

Chapter 2

Literature Review

Abstract This chapter presents the background information and reviews the existing literature relevant to the development of this project. In the first part of the chapter, a brief description of the existing investment approaches is presented. Particularly, in Sect. 2.1, the “*Value Investing*” and the related instruments and methods will be described in depth. In Sect. 2.2 the technical analysis and the corresponding strategies and tools to analyze the market are presented. A formal definition of multi-objective optimization (MO) problems and their concepts are given in Sect. 2.3. A brief description of evolutionary computation and evolutionary algorithms is presented, in Sects. 2.4 and 2.5, before the review of the existing literature on MOEA’s for portfolio management, in Sects. 2.6 and 2.7.

2.1 Value Investing

Value investing is a comprehensive investment philosophy to perform in-depth fundamental analysis to limit risk, resist the crowd psychology,¹ and achieve long-term investment results. It is also the practice of purchasing securities or assets for less than its intrinsic value [1].

Value investors seek stocks of companies that trade below their estimations of intrinsic value in the market, they act based on the theory that markets overreact to good and bad news resulting in stock price movements that do not correspond with the company’s long-term fundamentals. Next, the analysis of financial statements, the use of economic indicators, the fundamental ratios, the method of investment of Warren Buffett, and the approaches to evaluate the stock price are presented.

¹Members of the crowd often adapt and act to the expectations of the surrounding culture and modify individual traits in order to identify with the crowd.

2.1.1 *Fundamental Analysis*

A company's stock can be undervalued because of a disappointing earnings report, a restructuring of the company, a lawsuit, if the company fails its strategic or financial objectives, bear market tendency of the general market that provokes short-term trend in the price of the stock.

Fundamental analysis entails rigorous evaluation of the company's fundamentals as industry growth, the capacity of the competitors, the future global economic factors for its goods and service, and macroeconomic conditions that affect the company.

The work of fundamental analyst to evaluate a security entails the study of the financial statements and industrial and ratio analysis. The analyst needs to be always looking to find information about corporate actions, like restructuring, spin-offs,² merger and acquisitions, to get a better estimation of the true value of the company.

2.1.2 *Financial Statements*

Financial statements are reports issued by companies to demonstrate their financial performance, normally trimestral or annual. The objective of the financial statements is to provide information about the financial position, performance, and changes in financial position of the company. These reports are composed of an income statement, balance sheet, and cash flow statement and are used by the value investors to do quantitative analysis on the company.

(a) **Income Statement**

Income statement measures the performance of the company for a specific period of time, shows how much money the company operations generated (Revenues/sales), the operating expenses occurred during the period, the operating profit (EBIT), the financial costs (interest and taxes), and the net income [2].

Revenue or sales represents the amount of money a company earns through the sale of a good or service during a specific time period, sometimes managers break down revenue by business segment or geography. The best way for the company to improve its profitability is by increasing its revenues [3].

- **Competitive advantage in the income statement**

A company has a competitive advantage when they have some power in the market that other rivals do not have; normally these are monopolistic or oligopoly companies. They can price their products much higher than their marginal costs, obtaining higher operating margins [4]. In a case of increase of costs

²The creation of an independent company, through the sale of part of the company.

of production, it can be transferred to the final price for the consumer, if this is not possible the company does not have the competitive advantage and the increase in costs will generate lower profit margins.

Companies with gross profit margin above 40 % are more likely to have a competitive advantage and companies with low profit margins are probably in highly competitive industries [3].

In case of a competitive advantage as the result of some technological advancement, there is always a threat that a newer technology will replace it. Companies with business in the area of technology spend a lot on Research and Development, like 30 % of its gross profit or more, which means that probably they are inserted in very competitive industry and maybe not a good company to invest [3].

- **Interest Coverage**

Interest expenses represent the money out of the business to pay the interests of the debts that the company has in the balance sheet, it is a financial cost that depends on the level of leverage of the company. If the company has a low *Times Interest Earned ratio (TIE)* it is highly risky to invest, because an unexpected event that reduces the *EBIT* of the company can put it in position of not fulfilling the payment of its obligations.

$$TIE = \frac{EBIT}{\text{Annual Interest Expense}} \quad (2.1)$$

(b) **Balance Sheet**

Balance sheet is the instantaneous report of the financial condition of the company on a particular date and is generated normally at the end of a trimester, or year. This report states what the company owns and how it is financed, it is divided into three parts, assets, liabilities, and total equity with an accounting relationship given by Eq. 2.2 [2, 5].

$$\text{Assets} = \text{Total Equity} + \text{Liabilities} \quad (2.2)$$

Using the report format under U.S. generally accepted accounting principles (GAAP) the assets are registered in the balance sheet in the order of liquidity, in the top are the more liquid assets (the current assets), in the bottom the less liquid assets.

The part of assets are divided into current assets (assets that can be converted in cash in a short period of time), and noncurrent assets (assets that cannot be converted into money so quickly).

The first assets to appear are the cash and short-term investments, if exists a record of accumulation of money year after years, it is a good signal for the investor, in terms of profitability and stability of the company operations [3].

Liabilities are divided into two parts, the short-term liabilities, money that company owed and need to pay in 1 year or less time, this include account payables, accrued expensive, and short-term debt, the other part is the long-term liabilities that come due in more than 1 year.

In industries that have a fiercely competitive environment, the companies need to constantly upgrade their manufacturing facilities to stay competitive. The acquisition of assets creates ongoing expenses that are recorded in property/plant/equipment and according to US GAAP it is reported in the statement at the cost of acquisition less accumulated depreciation.

The recent year's assets acquisitions demonstrate the necessity of upgrade of the operations of the company and this helps to differentiate the companies with competitive advantage from the others.

Companies with higher profit margins have a ratio of property/plant/equipment to total debt higher than the others, meaning lower operations leverage. The high value of fixed assets represents a barrier to competitors to enter in is sector, because they need to do great investment [3].

Companies with durable competitive advantage require little or no long-term debt to maintain their operations, it is necessary to analyze more than one year of the financial statements to see if the operations work with low levels of debt. It may occur that a company generates so much profits that it decides to take advantage of tax shield generated by use of a higher level of debt; in such cases it is normal that net earnings can pay off long-term debt in 3 or 4 years.

Common stocks represent ownership of the company, give the right to elect a board of directors and to receive dividends. Preferred stock is other class of equity that does not give the right to vote, but has the right to receive a dividend before common stocks dividends [2].

Retained earnings are profits that the company retained to invest in the operations of the company, or in others investments considered profitable. The retention ratio defines the percentage of profits that is not distributed as dividends and is retained [2].

(c) **Cash Flow Statement**

Since the accrual method allows credit sales to be booked as revenue in the income statement, it is necessary to keep separate track of the actual cash that flows in and out of business, this is shown in the cash flow statement.

This statement reports only how much money enters (cash inflow) from ongoing operations and external investment sources, and how much money goes out of the company (cash outflow) to pay the business activities, investments, and financial expenses, during the period.

Companies with durable competitive advantage working in their favor generate a great quantity of cash inflow from operations that can be applied by the managers to buy back the company shares reducing the number of outstanding shares. These actions are taken because the managers prefer to finance the company with debt, because it is cheaper; second, they try to manipulate the price of stock in the market, or the manager board thinks the company is undervalued in the market and by

repurchasing their own shares can increase the wealth of the shareholders. This can be noted in the statement in the section of *cash from investing activities*, by analyzing the previous years reports [2, 3].

