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TECHNOLOGY OF INTELLIGENT AGENTS USED IN FINANCIAL DATA ANALYSIS

1. Introduction

Financial experts make a concerted effort to discover efficient methods of stock trading. The problem consists in optimal investing a given amount of money into a given stock on the market and, later, in managing the investment during a given period of time by a proper execution of buy and sell operations. In spite of the simple formulation, the problem is particularly difficult [Caldwell 1997]. However, several more or less efficient solutions have been worked out. They are based on a large number of various indicators defining the current state of the market and predicting its change. These methods range from theoretical models based on strong mathematical and statistical background [Huang, Litzenberger 1988; Sharpe 1964; Weigend, Gershenfeld 1993] to financial empirical models based mainly on experiences of professional traders [Bauer 1994; Colby, Meyers 1990; Murphy 1998].

Although the number of financial indicators is indeed huge, every financial expert bases on his own set of them, selecting favorite ones at his or her discretion. Naturally, the usage of various rules sets leads to various investment strategies, hence the opinion on the current market state may differ among the society of financial expert. The phenomenon is amplified by the fact that experts usually have different data; some of them can access a wide range of information while others are limited only to a small part of all available data. In real life, non-professional traders can access mainly information published in newspapers or in the internet, such as aggregated quotations, while financial companies can access not only full quotations in real-time, but also many issued reports, analysis or even confidential data.

Most of applied financial indicators and methods used to determine the investment strategy can be strictly defined and implemented, which leads to creation of artificial financial experts. These experts analyze the market, consult each other

and cooperate to work out an efficient investment strategy. The society of financial expert can be modeled using the concept of intelligent agents [Tecuci 1998].

An agent represents a financial expert acting on the basis of a selected set of rules. Thus, several agents correspond to financial experts preferring formal approaches, while others correspond to experts preferring experience-based methods. Agents can communicate with each other to take into consideration advice of other experts on a given subject.

The purpose of our approach is to combine the power of different methods of financial data analysis in order to create a more efficient system. This is an extension of our previous work on stock trading and portfolio management presented in detail in [Korczak, Lipiński, Lipiński 2002; Korczak, Roger 2000; Korczak, Roger 2002; Lipiński 2004].

The paper is organized in the following way: The next section provides basic concepts on agents and intelligent agents technology, and emphasizes several attributes which make agents intelligent: a knowledge base, reasoning and learning capabilities. In section 3, the commonly accepted agent standards have been pointed out and an agent framework has been presented in a broad outline. Section 4 presents a new approach to market analysis based on intelligent agents. Section 5 presents a validation of the proposed solution, and the last section concludes the article.

2. Basic concepts

2.1. Software Agent

Many different definitions of an agent have been proposed. The most general one says that an agent is just an object that perceives and acts on an environment [Russell, Norvig 1995]. To be precise, an agent is a software entity capable of watching an environment and taking action depending on events perceived. Activities of an agent may have an impact on the environment or may not affect it at all. The environment may be composed only of agents or it may also include other objects like external data, dependent on or independent of the agent society, system resources, products of user activities etc.

One of more complex definitions says that an agent is "a system situated within and a part of an environment that senses that environment and acts on it, over time, in pursuit of its own agenda and so as to effect what it senses in the future" [Franklin, Graesser 1996]. According to this definition, an agent should be an autonomous software unit being a part of the environment and having abilities to react to changes in its environment.

Another more specialized definition says that "agents are active, persistent components that perceive, reason, act and communicate" [Huhns, Singh]. This definition introduces two additional agent elements, namely reason and communication.

To summarize, the following definition has been used throughout this paper: an agent is an autonomous software entity responsible for performing a part of a programmatic process. It is capable of carrying out goals and may be a part of a larger community of agents that may have mutual influence on each other.

2.2. Intelligent Agent

Generally speaking, an intelligent agent is an agent that is able to take advantage of its knowledge to reason and to act. In other words, an intelligent agent is an object capable of thinking that behaves in accord with self-contained intelligence, knowledge and inference. It contains some level of intelligence ranging from simple predefined rules with inference engine to self-learning intelligent machines [Bigus, Bigus 2001].

The built-in learning mechanism enables the agent to develop by gathering experiences and widen the knowledge, which consequently enables the agent to tackle more and more complex problems or to solve the same problem more and more efficiently.

An intelligent agent is an auto-adaptable program, which means that the agent modifies its behavior in accordance with the environment condition perceived. This is the main characteristic of intelligent agents [Tecuci 1998].

