A Conceptual Framework for Fuzzy Multi-Agent-Based Stock Trading System (Case Study: Tehran Stock Market)

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ABSTRACT

The goal of a decision support system is to provide the human user with an optimized decision recommendation helping him/her during operation under uncertainty in complex environments. Developing a multi-agent recommendation system is a good way to overcome the problem of overloaded information. Stock trading as a dynamic domain is full of unexpected events and vague rules that make it more difficult to control its behavior and strive to provide an efficient trading platform for investors. A multi-agent framework for decision making in stock trading is introduced in this paper utilizing a fuzzy decision making approach, an application of fuzzy set theory, integrating the quantitative analysis with qualitative judgment. The framework is flexible in capturing an infinite range of trading strategies by market investors.

Key Words: multi-agent, decision making, fuzzy system, stock trading, framework.

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1. Introduction

The stock domain is chosen as our analysis prospect because the transactions can be completed electronically without any physical delivery of goods. It is also a good example because it can be modeled using a generic well-known supplier, retailer and customer relationship [1].

During the past decades, developing computerized decision support and intelligent systems to assist the process of decision making in stock trading, many researches have been undertaken by various researchers. The key note for decision making in stock trading is selection of the right stock at the right time. There are many analytical approaches for decision making in stock exchange categorized in two groups of technical and fundamental analysis [2].

A distributed problem solving system can be characterized as a group of individual agents running and cooperating with other agents to solve a problem. In spite of continuous ever-growing complexity of dynamic domains such as stock trading, it's becoming more and more useful. Moreover in this domain quantitative analysis and qualitative judgment are as discrete subjects. Hence, based on the concepts of fuzzy set theory, we use an agent based fuzzy decision making system to integrate them.

In a multi-agent-based system consisting of several agents the agents should be able to interact with each other and with their environment in an adaptable manner. Each agent has a local view of the environment, specific goals and is unable to solve the system devoted global task alone. The global characteristic of such a system thus emerges from the cooperation of its component parts. This cooperation, in turn, impinges on the interactions between agents and subtly modifies the properties of the system [3].

The idea to use intelligent software agents for recommendation in stock market originates from the agent based computational economics approach, the computational study of economies modeled as evolving systems of autonomous interacting agents [4]. The intention of this paper is to put forward a framework to improve the process of recommendation in stock trading system.

The outline of this paper is as follows. Section 2 explains the nation of intelligent agents. Section 3 clarifies the fuzzy system which is used in main framework. Section 4 gives some backgrounds about the decision making in stock trading domain. Section 5 is about agent based decision making in stock trading. Section 6 briefly describes the main framework and finally section 7 gives the conclusion for this paper.

2. Intelligent Agents

Intelligent software agents are probably one of the most fast-growing areas of information technology. They are being used and touted for applications as diverse as personalized information management, electronic commerce, computer games, etc. An agent can be thought of as a computer program that simulates a human relationship by doing something that another person could do for you [5] and performs a specific task on behalf of a user, independently or with a little guidance [6]. An agent is a self-contained program capable of controlling its own decision making and acting, based on its perception of its environment, in pursuit of one or more objectives [7]. There are more than just one type of agents been introduced so far;. In its simplest form it is a software object that sifts through large amounts of data and presents a subset of this data as useful information to another agent, user or system. These types of agents are called static agents. Mobile agents have the ability to migrate across nodes of a network in order to perform their tasks and report back their findings. These agents typically gather and analyze data from a multitude of nodes on the network, and present a subset of this data as information to a user, agent or system. Mobile agents can also act as brokers for users, for example a single sign-on agent can sign on to many different systems, relieving the user from typing in his/her password for every system [8]. An agent that roams the stock exchanges of the world and trades shares on its user's behalf can, using fixed rules, build up a valuable portfolio of shares

for a user. However in this paper we use static agents working together.

3. Fuzzy Systems

Fuzzy systems have been around since the 1920s, when they were first proposed by Lukaciewicz. The intellectual appeal of fuzzy systems is clear when faced with the restraints of Aristotelian logic, which says a thing is either something or it is definitely nothing [9]. A system becomes a fuzzy system when its operations are entirely or partially governed by fuzzy logic or are based on fuzzy sets. Operations of systems are defined by several basic problems such as control, estimation (prediction, forecasting), modeling, pattern recognition (classification, clustering), optimization, and data compression [10]. Thanks to the fuzzy systems, modeling, optimization, and data compression problems in stock trading systems can be solved easier. Fuzzy system in this article act as a special rule based system that use fuzzy logic in its knowledge base and drive conclusions from user inputs and fuzzy inference process while fuzzy rules make up the knowledge base of the system. The architecture of this system is composed of followings: fuzzy inference engine- a program which analyzes the rules and aggregated knowledge, user interface- investors who enter the real number of all linguistic variables via user interface, fuzzy rule base- experts experience is used to build up the fuzzy rules.