2.1.3 Fundamental Indicators to Use in Ratio Analysis

Ratio analysis is used to conduct quantitative analysis of the information of financial statements, it uses the ratios calculated from the current year and compared with ratios of previous periods to check the performance of the company and to select the best company in an industry. Next, in Tables 2.1, 2.2, 2.3, 2.4, and 2.5, some of the financial ratios used by investors are presented.

Table 2.1 Profitability ratios

Indicator	Profitability ratios	Description
Return on equity (ROE)	$\frac{\text{Net income}}{\text{Shareholder's Equity}}$	ROE measures corporation's profitability, by revealing how much profit a company generates with the money shareholders have invested
Return on assets (ROA)	$\frac{\text{Net income}}{\text{Total Assets}}$	ROA measures efficiency of management using the assets to generate earnings

Table 2.2 Liquidity ratios

Indicator	Liquidity ratios	Description
Current ratio (CR)	$\frac{\text{Current Assets}}{\text{Current Liabilities}}$	Measures the company's ability to pay short-term obligations
Quick ratio (QR)	$\frac{\text{Current Assets} - \text{Inventories}}{\text{Current Liabilities}}$	Measures the company's ability to pay short-term obligations with its most liquid assets

Table 2.3 Leverage ratios

Indicator	Leverage ratios	Description
Debt equity ratio (DER)	$\frac{\text{Total Liabilities}}{\text{Shareholders Equity}}$	Measures of financial leverage
Debt ratio (DR)	$\frac{\text{Total Liabilities}}{\text{Total Assets}}$	Indicates the leverage of the company along with the potential risks the company faces in terms of its debt load
Times interest earned ratio (TIER)	$\frac{\text{EBIT}}{\text{Annual Interest Expense}}$	A metric used to measure a company's ability to meet its debt obligations

Table 2.4 Efficiency ratios

Indicator	Efficiency ratios	Description
Average payment period (APP)	$\frac{\text{Account Payable}}{\text{Sales}} \times 12$	Average period taken by the company to pay to its creditors
Average collection period (ACP)	$\frac{\text{Account Receivables}}{\text{Sales}} \times 12$	Average period for the company receive its payments from its clients

Table 2.5 Market value ratios

Indicator	Market value ratios	Description
Earnings per share (EPS)	$\frac{\text{Net income} - \text{Dividends on preferred stock}}{\text{Average Outstanding Shares}}$	The portion of a company's profit, by each outstanding share of common stock
Payout ratio (POR)	$\frac{\text{Dividends per Share}}{\text{Earnings per Share}}$	This ratio shows the percentage of the earnings that are distributed to shareholders as dividends
Dividend yield (DY)	$\frac{\text{Annual Dividends per Share}}{\text{Share Price}}$	A financial ratio that shows how much a company pays out in dividends each year, relative to its share price

2.1.4 Economic Indicators

Economic indicators are separated into macroeconomic indicators to effectuate macroeconomic analysis to forecast the cycle of the economy, and the industry indicators to analyze the industries.

(d) Macroeconomic Indicators

Macroeconomic factors have a huge impact on the general market tendency and influence the economic fundamentals of the companies. It is important to know how to interpret and analyze the indicators presented next.

- **The gross domestic product (GDP)** is a measure of the economy's total production of goods and services. Growing in GDP indicates an expansion of economy with the opportunity for companies to increase their sales and services.
- **Balance of trade** is the difference between a country's imports and its exports. A positive balance attracts more capital (external and internal) for investments. Companies in these countries are more competitive internationally, and are more capable of increasing their operations and sales.
- **Inflation rate** is the rate at which the general level of prices rises. High rates are associated with economies with demand for goods and services where there is outstripping productive capacity, which leads to upward pressure on prices [6].
- **Sentiment of consumers and producers** has important impact in the performance of the economy, an optimistic sentiment in relation to the future causes a behavior to consume more products and services in the consumers and the

producers are willing take more risks through investments and increases of production.

- **Interest rate** is the cost of money; high rates decrease the present value (PV) of future cash flows, meaning that companies and investors will see decreasing attractiveness of their investments.
- **Monetary expansion**, depending if it is anticipated by the financial markets, can lead to an increase of stock price, because that expansion means lower interest rates for some time and higher output of the economy [7].

I. Industrial indicators

The performance of any company depends in great part to the economic future of its industry; industrial indicators are used to perform a sector analysis to have a clear picture of the actual state and future of the sector [6].

- **The number of customers** is important to evaluate the risk of the company, if total revenue was achieved by few customers or some millions is an important factor to evaluate the risk. A loss of one client when the enterprise has few clients or large portion of the revenue is generated by a couple of them is a situation riskier than when there are a large number of clients, and each of them without meaningful contribution for the total revenue.
- **Market share** gives some important information about the company and the business. A company that has more than 70 % of the market suggests that probably it has a competitive advantage like a barrier to enter into the market, or economies of scale.
- **Industrial growth** is a reference for estimating the growth rate of any company that composes the group. In a fast growing industry, companies will follow this growth and the best competitors can have higher growth rate than the industry.
- **The number of competitors** gives information about the competitive environment of the industry, when there exist lower number of barriers for entry and a large number of competing firms create a difficult operating environment for generating profits. With a low competition environment in the sector the companies can use the ability of pricing power and increase their profits or pass increase of production cost to the clients.

2.1.5 Categories of Companies

Lynch and Rothchild define six general categories of companies depending on the growth rate of the company, capitalization size, and its economic behavior [8].

1. **Slow growers** are large and aging companies that are expected to grow slightly faster than the GDP, with time every fast-growing industry becomes a slow growth industry and most of the companies in the sector lose momentum too and became slow growers. The best strategy to apply for investing in this case is

to purchase the shares with the objective to win a dividend, the aspects that investor needed to consider is the payout ratio percentage (lower the better), and see in the financial statements if the company has a good record of pay dividend and check its growth rate.

2. **The Stalwarts** are big companies (multibillion dollars), where their earnings growth is faster than the slow growers. The stock of this type of company purchased at fair price probably will generate 30–50 % gain in a good year. During recessions and hard times (bear market), normally these types of companies tend to perform better than the general market, this happens because they have a durable competitive advantage that in recession times allows the company to increase its earnings.
3. **The fast growers** are small companies, new enterprises that grow more than 20 % a year. They do not necessarily belong to fast-growing industries to have high rates of growth, but can expand in a slow-growing industry by taking the market share of its competitors. The share price of these companies represents the investments with the most potential for valorization, but they too have a higher risk of down fold and a higher volatility in the stock prices than the other types of enterprises.
4. **The cyclical** companies are inside industries that expand and contract with a high correlation with the GDP growth. The sales and earnings grow faster than in other types of companies in periods of economic expansion, but in a scenario of economic recession these companies can go bankrupt or need to pass many years for the industry to recover.
5. **Turnarounds** are companies that pass hard times caused by bad news about the future of the business, poor financial condition that can mean bankruptcy, or a scandal of corruption that affect the price of the stock. When the situation or factor that caused the devaluation of the share price is solved, a quick recovery of the price is probable.
6. **Asset play** is any company that holds a valuable asset that is worth more than what is recorded in the balance sheet, or it is unknown the existence of it by the market in its valuation of the stock.