Beside the perception unit and the execution unit, an intelligent agent contains also three other modules: the knowledge base, the inference engine and the learning mechanism. The knowledge base stores all information determining the behavior of the agent, which include rules delivered by the creator of the agent, available before the agent runs, as well as rules gathered by the agent itself during its execution on the basis of its experiences. The inference engine processes the available knowledge in order to adapt the agent behavior to current environment conditions, to react to the situation perceived or to perform other activity on the basis of the knowledge gathered. The inference engine usually uses not only the knowledge base but also some set of meta-rules using to interpret the knowledge. Finally, the learning mechanism enables the development of the agent by analyzing the possessed knowledge, the state of the environment and effects of past agent's activities. The learning mechanism usually changes the knowledge base by adding new rules and facts or removing doubtful hypothesis. Similarly to the inference engine, the learning mechanism contains a certain set of generalization rules which are used to discover new concepts.

2.3. Agent Attributes

Although properties of an agent depend on the specific implementation and the problem considered, some general agent attributes can be pointed out [Tecuci 1998].

First, agents can perform some activities autonomously, while other activities can be performed in cooperation with part of the community of agents. An agent should be able to carry out simple task itself while it can cooperate with others to conduct more complex work. In particular, an agent can use other agents to carry out some task beyond its capability. It can converse with the others to seek advice or information. Moreover, agents can get organized to solve problems, which require more involvement than one agent is able to do. Also, agents can cooperate to reduce the time needed to complete a task by dividing it among the community.

The communication of an agent with the community may have a cooperative or competitive character. In the cooperative community, agents communicate to solve the given problem, which is the main purpose of the collaboration. Usually, the problem is divided into several tasks performed by specific agents which act simultaneously. In some cases, there is an agent which supervises the work and manages the others, but generally agents work jointly. In the competitive community, agents cooperate to solve the problem but each of them works on its own account. There is no supervisor; in general, agents are independent. They may utilize the others to perform specific tasks or may ask for advice or information. Every agent tries to reap profits from the collaboration and be better than the others.

Besides the collaboration with the others, an agent may communicate with users or system resources. For instance, an agent may ask the user to specify or adjust some parameters, offer him several possibilities of further operating or present to him the results of its work. An agent may make use of available system resources such as memory, additional processing units as well as databases with supplementary data and knowledge.

A certain class of agents, so-called mobile agents, may move from one system to another. Hence, they can access remote resources, which can be more suitable for their current job, and return to the mother system after performing the part of processing. They may also emigrate in order to meet or cooperate with other agents. This enables the dynamic resource management, which leads to more efficient system usage.

3. Agent technology

There are a few widespread intelligent agent standards. One of them, viz. the FIPA standard, was designed by the Foundation for Intelligent Physical Agents, a group consisted mainly of computer technology and telecommunication companies. The FIPA standard describes methods of the agent management, its communications and integration. The first version of the standard, called the FIPA97, was extended and published as the FIPA2000. Another example of agent specification is the OMG standard worked out by the Object Management Group – Agent Working Group, which includes also the authors of the CORBA standard. This

standard concerns agent description in terms of object-oriented programming and also focuses on designing of mobile agents.

The agent exists in a certain environment which is perceived by the Perception Unit. This module receives also signals coming from other agents transmitted by the Communication Unit. The perceived events are analyzed and passed on to the Execution Unit which performs proper actions in order to react to the noticed changes in the environment. The executed actions may also affect the environment. During performing its activities, the Execution Unit may contact other agents by the agency of the Communication Unit. It may also use hand database which can contain information from earlier periods of the agent activity.

The agent contains also artificial intelligence modules. All the events reaching the Perception Unit are transmitted to the learning mechanism, where they are analyzed and compared to the knowledge gathered earlier. As a result, the Learning Mechanism modifies the Knowledge Base.

During its execution, the agent can refer to the gathered knowledge using the Inference Engine. On the basis of the possessed knowledge and the experience, the Execution Unit makes the decision on the kind of action which should be undertaken to react to the situation arisen in the environment [Bigus, Bigus 2001].

4. Architecture of stock trading system

4.1. Framework

There are a few attempts to apply the technology of intelligent agent to market analysis system [Sycara, Decker, Zeng 2002]. In this section, a framework of a stock trading system is proposed.

In our approach, several types of agents, each of them representing other analysis method, dealing with different kind of data and identifying different kind of events, are joined in one system.

Each of the agents is autonomous: it uses its own method to analyze the market, concentrates on its own field, and certainly has its own purpose. For instance, there are agents based on financial formulas which detect the general state of the market, its volatility, susceptibility to investing, and dominating behavior of investors. There are also agents based on technical analysis rules which detect the trends of stocks prices and make a detailed analysis of a given stock quotations. Examples of these agents are detailed in the next section. The idea of joining all the agents enables exploring the power of each method.

