfolio without money management; however, the Annualized Sharpe Ratio is 1.83. According to the annual period analysis, the portfolio was able to generate positive returns each year, as previously stated.

Let's examine each instrument's contribution to gain a better understanding of which strategies are most relevant for profit generation.

Market	Net Profit	Contribution	Max. Equity Draw Down(%)
@GC	376.100,00	14%	-11,45%
@CL	168.240,00	6,04%	-29,00%
@ES	1.312.187,50	47,15%	-10,06%
@US	707.488,25	25,42%	-14,78%
@NG	219.190,00	7,88%	-8,13%

	@GC	@CL	@ES	@US	@NG
@GC	1	-0,01	0,094	0,102	0,046
@CL	-0,01	1	-0,21	0,159	-0,05
@ES	0,094	-0,21	1	-0,24	-0,14
@US	0,102	0,159	-0,24	1	0,092
@NG	0,046	-0,05	-0,14	0,092	1

The reversal strategy on ES accounts for 47.15% of the performance, while the US accounts for 25.42%. The returns are more evenly distributed than without money management, reducing the contribution of the outlier and allowing the other strategies to benefit. The highest individual drawdown is provided by crude oil, which may be due to the instrument's changing structure in 2020 and 2021. Monthly correlation analysis reveals that the use of position sizing models enchants the negative correlations and the diversification of the portfolio's return. The ES, in particular, has a monthly negative correlation with the CL, US, and NG.

This proprietary portfolio outperforms the All-weather portfolio by more than 8x when money management models are used. It provides a higher level of risk exposure, with an average drawdown

of around 10% versus the benchmark's 2%. While the all-weather portfolio is less expensive and requires only semiannual or annual rebalancing, it demonstrates its limitations in terms of abnormal return generation. Active portfolio management with systematic strategies has a higher risk exposure and requires more frequent monitoring to ensure the effectiveness of the various strategies and margin maintenance, but it has generated profits of more than 30% per year on average in OOS periods.

The goal of this dissertation is to provide a step-by-step guide to the processes and methodologies used to build a fully diversified portfolio of trading systems. It starts with the environment that must be created before beginning coding and moves on to the structure of the strategy scripts. The dissertation then proceeds to an introduction to various trading system typologies, pattern individuation, metrics for performing a meaningful backtest, and the performance report to understand and evaluate the results obtained from the strategies' application. The optimization process follows, which can be done using Exhaustive Search Optimisation (ES), which analyzes every possible combination, or Genetic Algorithm Optimisation (GA), which selects only a small number of possible combinations that are closest to the objective function's optimum. This is the most critical process because excessive optimization can lead to overfitting, which produces optimal results during the test period but does not match the out-of-sample data, resulting in exponential losses. Following that, the trading system's performance and robustness are evaluated to ensure the system's consistency and stability and to determine whether a strategy is overoptimized. The main tools for these tests are the Performance Report analysis and the use of Walk Forward Analysis to maximize the number of OOS periods and stress tests on the system. It is critical to learn how to manage risk for a single position, a single strategy, and an entire portfolio after learning how to build a solid foundation for a trading system. This section describes the different money management models that can significantly increase the system's profitability. Because the additional return in most financial theories can only be justified by additional risk, using these position sizing models increases the average and maximum drawdown of strategies and portfolios. As a result, scenario analysis using Montecarlo Simulation is critical for retrieving 1000s of possible scenarios and evaluating the distribution and probability of both returns and drawdown for each money management model. The final step is portfolio construction, which incorporates all of the preceding steps. Portfolio construction is the combination of various instruments and strategies to maximize synergies through diversification. When the number of strategies in the portfolio begins to grow exponentially, it is possible to use different valuation metrics to select the best performing strategy and avoid losses due to whit worsening or flat performance. This process, which is usually done on a monthly or semi-annual basis, makes the portfolio more dynamic.

Each chapter includes descriptive and detailed examples, as well as codes, considerations, and the application of evaluation methodologies. The majority of the examples consider potential costs, which can reduce the strategy's profit by up to 50% in some cases. Each example, in particular, includes a reference benchmark to provide a higher level of significance and stability in the results obtained through the processes described. In addition, each example valuation is divided into IS and OOS periods to produce more realistic and non-overfitted results. The goal of each strategy and portfolio under consideration is to provide the highest level of risk-adjusted return by maximizing net profit while keeping the level of drawdowns in the systems under control. Another critical emphasis is on average trade, which is required to cover potential higher-than-expected costs.

To summarize, it is critical to concentrate on the potential risks that may arise when the systems are applied to the real market through the broker account. The two major risks that could result in higher unexpected losses are overfitting and costs. Overfitting, as previously stated, may result in abnormal returns during the test period but drastic negative returns during real trading. To overcome these issues, stress tests using Montecarlo analysis and Walk Forward Analysis should be performed to observe the potential behaviour of the strategy or portfolio with a small change in the optimized inputs, the length of IS-OOS periods, or the order of trades. The most important cost to consider is slippage. It is the tick that can be lost due to market volatility, a lack of liquidity, or a black swan event. To compensate for higher potential slippage, use limits orders rather than market orders, and try to increase the average trade of each strategy.

Finally, because the market's structure, efficiency, and correlation among instruments and strategies change over time, it is critical to rebalance the portfolio using the techniques described in the preceding chapter, as well as to perform periodic re-optimization of strategies to assess their effectiveness in the new market environment.

The most important piece of advice is to carry out all processes objectively. Do not be afraid to remove a historical strategy from the portfolio if it is not performing as well as it has in the past and try to disrupt the trading systems during the robustness evaluation process, in other words, do not cheat yourself with "ad-hock constructed" results, because the experience in the real market with overfitted systems can be extremely dangerous and unprofitable.