2.1.6 Warren Buffett Method

The Warren Buffett method consists in investing exceptional companies, with a durable competitive advantage, normally an economic monopoly or oligopoly, where the increase of the price of its products, leads to growth of operating profit. The most important factor for him is the durability of the competitive advantage, if it lasts for a long period of time the tendency to the business and stock price is to increase in the long run.

Warren Buffett invests only in business inside what he defines by “*circle of competence*,” those are companies inside industries that an investor understand and

had a profound knowledge [9]. The circle can be amplified and improved with research and experience, this mean that an investor can increase the number of hypotheses to invest and diversifies his portfolio.

He looks for companies with a consistent earning history and with favorable long-term prospects. The business needs to have a good return of equity ratio, low debt, high profit margins, and be managed by honest people for him to invest. After finding a company with these characteristics he calculates the intrinsic value of the shares by discounting the PV of his estimations of future cash flows of the investment, and only purchases a share below its calculations more a margin of safety.

The characteristics of companies are divided into three parts, business, management, and financial.

1. Business characteristics:

- The business needs to be simple and understandable for the estimation of future cash flows with a high degree of confidence.
- Business with a consistent operating history gives the guarantee that competitive advantage is durable.
- Sell a unique product or service.
- Companies with bargaining power in its purchases (occurs when a company that purchases a large fraction of an industry's output can demand price concessions) or seller power (company has a monolithic control on type of product and can demand higher prices) [6].
- Company with low need of innovation and new products (meaning a Research and Development costs lower).

2. Management characteristics:

- Management needs to be honest and rational to allocate the capital for providing returns above the cost of capital.
- Management should be candid with the shareholders by disclosing all the information relevant to them.

3. Financial tenets:

- Low debt in balance sheet.
- Consistent growth in earnings.
- High ROE, the companies can give a higher return for each dollar invested.

The method of investing by Warren Buffett defends to hold the investment as much time as possible, but sometimes it sells a winning position due to some motives. The first reason to sell is when a better investment is found, and need capital for that investment. Second, when it is almost certain the company will lose its durable competitive advantage. The last reason is when the stock price reaches value that is far beyond the estimated theoretical value the future of the business and the economy is considered [3].

2.1.7 Approaches to Equity Valuation

In this section, two groups of general approaches for evaluating companies are presented, respectively, the discount cash flow techniques, where the value of the stock is estimated based on the PV of the future cash flows, and the relative valuation techniques, that measure the level of overvaluation or undervaluation of a stock based upon its current price relative to earnings, cash flow, book value, and sales.

(e) Discount Cash Flow Model (DCF)

DCF valuation models recognize that common stock represents the ownership of a business and the value must be related to the future returns of owners.

Blanchard defines intrinsic value of stocks as the PV of the future expected cash flows, by estimating the total cash flows that are likely to occur in the life of the business and discounting it at an appropriate rate [7].

$$PV = \sum_{i=1}^n \frac{\text{Cash Flow}_i}{(1+R)^i} \quad (2.3)$$

R Discount rate

i Year to discount.

Financial analysts have developed different versions of the DCF, the *dividend discount model* (DDM), the *free cash flow discount model*, and the *residual income model* [2].

Next, the three cases using the DDM to evaluate equity, depending on the rate of growth of dividends, are presented.

I. Case with a zero growth rate

In a case that the company pays a constant dividend and the investor holds the stock forever, the value of equity is given by Eq. 2.4

$$P_0 = \sum_{i=1}^n \frac{\text{Div}_i}{(1+R)^i} = \frac{\text{Div}_1}{R} \quad (2.4)$$

R Discount rate

Div_i Dividend year i .

II. Case with a constant growth rate

Considering that the company will keep a dividend growth rate constant during his life, the value of the equity is determined by Eq. 2.5.

$$P_0 = \frac{\text{Div}_1}{R - g} \quad (2.5)$$

g Growth rate of dividends.

III. Case with differential growth rate

This case is more complex, and occurs in the real world. For determining the value of a share the financial analyst needs to do a prevision of the future growth rates of dividends applied to Eq. 2.6. More correct are the previsions of the analyst as he can take better advantage of the inefficiencies in market, due to valuation errors from other investors.

$$P_0 = \frac{\text{Div}_1}{1+R} + \frac{\text{Div}_1 \times (1+g_1)}{(1+R)^2} + \dots + \frac{\text{Div}_{n-1} \times (1+g_n)}{1+R^n} \quad (2.6)$$

(f) Relative Valuation Techniques

These techniques estimate the economic value of a company by comparing it with similar companies and past values. The relative ratios compare the stock price to the financial and economic information of the company.

The PER, price to cash flow (P/CF), price to book value (P/BV), and price to sales (P/sales) will be discussed.

I. Price earnings ratio

A valuation ratio of a company's current share price compared to its per-share earnings. It is a way to estimate the value by determining how much dollars are necessary to pay for one of the earnings.

$$\text{PER} = \frac{\text{Share Price}}{\text{EPS}} \quad (2.7)$$

II. The price/cash flow

The price over cash flow is a ratio similar to PER, which measures the firm's financial health, the definition uses the cash flow to calculate the ratio, because of that this ratio do not have the effect of depreciation and noncash factors, and represent the price to pay for the money entering in the company.

$$\frac{P}{\text{CF}} = \frac{\text{Share Price}}{\text{Cash flow per share}} \quad (2.8)$$

III. Price/book value ratio

The price over book value ratio measures the valuation done by the market to the assets of the company, the premium pay over the book value represents the valuation of the capacity to growth and the ROE.

$$\frac{P}{B} = \frac{\text{Share Price}}{\text{Total Assets} - \text{Intangible Assets} - \text{Liabilities}} \quad (2.9)$$

IV. Price/sales ratio

The price over sales ratio evaluates a company in terms of the sales, it is an important ratio because the sales growth is a request to the company's growth. This ratio is used by investors because it is difficult to manipulate the sales in the statement, and give a more exact relative evaluation.

$$\frac{P}{S} = \frac{\text{Share Price}}{\text{Sales}} \quad (2.10)$$

2.2 Technical Analysis

Technical analysis is a method of evaluating securities by analyzing the market activity, the past prices, and transactions volume. The technical analyst uses a set of tools like indicators and chart patterns to determine the possible future movement of the market. The balance of supply and demand is the factor that changes the price and volume of the securities.

This theory ignores totally the fundamental analysis and the intrinsic value of the securities; it is based on the philosophy that the change in the price and volume discounts the fundamental factors and information available [10].

Another important belief is that history tends to repeat itself in terms of price movements. This is justified by the human mentality, the investors and traders tend to have the same reactions and actions in similar conditions of the market. The Chartist technicians analyze the actual chart pattern that the market is forming and compare with past patterns to predict the future market movement. The Dow theory is other form of technical analysis that defines the markets as three trend movements, and each trend is composed of a phase of accumulation of stocks, absorption phase, and distribution phase. The trend to be real needs to be confirmed by increase of volume and they finish with a definitive signal of end.

2.2.1 Trends in the Market

The prices fluctuate constantly in the market, but sometimes tend to describe oscillations with a tendency corresponding to a bull market in case of the tendency

for price growth, when the trend decreases in price it is called bear market. The Dow theory describes the market as three forces simultaneously that affect the stock price, described below.

(g) Primary Market Trend

The main tendency or primary trend is the price tendency with higher time frame, usually lasting several months or years. Defined by economic fundamentals of the company and economy, it starts when the market recognizes the fundamentals and moves in concordance with them, creating a price trend.