The general outline of the system is presented in Fig. 1. The starting point of the diagram is the market on which all the events occur. The incoming data from the market are preprocessed by database agents and are stored in the financial database. The preprocessing consists in aggregating data, clustering, calculating the average, etc. It is necessary because enormous amount of data is coming from the

market every second, and it is useless, and even impossible, to store it all. Although the data is preprocessed and stored in the database by a few agents, the market is continuously observed by other intelligent agents (the Market Watch IAs), which try to detect some important events on the market as soon as possible to inform the rest of the system, and consequently to adapt the system to the new situation. For instance, in the case of a sudden fall of prices – a market slump – the agent will perceive it and will cause a suitable modification of the system behavior. If the agent does not warn the rest of the system about the drop of prices, agents analyzing individual stocks may not react quickly enough and they may advise to buy the stock, which could be a result of the quotations analysis not respecting the fact of recent falls, while the correct advice should be to sell.

When preprocessed data comes to the financial database, it is processed by two classes of agents. The first class focuses on the global market analysis like volatility analysis, while the second class concentrates on the analysis of individual stocks. Thus, the second class agents, marked on the diagram as the Stock Analysis IAs, are highly specialized experts which are used to define the state of quotations of a particular stock such as Peugeot or Renault on the Paris Stock Exchange. Some of these agents require additional knowledge, stored in the Experts Database, which is managed by the Experts Watch IAs and the Expert Generator. The Expert Generator was described in details in [Korczak, Roger 2002; Lipiński 2004].

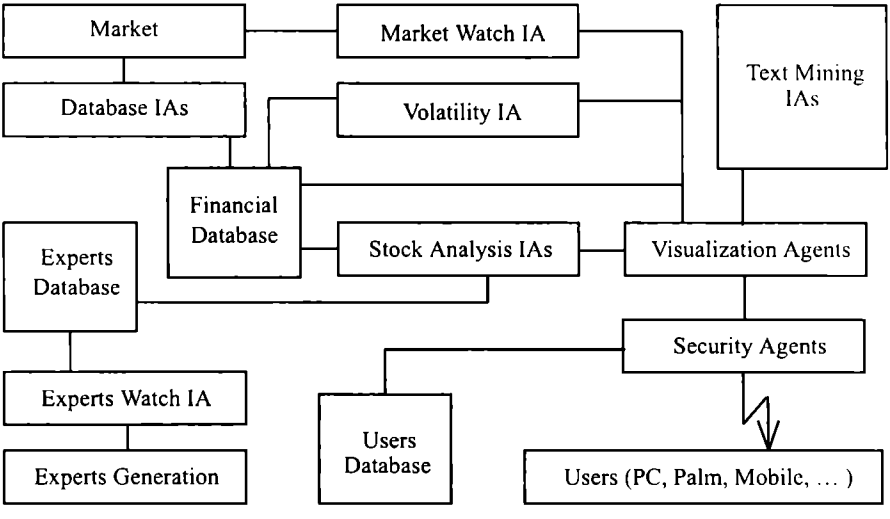

Fig. 1. The framework of the system

In addition to agents dealing with the numerical data, there are also agents based on text analysis. Some agents can observe the incoming news and look for dispatches concerning a particular stock. Next, after a text mining phase, they can

generate an additional signal for other agents to modify some parameters, for instance to raise the investment risk for the particular stock.

Finally, results of the strenuous work of all the agents are gathered by visualization agents and presented to the user. The visualization has to be also intelligent, which means that depending on the market situation, the visualization agent should display information using the most appropriate techniques and tools. The displayed information should be adapted to the user expectations and preferences as well as the current market situation. It is obvious that the user focuses on the incoming data when something is going on, while he is less careful during the period when the market is sluggish. Naturally, in the modern system, there must be security agents which prevent unauthorized users from accessing the system. The additional task for visualization agents is to adapt the system to user preferences and especially to the user hardware and software environment.

4.2. Agent Examples

Market Watch Intelligent Agent

A market watch intelligent agent observes the market and tries to detect any anomalies which can be significant for the stock analysis made by other parts of the system. The market abnormality may be defined on the basis of some financial indicators as a sudden change of these factors. As soon as an anomaly is perceived, a signal for the rest of the system will be generated.

A few simple rules among those used by the agent are presented below.

$$\text{IF } (\text{Price}[t_1] < 0.9 * \text{Price}[t_0] \text{ THEN SIGNAL mwPriceDown}$$

$$\text{IF } (\text{Volume}[t_1] > 1.1 * \text{Volume}[t_0] \text{ THEN SIGNAL mwVolumeUp}$$

$$\text{IF } (\text{CAC40}[t_1] < 0.9 * \text{CAC40}[t_0] \text{ THEN SIGNAL mwCAC40Down}$$

Volatility Intelligent Agent

The volatility intelligent agent observes the market volatility and, on the basis of it, tries to predict changes on the market. There are a number of financial factors constructed on the basis of the volatility, but of course the simplest one is the change of the value itself. Thus, the sample rule used by the agent may be formulated as follows:

$$\text{IF } (\text{Volatility}[t_1] < 0.9 * \text{Volatility}[t_0] \text{ THEN SIGNAL vDown}$$

There are several ways of defining the market volatility commonly used in finances. It may be defined as the difference between the lowest price of sell offers and the highest price of buy offers in the current book order.