4. Decision Making in Stock Trading Process

In stock trading, there are two approaches to analyze the stock market: a) Technical analysis b) Fundamental analysis. Technical analysts believe that the prediction of stock future price is possible through studying stock prices in the past [11]. There are technical indicators for studying price patterns and trends of each stock such as moving averages, relative strength index (RSI), moving average convergence divergence (MACD) and so on [12]. In this approach, the future price of stock is predicted by an individual agent, based on the decision making rules of each indicator.

Fundamental analysts analyze audit reports, income statement, quarterly balance sheets, dividend records, sales records, management capabilities and competitive situation of the company and then calculate intrinsic value of each stock based on prediction of cash flow for next few years [12] which is covered by an independent agent in this paper. Many methods are applied based on one of these two approaches or the combination of them. For example, Kwasnica and Ciosmak [13] have analyzed the stock market with a fuzzy expert system for technical analysis and artificial neural network for fundamental analysis.

Stock market data are distributed on internet sources are difficult to be retrieved, thus intelligent agents' technology has been applied to do so and to support buy or sell decisions based on fundamental analysis principals and technical indicators.

5. Agent Based Decision Making in Stock Trading System

The stock trading system is based upon the task-sharing [14] framework, where the overall strategy-making problem is decomposed into several particular sub-problems. So, this framework has been used to decompose recommendation problem in stock trading services and refer them to relevant agents managed by a coordinating one.

Apart from price formation, the market structure also determines many of the trading actions by market participants. Based on their tasks and role in the market there are three types of participants (traders): *investors*, *brokers* and *market makers* [15]. Investors (e.g. individual or company) are simple traders, and generally not considered part of the market itself. Brokers are primarily required to execute orders for investors. Market-makers are responsible for the liquidity of the stocks assigned to them, and generally have to provide bid and ask quotes (The quotes must specify the number of

shares and the price for which market makers are prepared to buy and sell).
As is explained subsequently, the vast number of trading strategies in a broad range of market structures motivated us to use agents instead of *investors*, *brokers* and *market makers* and design a framework that accommodates this diversity: *A. Investors*- From the viewpoint of an outsider, investors collect information and place orders. Accordingly, investor-agents performs the following generic behaviors: a) understanding all share's quotation of current day; b) browsing stock technical analysis charts over a period; c) preparing price chart over a period, and d) collecting fundamental analysis data and market statistic information over a period. *B. Brokers*- The brokers' primary task is to execute orders on behalf of the investors. So, the functions of the broker agents are: a) monitoring price fluctuation, trading volume, technical indicator's status, price chart pattern, and break news relating to the given shares; b) calculating of profits/risk ratio based on shares' market status and user's investment, and c) reminding of the stop-loss level for user's holding shares according to the user's profile. *C. Market makers*- The market maker provides the basic functionality by implementing the generic behavior of market makers. Normally it needs a set of rules which take into consideration share price, price pattern, price trend, trading volume, and so on. Therefore market maker agents duties consist of: a) risk evaluation for all shares; b) trade assessment; c) assessing the correlation between the individual share, the market trend and the share price trend, and the share's trading volume trend [16], and d) evaluating the value of the share.
In order to complete the objectives of market makers, fuzzy system has been used. Indeed, fuzzy system attempt to systemize the natural variations in human perception of truth and imitate rudimentary skill of approximation [10].

6. Fuzzy Multi-Agent-Based Stock Trading Framework

Concerning Tehran Stock Market, it contains sophisticated processes in decision making frustrating the creation of a standard decision making Procedure for it. Thus, a fuzzy multi-agent-based stock trading framework is designed in this paper which is pursuant to Tehran Stock Market.
Within the multi-agent-based stock trading system, fuzzy set theory is employed to embody and automate decision making process by recommending to the user based on vague rules and environment in stock trading area of Tehran. The fuzzy multi-agent-based framework of the stock trading system in favor of Tehran is illustrated in Fig. 1. This framework has been proposed for Tehran Stock Market in order to reduce the complexity of decision making in Tehran Stock Market.
This multi-agent-based framework provides a unified environment in which several agents are integrated. These intelligent agents are utilized to collect, filter, and fuse information from distributed, network-based information sources in Tehran and to make buying and selling decision suggestions for investors in their daily stock trading.
The main components of the multi-agent stock trading framework of Tehran Stock Market are briefly described as follows.

6.2 Investor Agents

The human decision making agent interacts with the user, receiving user tasks and specifications and delivering results with aid of coordinator agent.
The coordinator agent is a key component in Tehran Stock Market that is responsible for task decomposition and planning. It maintains a set of believes about the capabilities of all agents and decomposes a given task into a number of sub-tasks and dispatches the sub-tasks to relevant agents to be performed, achieving their goals. Meanwhile, the coordinator agent represents the recommendation of fuzzy recommendation agents (fuzzy decision making, fuzzifier, interface, and defuzzifier agents) to the human decision making agent for the conclusive decision to be made.