(h) Secondary Market Trend

The secondary trend corresponds to market fluctuations against the primary trend with a lower period of time. These trends are also often called price correction when the market evolves too quickly relative to their fundamentals and performs a secondary tendency to correct the price.

(i) Tertiary or Minor Trends

Minor trends are daily fluctuations of little importance, normally called noise.

2.2.2 Strategies to Invest

Technical traders define two principal strategies to invest the trend following and band trading. Next, these strategies will be explained.

(j) Trend Following

In this approach sometimes the stock price moves in one direction for a long period of time, generating a large price movement [11].

Trend followers enter long in the market when the price break a reference value and enter short with the inverse conditions. The strategy to be successful needs to have good exit rules to limit its losses and the trader needs to be disciplined to stay with the movement for a long period of time to generate the expected return.

(k) Band Trading

Band trading strategies are used when the investor assumes that the market is in a range bound, the trading concept is the opposite of trend following, where the band traders buy at prices close of reference low and sell at a reference high [12].

2.2.3 Types of Markets

There are different types of volatility in the market and they can be very dynamic and changing, sometimes very quickly. Faith defines four types of volatility in any financial instrumented trade [12].

(l) In a range stable and quiet

Prices tend to stay within a relatively small range with little movement up or down outside the range, as can be seen in Fig. 2.1. The strategy to explore this market is the band trading, but sometimes the volatility is so low that is better to stay out of the market, waiting for a break of the range, and using a trend following strategy.

(m) In a Range Stable and Volatile

Prices tend to stay within a big range that is formed in time horizon of weeks, where inside the range has great volatility, as demonstrated in Fig. 2.2. Band trading is the correct strategy to apply when this type of market is identified.

(n) Trending and Quiet

Prices move in one direction, with retracements with low volatility in opposite direction, Fig. 2.3. The trend following is the appropriate strategy to use in this case.

• Trending and Volatile

Trending and volatile happen when there are large changes in price in one direction, with occasional significant short-term reversals of direction, Fig. 2.4. This case is similar to the one before, but it needs to adapt the trend following strategy to the higher volatility of the correction.

2.2.4 Designing a Strategy to Invest

After developing the approach to invest there is the need to create a system to implement the strategy. The building blocks of any strategy are the trading costs, markets to invest, market timing, protection capital, and exit of a winning position.

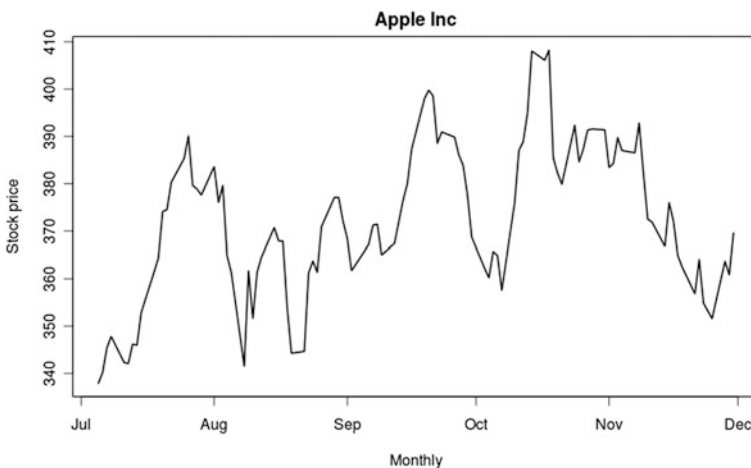


Fig. 2.1 Market with a stable and quiet volatility

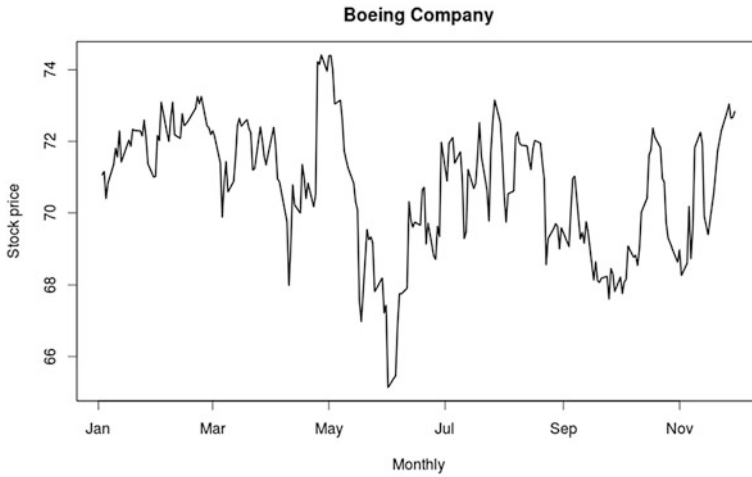


Fig. 2.2 Market stable and volatile

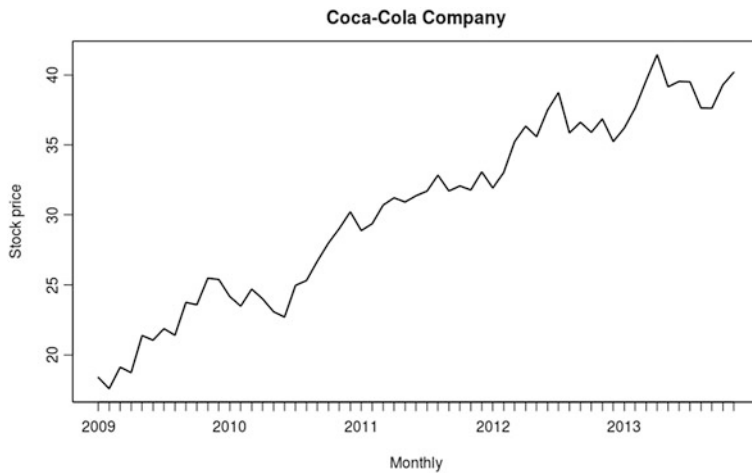


Fig. 2.3 Trending and quiet

(p) Trading Costs

Trading costs are expenses incurred when buying or selling securities, they include the commissions and spreads charged by the brokers for doing the transaction for their clients.

The costs of doing business are important because they reduce the net return of the investments and need to be considered in the investment decisions. High transaction costs and high frequency of trading mean a great percentage of money



Fig. 2.4 Trending with high volatility

paid in commissions, this can be the difference between being profitable or not in the long run. Investor should avoid possible high commissions and stocks with low liquidity, because these are the stocks with higher spreads.

(q) **Select Markets to Invest**

The first decision of any investor is to select the markets to trade, considering the available budget, possible cost in transactions, the knowledge it has about the different products, the access to information, and its experience.

(r) **Entry or Market Timing**

This is the exact price and the market conditions that need to be present for entering in position of a common stock, the objective is defined a set of rules that give the entry signal to improve the timing of buying and increase the reliability of the system [11].

For *Peter Lynch* the right time to enter is during collapses, free falls, and correction of the retracement of the price, due to lowest price of the securities [8].

(s) **Stops Loss and Protection of Capital**

Stop loss are predetermined policies that reduce a portfolio exposure, it is a component of the system to get out of a losing position, not allowing one or more investments to continue to losing money and protect the remaining capital available to continue the investing activity.

(t) **Exit of a Winning Position**

In any system it is important to define the exit conditions of a winning position, for profits maximization, to perform this are incorporated a set of rules in the system, for selling a position. Technical traders normally sell their positions, when one or more of the next conditions are achieved:

- Sell signal given by a technical indicator
- A retracement of the market in the opposite direction
- When an amount of time pass from the time of entry
- A type of chart pattern done by the market
- When a predefined amount of profit is achieved.