Agents based on Technical Trading Rules

Agents designed for particular stock analysis constitute the most important part of the system. Many various methods for stock analysis were developed. Some of them are based on statistical background; others use so-called technical analysis or apply the power of neural networks.

The principles of a trading system based on technical analysis rules were presented in [Korczak, Roger 2002]. Artificial trading experts generated by the genetic algorithm described in [Lipinski 2004] have given rise to agents which are used in the system. These agents, on the basis of a set of technical trading rules which constitute their knowledge, analyze the stock quotations and return a recommendation: to buy, to sell or to do nothing, which supports the user in the decision making process.

Text Mining Intelligent Agent

As mentioned before, in addition to agents using the numerical data, i.e. quotations, there are also agents based on text analysis. A hypothetical agent can search through the list of latest news, for instance provided by an information agency or communication network, for dispatches concerning a particular stock. Depending on the intelligence level included in the agent, it can analyze the text to recognize the context or simply announce that a given stock was mentioned suspiciously often in the news. This may be a signal for other parts of the system that the interest in the stock is growing, which may cause the intensification of operations on the stock and amplify current trends.

A simple rule used by the agent can be constructed as follows:

IF (company X appears often in news headlines) THEN
SIGNAL tmX

Other Agents

Other agents can also be included. For instance, agents applying neural networks to market analysis or agents representing statistical methods such as ARIMA models.

4.3. Agent Collaboration

Every agent is autonomous, which means that it is capable of solving the problem itself, but it is also able to cooperate with others in order to tackle problems beyond its capability. Agents can negotiate with one another to exchange the opinion on a particular problem. Moreover, highly specialized task-oriented agents can be hired to perform a part of other agents activities.

Some agents, like the Market Watch Intelligent Agent or the Volatility Intelligent Agent, generate signals which are received by other agents and affect their behavior. Moreover, agents specialized in the analysis of a particular stock cooperate

with one another in the case of detection of a high correlation between their stocks. Certainly, agents concerning the same stock consult each other to compare opinions and exchange information.

However, in the system, the collaboration has always non-competitive character, which means that agents work together to achieve a common aim without competing, without trying to beat others.

5. Validation

Results of the preliminary experiments confirm the efficiency of the approach. In order to assess the system robustness, a number of tests have been performed, a summary of which is presented below.

Table 1. Summary of results

Experiment	Return Rate (%)	B&H (%)	CAC40 (%)
1.	3.56	3.60	3.22
2.	2.17	1.96	-2.47
3.	2.48	2.06	2.80
4.	0.71	0.62	–1.56
5.	1.87	2.43	0.13
6.	0.17	0.40	–4.90
7.	0.01	–0.17	–1.10
8.	1.21	1.18	–4.96
9.	1.89	2.16	–0.03
10.	3.89	3.90	3.08

The system is built of a number of autonomous modules which can be configured in several manners. The soul of the system is made up of agents based on technical trading rules. They are carefully tested, and results have been compared with two general factors, i.e. the return of the so-called B&H strategy and the rate of the market index. The comparison is presented in the Table 1.

6. Conclusions and perspectives

In this paper, an approach to stock market analysis based on the modern technology of intelligent agents has been proposed. The most significant advantage of the system is the possibility of joining the power of different analyzing methods such as genetic algorithms, neural networks, statistical analysis, and text mining. The preliminary tests have shown that the approach is rather promising and it seems to be efficient.

Further tests are needed to verify the approach efficiency and develop a proper parameters set. Moreover, additional agents may be introduced in order to improve the quality of results and increase the accuracy of the prediction. An additional effort is needed to work out the optimal system structure and configuration.

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ZASTOSOWANIE TECHNOLOGII INTELIGENTNYCH AGENTÓW W ANALIZIE DANYCH FINANSOWYCH

Streszczenie

W niniejszym opracowaniu została zaprezentowana koncepcja systemu analizy rynku papierów wartościowych oparta na technologii inteligentnych agentów. Opracowane podejście czyni możliwym połączenie różnych metod analizy danych finansowych w jeden efektywny system wspomagania decyzji giełdowych. Po krótkim przeglądzie technologii inteligentnych agentów z perspektywy cech agenta, który posiada wiedzę, umiejętność wnioskowania i zdolność uczenia się, uszczegółowiono strukturę funkcjonalną zaproponowanego systemu.

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