

Investment Portfolio Optimization based on Risk and Trust Management

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Abstract—The goal of this paper is to develop a system able to coordinate a trader in optimizing a stock market portfolio in order to improve the profitability of a short or medium time period investment. The system is able to classify the risk and quantifies its effect on an investment based on sentiment analysis, certain characteristics and the traders level of confidence. It also uses an ontology to describe the markets status and expectations based on future events (text features) and to determine the relationship and correlation between news articles. The system also verifies the effect of a similar percentage of positive and negative news articles, and which of this information will influence more the stock price movement and trend.

We proposed a multi-agent system that uses text mining, ontology, sentiment analysis, trust and risk models in order to choose the appropriate mix of investments to minimize the risk and maximize the gain on a stock portfolio. A prototype was developed on which we validated our research.

Index Terms—Risk Management, Portfolio Optimization, Sentiment Analysis, Trust, Trading Strategies, Stock Market Prediction, Multi-Agent System

I. INTRODUCTION

Stock Market Prediction has played an important role in finding the next day price of a stock or in determining the trend direction based on textual and numerical data. Another approach based on this information, on risk and on trust management is to optimize an investment portfolio. A portfolio optimization involves a classification of stock investments based on risk and on the return attached to it in order to choose the "perfect" combination of investments to maximize the gain and in the same time minimize the risk. In order to optimize a portfolio there are a series of methods that must be taken in consideration as sentiment analysis, trust model based on levels of confidence, risk management, traders behavior effect on the market and the effect of news articles on the stock price movement.

Sentiment analysis is based on determining whether a message is positive or negative taking in consideration past patterns and stock traders knowledge and behavior [6], [12]. A sentiment analysis model must be trained with relevant data in the domain and store the reaction of the system in different situation based on the same information. It also quantifies the effect of different information applied to the same price data and which is the influence degree.

Another information that a system must extract from this kind of data is the level of confidence on the trader’s knowledge, influence and behavior, the effect of negative and positive news articles on the stock evolution, and the quantified level of risk on an investment. A trust model applied on the stock market refers implicitly on the degree of confidence that a trader has in all the factors that can influence the movement of a price.

A critical part of investing on a stock market is to analyze the related risk and find solutions in order to minimize it and maximize the return. The risk related to a stock market portfolio is influenced by a series of macro-economical, financial and behavioral factors. Some factors that influence risk behavior along with the traders’ behavior are economic growth, recessions, inflation, currency fluctuations, the position of a stock in a group of stocks (the strongest stock), the psychology of the crowd and the effect of financial news article on the stock price evolution.

Starting from an existing framework called Multi-Agent Stock Trading System (MASTS) [18] and based on the information above, we added certain utilities in order to choose the appropriate combination of investment techniques that will have as a result minimizing the risk while having a favorable price return on a stock market.

Researchers use ontology in stock market prediction due to their ability to capture and represent the knowledge of a certain domain and show the relationship between conceptual pairs. In the proposed system we define an ontology that describe the markets status and expectations based on future events (text features). It also describes the relationship and correlation between news articles.

The system starts from the news articles information extracted and searches for correlation between positive and negative terms and the traders reaction on a certain situation and quantifies the effect of a similar percentage of positive/negative news articles applied on the same time to a stock price evolution. An agent was introduced that is able to find which kind of news has a greater influence on the traders behavior and implicitly on the price movement. A sentiment analysis agent was added in order to depict the reaction of stock traders based on structured and unstructured information, their knowledge and pattern correlations and relationships. The system also adds a risk management agent that classifies the risk based on certain predefined characteristics and the traders knowledge from past experiences. This agents goal is to depict and quantify the risk of certain actions/investments.
The framework’s goal is to provide a stock market portfolio optimization based on the stock traders’ behavior, a defined level of confidence, the evolution of risk on a certain action and the influence of a similar amount of different types of messages applied in the same time to a stock movement.

The rest of the paper is structured as follows. In Section 2 are presented some literature review about sentiment analysis, trust and risk models on a portfolio. Section 3 presents our system architecture description. Section 4 presents an analysis of our model, the results obtained and a comparison with similar frameworks. Conclusions and future work are described in Section 5.

II. RELATED WORK

Portfolio optimization is possible if a trader takes in consideration the influence of certain phenomena (financial news influence, risk, trust and market evolution) to compute the effect of some properties and its size on the stock market [1]. Portfolio optimization is defined as the combination of investment that can have a large return and a minimized risk [11].