2.3 Introduction to Multi-objective Optimization

Multi-objective optimization (MO) is a method used to solve real-world problems that involve simultaneously several incommensurable and often competing objectives. Normally there is not only a single optimal solution, but a set of optimal solutions.

Multi-objective optimization is the problem of finding the best solutions to optimizing two or more objectives that are in conflict, subjected to certain constraints [13].

The objective function (OF) is an equation to be optimized (maximized or minimized), composed of variables with need to respect certain constraints. Mathematical algorithms are used to optimize the OF, in single-objective optimization there is only one OF to optimize, and in multi-objective there are two or more. The nomenclature used for these functions is $f_i(x)$.

The search space Ω is composed of n parameters, the decision variables. The solutions found for the optimization of the OF are called vector solution or decision vector, they are composed of a set of values each one corresponding to one decision variable. The process of optimization corresponds to varying the value of the decision variables to search in the space the optimal solutions to the OF.

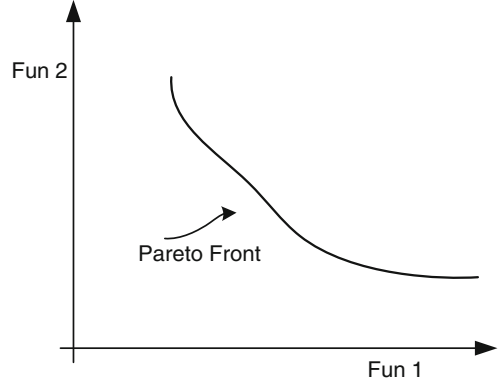
$$x = (x_1, x_2, x_3, \dots, x_n) \quad (2.11)$$

2.3.1 Multi-objective Description

The MO problem can be described as for each point in the space (Ω) defined by n decision variables, which have a vector function $F(x)$ composed of m functions $f_i(x)$. The goal is to find all the solution vectors that solve the problem, considering the restrictions imposed. The mathematical formulation to the problem is described in Eq. 2.12:

$$\begin{aligned} F(x) &= [f_1(x), \dots, f_m(x)], \quad m \text{ number of OF} \\ g_i(x) &\leq b_i, \quad \text{for } i = 1, \dots, k \\ x_i &\geq 0, \quad \text{for } i = 1, \dots, n \end{aligned} \quad (2.12)$$

k the number of constraints.

Fig. 2.5 Pareto front

The concept of Pareto dominance defines that a vector x_1 dominates another x_2 for a maximization problem, if for each component of the vector $F_1(x)$ is bigger or equal at each component of $F_2(x)$, but at least one component is greater [14].

$$\begin{aligned}
 &x_1 \succ x_2 \text{ if,} \\
 &f_i(x_1) > f_i(x_2), \quad \text{for at least one } i \text{ of } \exists i \in \{1, \dots, n\} \\
 &\text{and for the remaining comonents of } f_i \\
 &f_i(x_1) \geq f_i(x_2), \quad \text{for } i \in \{1, \dots, n\}
 \end{aligned} \tag{2.13}$$

A vector solution is called *Pareto optimal* if there is no other vector in the solution space that improve any $f_i(x)$ without deteriorating at least other $f_j(x)$.

From this definition it is constituted the *Pareto set* that represents the objective vectors not dominated with different trade-offs between the objectives.

The Pareto front (PF) or Pareto set (PS) is composed of the set of efficient solutions nondominated. Figure 2.5 represents a MO problem with two OF to minimize, where the solutions to the problem are in feasible region.

$$\begin{aligned}
 &PS^* = x_i^* \subseteq \Omega \\
 &F(x_i^*) \subseteq F(\Omega) \\
 &\nexists x_m \in \Omega : x_m \succ x_i, \forall x_i \in P^*
 \end{aligned} \tag{2.14}$$

2.4 Evolutionary Computation

A number of stochastic search strategies are used by researchers to solve the MO problem, the evolutionary algorithms, genetic algorithms, genetic programming, simulated annealing (SA), and ant colony optimization. Those heuristics do not guarantee the identification of optimal Pareto front, but find a good approximation to it.

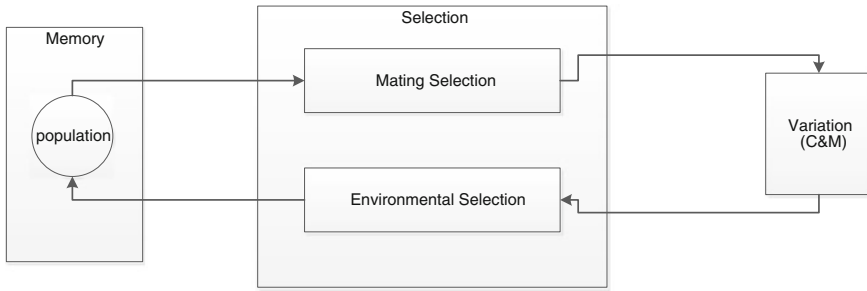


Fig. 2.6 General model of search heuristic

A search heuristic is composed of working memory, selection module, and reproduction model, as represented in Fig. 2.6.

2.4.1 Memory Module

This module contains the currently considered population, each time a reproduction is made the new population found is recorded in the memory by replacing the previous one.

2.4.2 Selection Module

The selection model are composed of two processes the mating and environmental selection. The mating process picks the most promising individuals from the population and sends these individuals to the reproduction module. After the reproduction process creates new solutions the environment selection determines which of the new solutions are stored in the memory as the new population.

2.4.3 Reproduction Model

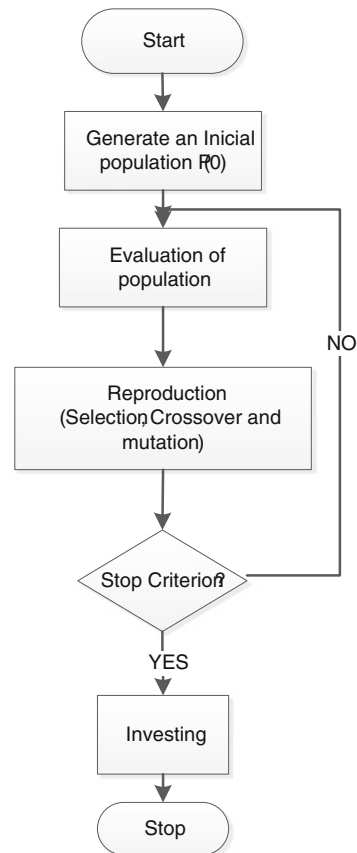
The variation or reproduction model uses a set of solutions for systematically or randomly genetically changing these solutions to generate a new set of potential better solutions.

2.5 Evolutionary Algorithms

EA are optimization computer algorithms inspired by the biological model of evolution that improve automatically through experience. They use a mechanism that simulates the process of evolution to search in the space of solutions the global optimum of the problem. Using a method to evaluate the quality of randomly generated solutions they progress toward the optimum using a fittest measure to choose the best candidates for reproduction.

The research done in the field proves that it is a heuristic capable to solve the optimization problem and find the Pareto set, because EA are capable of processing a set of solutions in parallel and finding a good approximation in a single run [15] (Fig. 2.7).

Fig. 2.7 Flow chart of an EA



2.5.1 Representation

EA solutions are represented as a chromosome that is a collection of *genes*, each gene represents one decision variable. The chromosome is an encoding of the solution to the problem, and is called genotype.

2.5.2 Population

The set of solutions that the algorithm finds at each iteration is called population, normally in the first one is used a random population, or a population from a previous simulation to initiate the process can be used.

2.5.3 Quality Indicator

The quality indicator or fitness function is designed to give a quantitative measure of the quality of the chromosome in solving the problem. The selection module uses the evaluation done by the fitness function to select the chromosomes for reproduction. At each iteration it is expected that the average fitness of the population improves meaning that the algorithm is learning.

In single-objective optimization the OF and fitness function are often equal, but for multi-objective different strategies are used to do the fitness, they are aggregation-based, criterion-based, and Pareto-based fitness assignment strategies [14].

2.5.4 Selection

After the fitness is performed the algorithm needs to decide what are the individuals obtained in the reproduction that compose the next population, this is done by a mechanism where the best individuals from the population are selected to be used for reproduction in the next iteration. This process of selection and reproduction steers the search in the direction of the nondominated front at each selection. The common selection operators are the fitness proportionate selection, truncation selection, ranking selection, tournament selection [16].

2.5.5 Variation or Reproduction Operations

Variation operations are realized in the individuals who are selected for reproduction to generate the next population, by the processes of mutation and crossover.

(u) **Crossover**

Recombination or crossover operation uses a certain set of solutions to create a predefined number of new solutions called children, by recombining parts (genes) of each solution [14].

(v) **Mutation**

Mutation is the operation that selects some individuals of the population to reproduction randomly, consists in modifying these individuals by changing some genes according to a given mutation rate.

2.5.6 *Algorithm Design Issues*

According to [14] in MO the goal is to achieve the set of solutions that are as close as possible to the global Pareto optimal front, by minimizing the distance of the solutions generated to the Pareto front. This is obtained by selecting the individuals that are nondominated for them to reproduce. The algorithms need to maximize the diversity of the population obtained to cover the whole Pareto front, this is done by avoiding populations that contain too much identical solutions.

Next, is explained the considerations to take in the design of a multi-objective evolutionary algorithm (MOEA).

(w) **Diversity Preservation**

For a MOEA to preserve the diversity within the current Pareto set approximation, it is needed to incorporate density information in the algorithm to be used in the selection process. This implies that in the selection module the chances of individual's being selected for reproduction decrease, if the density of individuals in its neighborhood is greater. For doing the diversity preservation there are three techniques, the kernel methods, nearest neighbor techniques, and histograms and these techniques are described in [14].

(x) **Elitism**

Elitism addresses the problem of losing good solutions during the optimization process, due to random effects. For solving this problem in the new populations the best elements of the old population are preserved [14].

(y) **Limit Behavior**

Limit behavior of the MOEA is what the algorithms can achieve in terms of performance, when they have unlimited resources, infinite time to continue the evolution and space in memory to store all the solutions.

(z) Global Convergence

Global convergence for MOEA is when the Pareto front approximation $PF^{*(t)}$ achieved by the algorithm is practical, identical to the true Pareto front when the number of generations t goes to infinity. In real implementations the algorithms have to deal with limited resources and should guarantee the convergent approximation to the true Pareto front $PF^{*(t)'} \subseteq PF^*$ [14].

2.5.7 *State-of-the-Art Multi-objective Evolutionary Algorithms*

MOEAs are distinguished from standard EAs by employing the Pareto dominance concept in the fitness evaluation to allow the comparison between individuals based on multiple conflicting objectives.

The first implementation of a MOEA, dated from 1984 with the algorithm VEGA, was a simple genetic algorithm with a modified selection mechanism, developed by Shaffer; from then many new algorithms have been developed. Srinivas and Deb developed NSGA in 1989 that ranked the population with the Pareto dominance and used a dummy fitness value proportional to the population size; MOGA uses a scheme in which each is given a rank proportional to the number of individuals, created in 1993 by Fonseca and Fleming; Horn, Nafpliotis, and Goldberg developed NPGA in 1994, this algorithm uses a tournament selection scheme based on Pareto dominance; SPEA uses an external archive for saving the nondominated solutions found in each iteration, which was introduced by Zitzler and Thiele in 1999; PAES developed by Knowles and Corne in 1999 uses an evolutionary strategy with one parent produce on child by mutation; PESA uses hypergrid scheme technique for selection and diversity maintenance, developed in 2000 by Corne, Knowles and Oates. Deb, Pratab, Alagarwall, and Meyarivan propose the NSGA-II, whose main characteristic is the computational implementation is easier than NSGA; Erickson, Mayer, and Horn created NPGA-II in 2001, it uses a Pareto approach with tournament selection scheme; SPEA- II introduced by Zitzler, Laumanns, and Thiele in 2001 is an improved version of SPEA with an improved fitness assignment; Corne, Jerram, Knowles, and Oates have developed PESA-II in 2001 which uses a selection method where the selective fitness is done to the objective space and not to the individuals; in 2012 Liang, Jane You, Han, Li, proposed the DS-MOEA which uses three alternative operations to perform the learning of the population (evolution in the objective space, evolution in the solution space and self-evolution); and a new algorithm called PSS uses a method to select the nondominated solutions using an global valuation done by fuzzy measures with the user's degree of consideration objective and partial objective evaluation, it was created by Jong Kim, Ji Han, Ye Kim, Seung Choi, Eun Kim in 2012.

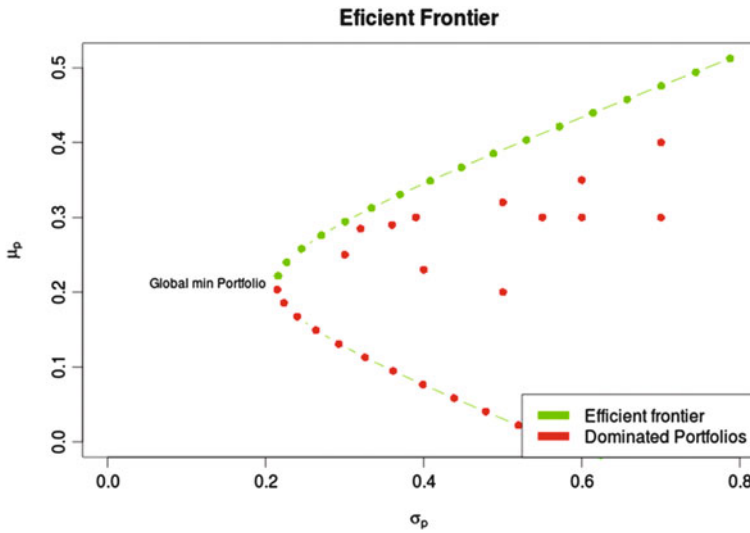


Fig. 2.8 Efficient frontier

2.6 Portfolio Optimization

A portfolio can be defined as a set of selected investments done by its manager. He has at their disposal an amount of capital and a range of assets, to maximize the portfolio return and minimize the risk using asset allocation.³ The efficient frontier in Fig. 2.8 represents the portfolios with highest expected return for any risk level.