Risk management on a portfolio plays an important part [10]. A series of approaches where developed in order to minimize the risk effect on an investment based on risk’s characteristics and the market behavior. One of this approach is based on the Karsei evaluation that quantifies the trader’s sentiment based on certain phenomena as market characteristics and stock trading. This system’s aim is to reduce losses and to take expert decisions in order to maximize the return in complex situation [16].

There are many types of risks that can be encountered when dealing with a portfolio optimization. Tail risk can be evaluated by using skewed Student-t GJR-GARCH model and the SJC copula. By evaluating the effect of this risk on a stock portfolio it is more than clear that it has a lower effect on investable portfolios [14].

The most used models in determining the risk on a stock market or on a stock portfolio are the Value-at-Risk Models [17]. A model was developed based on Value-at-Risk [8] models(FHS1 and POT2) applied to some equity portfolios and a large number of emerging equity portfolios, by taking in consideration, also critical periods in the market evolution as crises and post-crises. The conclusion of this model is that on an emerging market portfolio the system overestimated VaR if the estimation sample is larger, while on the developed markets the VaR is underestimated unconcerned by the estimation sample [7].

A system was developed [19] that searches for existent internationally patterns in portfolio return and makes the correlation between these evidence and an unexplored equity market. It also verifies if there are some connections between the market risk factor and the sensibility of stocks. In this approach there are considered some sorting categories as momentum, idiosyncratic risk [3], portfolio size, some fundamental analysis ratios.

Another approach is to take in consideration liquidity [4] and risk management[15] in order to predict certain unfavorable actions in bad times and equity issues in good times. A system was developed based on this issues in order to obtain a positive return evaluation and a better reaction to stock market shocks of the companies[2].

Textual data can also influence the evolution of a stock and in the same time a risk management can appear due to the fact that unstructured data represents a valuable source of information and can influence the behavior of the market[9].

Sentiment analysis and trust analysis can also decrease the risk that is associated with a stock market portfolio. If a trader has some confidence that an action on the market will occur then he will probably make an investment [5], [13]. These signals can be depicted by a trader based only on the experience, expertise and knowledge that he acquired in time.

III. ARCHITECTURE

A. Problem Domain

Stock market prediction takes in consideration stock price and financial textual information in order to determine the next day price and trend of a particular stock. A problem that appears is how to create and optimize a portfolio in order to maximize the return and in the same time minimize the risk that is associate to it. An approach in this direction is to create a valid portfolio based on the information that a trader has about a company and it’s evolution along with the associated price evaluation. In order to optimize a portfolio a trader has to take in consideration the effect of certain phenomena.

Trust management is based on social trust representation more precise on the level of confidence that a trader acquires over time and through experience. Based on the knowledge acquired and the level of confidence that the traders gives to a situation, this utility can help in the process of taking automated decisions.

Risk management refers to determining the risk associate to an investment and how can the system handle and neutralize the effect of risk in order to maximize the price return and optimize the investment portfolio. A system can neutralize all the risk on an investment portfolio, but he can develop an algorithmic trading strategy that can make some risky transactions in a sectors with a higher degree of confidence and obtain a good return and minimize the risk on a sector that has a minimum and medium degree of confidence in order to obtain a medium safe return.

B. Architecture Description

The proposed system’s aim is to optimize a stock price portfolio based on stock price past information, news articles effect, traders effect on the market, sentiment analysis, trust and risk evolution and evaluation. Portfolio optimization’s goal is to minimize the risk effect on an investment and maximize the price return. The system’s architecture is presented in Figure 1.

The system uses three databases one for stock price information, and the other two for storing news articles and financial reports and information related to them. The new system is

1Filtered Historical Simulation
2Peak-Over-Threshold
based on MASTS system and Text Mining News Articles tool developed by our team.

Our Multi-Agent Stock Trading System (MASTS) uses historical data and determines the next day price and the stock trend direction based on neural network models, Elliott Wave principle and technical and fundamental analysis techniques.

The system has another utility that extracts relevant information from textual and financial data in order to classify the news and determine if there are some connections between a released new and the stock price movement.

Based on the extracted information we define a Textual Data Interpretation Agent that determines the effect of textual information on a stock price evolution. The News Articles Effect determines what happens in the case when there is a similar number of negative and positive news articles applied in the same time to the same stock. This situation is possible because we use different types of news, from financial to social news.

Pattern Learning Agent is the one that learns from past investment, stock evolution, traders behavior and news articles effect on the market in different situation and helps the system determine the news articles effect in present.

Traders Behavior Agent analysis the traders reaction in different situations based on their knowledge and characteristics. The Traders Definition Library stores the traders characteristics and knowledge.

Sentiment Analysis Agent determines and quantifies the reaction of an informed and noisy trader based on the information that he receives. In this case a negative information can cause a sell action and a positive information can cause a buy action. This agent is in correlation with the Traders Behavior Agent due to the necessity of evaluating the traders knowledge in order to take a favorable decision.

Trust Analysis Agent quantifies the confidence that a trader has in an action based on past experience and financial knowledge. Trust Management implies the existence of two actors: the trustor and the trustee. A trustor is considered to be the trader and the trustee are considered to be all phenomena and information that can influence the price movement and the traders reaction on the market. In order to quantify the confidence certain Confidence Levels were defined.

The Risk Analysis Agent classifies and quantifies the risk effect on an investment based on the data obtained from the others agent and on the risks characteristics and influence. A Risk Definition Library was defined in which we store all the characteristics of each type of risk and which are the methods that can be used in order to minimize it’s effect on an investment.

Based on the information received from these agents, the Portfolio Optimization establishes a maximum loss or portfolio draw-down policy, evaluates the risk and takes advantage of
volatility by applying tactical stock allocation and also can apply some trading strategies in order to make a good investment. A Stock Market Characteristics library is associated to this agent. Here we store all information about the stock market: growth capital, liquidity, transparency, organization, economic indicator and regular risk/reward.

IV. Results

A. Experimental Data

This system extracts from the Bucharest Stock Exchange all necessary information regarding stock price, volume, number of transaction. The financial reports are extracted from the companies’ websites and from specialized financial sites (we are interested in all financial information about a company). The financial news article are extracted from specialized news articles websites. We also create a risk library based on the defined characteristics of all possible existing risks. A level of confidence library is defined based on the trader’s knowledge and experience. A period of three years of valuable data, from January 2010 until January 2013, was considered in order to evaluate and validate our system.

B. Experimental Results

Based on our previous experience and on brokers’ advice in order to minimize the total portfolio risk. By investing no more than 30% of total investment value in a single stock and by exiting from that position when a depreciation of -7% is reached, we will have a total loss of -2.1% from the total investment value, which can be corrected by the other stocks gains. By investing in different industries, we can also reduce our portfolio risk because if one industry sector is having an unpredictable evolution we can compensate with the stocks from the other sectors.

The goal on any investment is to buy shares at the very best stocks; of course the most difficult part is finding that stock. We define that a stock is “the best” when the investment risk is the lowest and the expected return is the highest. The most important moments when creating a stock portfolio (for short and medium time period) are when we actually enter to a stock position (buy moments), because if we buy shares when the prices are high (a typical indicator of price momentum is Williams %R) our expected return can not be predictable as the technical indicators will indicate that a negative evolution of stock price is imminent. For long time period investment we must take into consideration the trend prediction indicators. Also, if we buy shares little by little when certain strength levels are pierced, then it can reduce the risk of buying at the wrong moments.

An investment portfolio should be structured based on these six rules: invest no more than 30% in a single stock; buy little by little only when the stock breaks strength levels; invest in different types of industries; allocate the most capital to the best stocks; cut losses at a maximum of 7% of initial purchase; and take profit when gain is +20%, +25% of initial purchase or sell when technical analyzers discover sell signals.

Every stock has a certain risk that can be quantified by several types of indicators (standard deviation, technical analyses values) but we would also want to quantify the influence of positive and negative news terms upon the stock price. The higher the influence of news articles upon the stock price, the higher the news risk is as the price volatility is possibly higher. Figure 2 represents the technical analysis of price trend based on EMA\(^3\) - Williams %R indicator and the price Standard Deviation during the same period for BRK\(^4\) symbol. For this stock (BRK) the risk is at maximum as the Price Trend Indicator (PTI) is at 100% of its value and the Standard Deviation (SD) also approaches the maximum (1), meaning that the stock has a high risk in short term (1 month). On medium time frame (2 months) it has a medium to high risk (average SD is bellow 6 but PTI is above 60%) and on long time frame (6 months) it has medium risk (SD and PTI are bellow 6/60%).