2.6.1 Diversification and Risk of Portfolios

The arbitrage pricing theory using one factor model of Eq. 2.15 is a tool that allows describing and quantifying the factors that affect the rate of return of a security.

$$R = R + \beta F + \varepsilon \quad (2.15)$$

The risk of a stock is the unanticipated part of the return ($\beta F + \varepsilon$) and can be separated in two components, the systematic risk (βF) or market risk due the

³Investment strategy that attempts to balance the risk versus return by adjusting the percentage in each asset selected to incorporate the portfolio.

macroeconomic environment that affects the general market, and unsystematic risk (ε) that affects only the company or the industry where it is insert.

This concept applied to the portfolios theory, defines that the return of a portfolio is given by the weight sum of individual returns, Eq. 2.16. It can be noted the diversification effect in the risk reduction of the portfolio in the equation, because the unsystematic risks are independent, the increase of securities in the portfolio decreases the value of the sum of weights of unsystematic risks.

$$R_p = w_1 \times (\bar{R}_1 + \beta F_1 + \varepsilon_1) + \cdots + w_n \times (\bar{R}_n + \beta F_{2n} + \varepsilon_n) \quad (2.16)$$

This theory is applied to the portfolios when it used some diversification to reduce the weight average of the unsystematic risk by diversification.

2.6.2 Mean-Variance Model

The classical mean-variance portfolio optimization model introduced by Markowitz aims to select a set of assets to invest from the space of available assets and determine the fractions w_i of the budget to be invested in each asset selected. In this model the objective is to minimize the risk for each level of expected return of the portfolio.

The Markowitz portfolio optimization can be stated mathematically as follows [17]:

$$\text{Min } \rho(w) = \sum_{i=1}^n \sum_{j=1}^n \sigma_{ij} w_i w_j \quad (2.17)$$

σ_{ij} Covariance of asset i with the asset j .

The portfolio (P) is a set of real-valued weights (w_i) of the stocks selected from the n available assets in the market.

$$\sum_{i=0}^n w_i = 1, 0 \leq w_i \leq 1, \quad i = 1, \dots, n \quad (2.18)$$

The return of each asset is given by

$$E_i = w_i \times r_i \quad (2.19)$$

r_i valorization of asset i .

The expected return of the portfolio is given by the sum of the expected returns of the individual assets:

$$r_p = \sum_{i=1}^n w_i \times r_i \quad (2.20)$$

2.6.3 The Mean-Variance Cardinality Constrained Portfolio Optimization Model (MVCCPO)

In the real world, portfolio managers need to deal with a number of realistic constraints that arise from normal business practices and industry regulations [18].

The model MVCCPO is an expanded model of the Markowitz, where it is added two constraints, the cardinality constraint and the quantity constraint.

Cardinality constraint imposes a limit on the number of assets to be selected, it is used by managers to restrict the number of assets in the portfolio to a number that is possible following the economic factors of each asset, and control the transaction costs.

Quantity constraint or buy-in threshold restricts the weight of each asset in the portfolio between lower and upper bounds. The low limit is used to avoid small holdings that do not have almost any effect in the performance of the portfolio, and to prevent to pay higher costs of transaction. The higher limit is used to prevent the excessive exposure of the portfolio to a single asset [19].

Mathematical formulation of MVCCP Model:

$$\text{Min } \rho(x) = \sum_{i=1}^n \sum_{j=1}^n \sigma_{ij} x_i x_j \quad (2.21)$$

$$\text{Max } r_p(x) = \sum_{i=1}^n r_i x_i \quad (2.22)$$

$$\sum_{i=0}^n x_i = 1, 0 \leq x_i \leq 1, \quad i = 1, \dots, n \quad (2.23)$$

$$\sum_{i=0}^n \delta_i \leq K \quad (2.24)$$

$$l_i \delta_i \leq x_i \leq u_i \delta_i, \quad i = 1, \dots, n \quad (2.25)$$

$$\delta_i \in \{0, 1\}, \quad i = 1, \dots, n$$

In this model Eqs. 2.21 and 2.22 are the objective functions to optimize the MOEA, in Eq. 2.23 it is imposed a restriction that the total amount invested need to be equal to the capital available, Eq. 2.24 represents the cardinality constraint, and Eq. 2.25 limits the weight of each investment done ($\delta_i = 1$) to an inferior limit l_i and upper limit u_i .

2.7 State of the Art of Portfolio Optimization

Some real-world problems involve simultaneous optimization of several incommensurable and often competing objectives. Normally, there is not only a single optimal solution, but a set of optimal solutions.

Multi-objective optimization is a method to solve the problem of finding the best solutions when optimizing two or more objectives that are in conflict with each other, subjected to certain constraints [20].

There are many measures of risk and return to evaluate the performance of a portfolio, and these measures can be used as the objectives to be optimized by the EA. The most popular in portfolio management are the compound annual growth rate (CAGR) percentage, managed account report (MAR) ratio, Sharpe ratio, value at risk (VaR), conditional value at risk (CVar), the mean (Portfolio Expected Return), and the variance [13].

Tettamanzi and Loraschi in 1995 describe a MOEA using the Markowitz model, but the measure of risk used is the lower partial moments or downside risk introduced by Harlow [21]. This objective takes into account the downside part of the distribution of returns. The research proves that downside risk make the use of quadratic optimization techniques impossible, because the shape of the OF is non-convex.

Cesarone, Scozzari, and Tardellain (2009) used an algorithm-based approach that starts from a pair of assets in the portfolio and tries to add one each time for the MVCCPO model. The simulations proved that this model of investment has better performance than the Markowitz classical model.

In the work done by Chang, Meade, and Sharaiha in 2000 three heuristics TS, GA, and SA are used to solve the portfolio optimization problem. They also study the problem of finding the efficient frontier using the MVCCPO model. The results prove the existence of cardinality constraint that affects in the shape of the efficient frontier, causing discontinuities in the curve.

In the work Lin and Wang in 2001, NSGA-II is used in the Markowitz's model with constraints of fixed cost and minimum lots. The results show that the efficiency

of the GA is undermined without the fitness scaling, and the transaction costs dislocate the Pareto curve in the vertical axis.

Schaerf in 2002 uses MVCCPO model to compare and combine different neighborhood relations in the Pareto front, with local search strategies to find it.

Schyns and Crama in 2003 describe the application of SA for solution of the classic Markowitz model with more realistic constraints, the quantity constraint, cardinality constraint, turnover constraints, and trading constraints. The advantage of using SA over other heuristic methods is the ability to avoid getting trapped in optimal local points, its flexibility and ability to approach global optimality. The important conclusions of this paper are the introduction of trading constraints that are difficult to handle, and there is a trade-off between the quality of the solutions and the time of the simulations to find them.

Lozano and Armañanzas in 2005 uses the heuristics greedy search (GS), SA, and the ACO. For the simulations they used data from five different market indexes. They varied the number of assets (K) in the portfolio for each simulation. The simulations show that fewer assets in a portfolio can represent a higher expected return but it is obtained with a higher variance of the return. They concluded that ACO is a better heuristic than the others to obtain portfolios solutions with higher risk more close to the true Pareto front, and the SA fits better for lower risk values.

Clack and Patel in 2007 compared the performance of a standard EA against an Age-Layered Population Structure EA (ALPS EA). They use in the portfolio a basket of 82 stocks of the 100 available. The simulations performed showed that ALPS EA reduces the premature convergence, providing better fittest solutions than the EA.