![Figure 2: Price Trend and Standard Deviation evolution](image)

We created three database for stock price-volume, financial reports and news articles from the past 3 years and we try to create and structure a stock portfolio by determining the optimal number of stocks, type of industries and optimal stock shares using data mining (to find the relations between news and stock price) and neural networks (to predict the future trend of the stocks).

Risk Analysis Agent uses the data gathered by News Articles Effect and creates a tree map having as root the BVB stock market and as leaves industries type and stocks. We quantify the influence of news terms on stock price (news risk) as a normalized value defined by the total number of terms found with a high score (relevance) that influence the stock price by more than +/-5%. A value in interval \([0, 0.33]\) represents high news risk, \([0.33, 0.66]\) - medium news risk and \([0.66, 1]\) - low news risk. Figure 3 represents the relationship tree discovered that has medium and low news risk on a medium period of time.

We are using only stocks that have a low to medium news risk and for these stocks we compare the PTI and SD values in Table I (the bold numbers represents that the specific stock has a low risk for that time-frame).

The total risk of a stock is made by averaging the values for SD, News and PTI risk and correlate to each stock a specific investment risk. This risk is materialized by price volatility. Using the stocks above our system had generated for a medium time period investment a portfolio structure as described Table II

By adding the trust management to our multi-agent system, we can better detect the buy/sell moments and so we can maximize the portfolio evolution over different time-frames.

\(^3\)Exponential Moving Average

\(^4\)S.S.I.F. Broker S.A.
<table>
<thead>
<tr>
<th>Stock</th>
<th>SD Risk[0-10]</th>
<th>News Risk[0-1]</th>
<th>PTI Risk[0-100]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Short</td>
<td>Medium</td>
<td>Long</td>
</tr>
<tr>
<td>ATB</td>
<td>2</td>
<td>4.2</td>
<td>2.15</td>
</tr>
<tr>
<td>OIL</td>
<td>6</td>
<td>3.7</td>
<td>3.3</td>
</tr>
<tr>
<td>SNP</td>
<td>5.2</td>
<td>5.2</td>
<td>2.1</td>
</tr>
<tr>
<td>BRK</td>
<td>7</td>
<td>5.2</td>
<td>3.6</td>
</tr>
<tr>
<td>SIF1</td>
<td>6.1</td>
<td>5.7</td>
<td>3.4</td>
</tr>
<tr>
<td>SIF3</td>
<td>4</td>
<td>3.1</td>
<td>1.3</td>
</tr>
<tr>
<td>FP</td>
<td>2.5</td>
<td>4</td>
<td>3.1</td>
</tr>
<tr>
<td>TLV</td>
<td>3</td>
<td>2.1</td>
<td>1.7</td>
</tr>
<tr>
<td>BRD</td>
<td>4</td>
<td>3.1</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Table I: Risk evaluation table for a group of stock

![Relationship tree](image)

Figure 3: Relationship tree

![Portfolio Evolution](image)

Figure 4: Portfolio Evolution

Each buy/sell signal detected by MASTS or by Trust Analysis agent is quantified and a level of confidence is created after the signal is confirmed or inferred. These levels of confidence are then used in calculating the next buy/sell signals.

In order to establish that this generated portfolio has an optimal structure of stocks it must be compared with other types of portfolios structures. We present in Figure 4 the evolution of the total portfolio value compared with portfolios structured with low risk and high risk stocks.

We can notice that a portfolio structured with high risk stocks has an unsatisfactory evolution on medium time-frame due to unpredictable price evolution. Also the portfolio structured with low risk has a positive evolution on medium and long time, but on short time interval the portfolio has a negative evolution.

The best rated (4/5 stars) software is Portfolio Optimization Model from Business Spreadsheets (POM), which we used to compare with our system. It uses the minimum risk model for POM in order to create an optimized portfolio model. Figure 5 show the portfolio structure generated for each system using the BVB stocks.

![Portfolio structure for each system](image)

Figure 5: Portfolio structure for each system

We can notice that the POM portfolio structure contains fewer stocks as the model is risk averse. By using fewer stocks with lower investment risk we can predict a lower return value, as demonstrated in Figure 6.
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REFERENCES