Ghang, Yang, and Chang in 2009, tested different risk measures in substitution of the mean-variance, one of them is the variance with skewness, developed based on the theory that portfolio return may not be a symmetrical distribution, this means that the distribution of return of individual assets tend to exhibit a higher probability of extreme values, like it has been suggested first by Samuelson in 1958. The results show that MOEO is capable of finding a wider spread of solutions than the others algorithms, and is capable of competing with NSGA-II, SPEA 2, and PAES in portfolio optimization problems.

Hirabayashi, Aranha, Hitoshi in 2009 proposed a GA to generate trading rules based on technical indicators (RSI, MA, percent difference from moving average). The algorithm after entering in a position, will exit it based on the following genes stop loss or take profit optimized. They used this system to trade in the forex market (FX).

Golmakani and Fazel in 2011 used an extended model of Markowitz, with four constraints (minimum transaction lots, sector capitalization lots, cardinality, and

quantity constraints). The authors proposed a heuristic called CBIPSO (combination of binary PSO with improved PSO) to solve the portfolio optimization problem of Markowitz.

They compared their heuristic against the GA proposed by Soleimani in 2007. In the simulation they tested different portfolio sizes and expected returns, and they conclude that the CBIPSO outperforms genetic algorithms (GA), which can achieve better solutions in less amount of time.

Hassan and Clack in 2009 [22] tested the combinations of two techniques mating restriction and diversity enhancement in the algorithm SPEA2, to improve the robustness and the diversity of the solutions. To evaluate the quality of the solutions they used the Sharpe ratio.

Casanova in 2010 used a learning classifier system (LCS) in a dynamic learning system to select the stocks to invest based on technical and intuition analysis, the revaluation period RP, average revaluation period (ARP), RSI, MA, DMA are the indicators used for ranking the best stocks for trade, considering the genes parameters (days; minimum value selection of the parameter, variation allowed of the best stock, type of price) for each indicator; with a system for tactical asset allocation called Tradinnova-LCS simulates the intelligent behavior of an investor in a continuous market to form the portfolio. The system tested outperforms all the investment funds analyzed by the INVERCO in the periods of simulation.

Gorgulho, Neves, and Horta in 2011 implemented an expert technical trading system, describing the system architecture and the investment simulator, and used GA to find the solutions. They tested the system against B&H strategy, and random selection, to prove the superiority of the GA system based on technical signals.

The approach of Kaucic presented in 2012 is a trading system based on technical analysis, where an investment module is used to manage a portfolio with long and short positions to generate the so-called long-plus-short portfolio. A technical module is used for detecting overbought/oversold conditions and short-term changes in relative value in contrast to long-term through a learning mechanism using EA that manages the information derived from the technical indicators incorporated.

Pandari, Azar, and Shavazi in 2012 developed a MOEA model with six objectives to optimize, and tested it against the classical model of Markowitz. The conclusion that they arrive is that their model use less risk due to the higher number of objectives optimized by the algorithm.

In Table 2.6 a summary of the different solutions related to the optimization of portfolios using several parameters to describe their main characteristics is presented.

Table 2.6 Overview approaches to portfolio optimization

Reference	Period of simulation	Algorithms utilized	Markets tested	Fitness functions	Constraints	Portfolio analysis	Results obtained
Chang et al. [19]	Mar 1992 to Sep 1997	GA, TS, SA	Hang Seng, DAX, FTSE, S&P, Nikkei	Mean, variance	Minimum lots	Markowitz's model	Best results obtained with the GA Heuristic
Lin and Wang [23]	Mar 1992 to Sep 1997	GA based on NSGA-II and Genocop	Hang Seng index	Mean, variance	Fixed transaction costs minimum lots	Markowitz's model	The proposal GA solves the portfolio selection problem efficiently
Schaerf [24]	NA	TS, SA, LS	Hang Seng, DAX, FTSE, S&P, Nikkei	Average percentage loss	Cardinality, quantity	Markowitz's model	The Tabu search is the heuristic that achieves the best Pareto curve
Schyns and Crama [25]	Jan 6, 1988 to Apr 9, 1997	SA	151 US Stocks	Mean, variance	Floor ceiling, turnover, trading and quantity	Markowitz's model with	The SA is able to handle more classes of constraints than other heuristics
Lozano and Armañanzas [26]	Mar 1992 to Sep 1997	GS, SA, ACO	Hang Seng, DAX, FTSE, S&P, Nikkei	Mean, variance	Cardinality, quantity	Markowitz's model	They obtained a portfolio with a return of 3 and risk 0.1
Clack and Patel [27]	May 31, 1999 to Dec 31, 2005	ALPS system incorporated in GP	FTSE 100	Sharpe ratio		Nonlinear model	The ALPS GP obtained a return of 50 %, and the standard GP a return of 33 %

(continued)

Table 2.6 (continued)

Reference	Period of simulation	Algorithms utilized	Markets tested	Fitness functions	Constraints	Portfolio analysis	Results obtained
Ghang et al. [28]	From Jan 2004 to Dec 2006	GA	Hang Seng, S&P, FTSE, S&P	Mean, variance, semivariance, variance with skewness		Markowitz's model	The higher return obtained for S&P was 0.0023 with a risk 0.0008
Chen et al. [29]	Mar 1992 to Sep 1997	MOEO algorithm	Hang Seng, DAX, FTSE, S&P, Nikkei	Mean, variance	Cardinality, quantity	Markowitz's model	Best performance obtained with a MOEO with a return of 0.00859 and risk 0.000417
Anagnostopoulus and Mamanis [30]	Mar 1992 to Sep 1997	NPGA2, NSGA-II, PESA, SPEA2, e-MOEA	Hang Seng, DAX, FTSE, S&P, Nikkei	Mean, variance	Cardinality, quantity	Markowitz's model	The SPEA2 is superior than other MOEA
Casanova [31]	2005 to 2009	LCS model	IBEX 35	ROI		Technical analysis	15.3 %
Gorgulho et al. [32]	Jan 06, 2003 to Jan 06, 2009	GA	DJI	ROI		Technical trading system	60 %
Kaucic [33]	Jan 25, 2006 to Jul 19, 2011	EA	DJI	Information ratio, omega, Sortino ratio		Technical trading system	70 %, 125 %, 119 %
Pandari et al. [34]	Mar 2002 to Mar 2008	MOEA	Tehran Stock	Cumulative return, mean return		GA model using Sharpe ratio, Markowitz's model	600 %, 350 %

2.8 Conclusion

In this chapter major investment approaches were presented, in particular the value investing, where it is explained their components, such as financial analysis performed using financial statements of the companies, the economic indicators that influence the business sector, and macroeconomic indicators to take into account in forecasting the economic cycle, for investors have a better perspective of the future and profitability of investments.

It has explained the method of investment of Warren Buffet, and the DCF methods used to evaluate companies depending on the cash flow generated and growth rates. It was presented the different types of markets, and the necessary components to build a complete trading system.

The optimizing concepts of multiple objectives, such as Pareto curve, and the Pareto set, were discussed in this work in a way to be applied in the development of the MOEA. It was made a brief introduction to evolutionary algorithms and how to implement them. It is explained the most important considerations to have in implementation and possible problems of the EA.

After a description of the state of the art of multi-objective EA, are introduced the mean-variance model, and the mean-variance cardinality constrained portfolio optimization model (MVCCPO). It is presented the state of art of the investigation than with portfolio optimizations, the models of investment, approaches to manage the portfolios used, and the objectives to optimize.

The active strategies of investment based mainly on technical analysis, demonstrate that there exist a number of possible applications of intelligent computing applied to investments in stocks, and can achieve good investment returns.

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