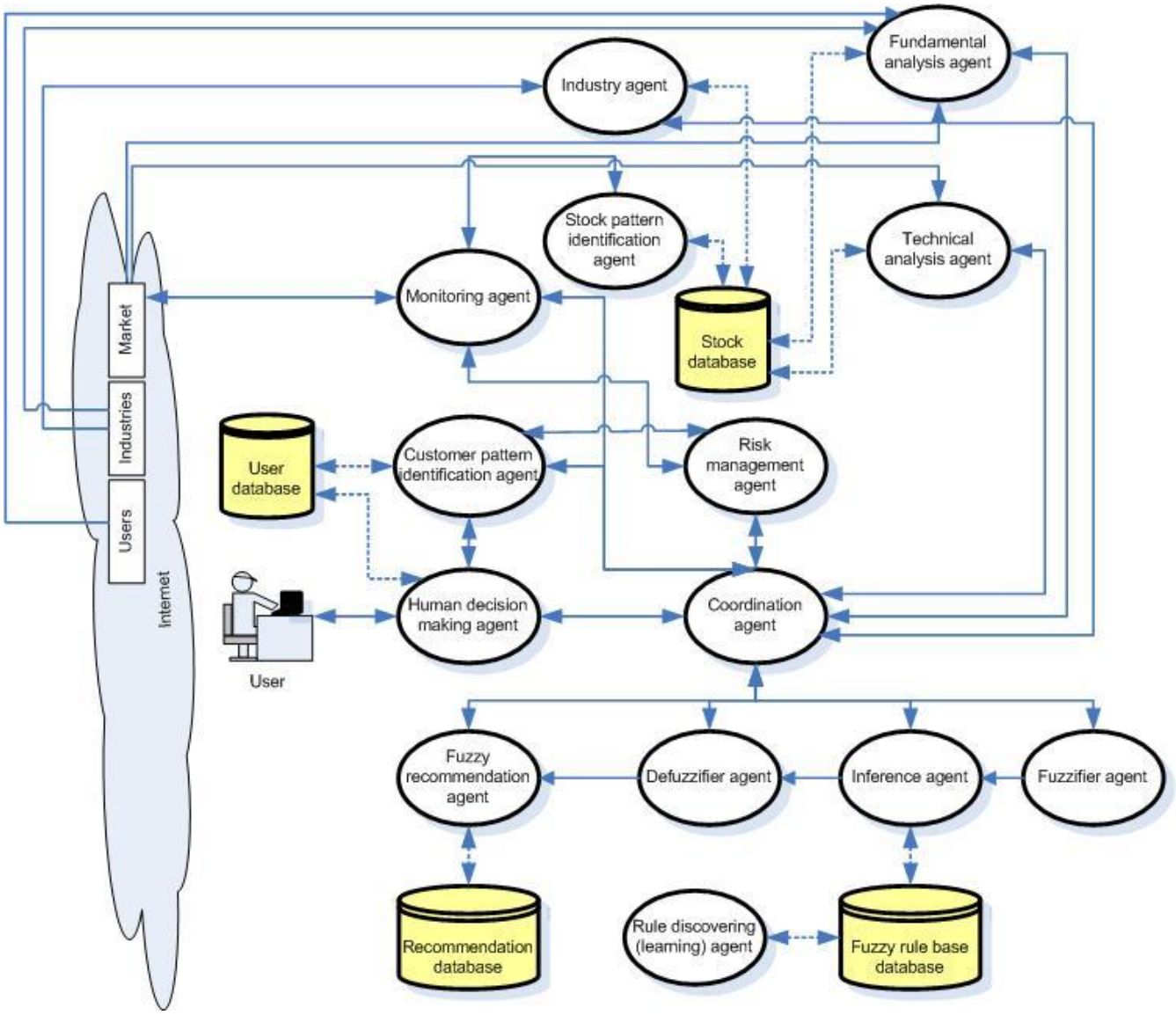

Fig. 1. The fuzzy multi agent framework of the stock trading system (due to Tehran Stock Market)

6.3 Broker agents

In Tehran Stock Market each user needs to be considered separately. The customer pattern identification agent provides the mechanism by which a user's profile are generated, updated, and maintained. The customer pattern identification agent interacts with the coordinator agent to receive information from the user and the environment to determine the user's interests..

The stock pattern identification agent analyses the stock database in order to extract the pattern that exist in this database.

Situation of Tehran Stock Market is not unflinching; as a result, the monitoring agent is used in our framework to monitors the status of the given stocks on behalf of users according to the user's profile obtained from the coordinator agent. This agent gives the reports about the technical indicators' status of the given stocks and notifies any abnormal change in trading volume and price.

Risk management in Tehran Stock Market is a critical factor in decision making. The risk

management agent, on the basis of the user profile, hence, interacts with the monitoring agent and fuzzy recommendation agent (with coordination agent) to analyses the risk levels of user's share holdings, report the profit status and suggest a stop-loss level for the holding shares.
The technical analysis agent retrieves and processes the raw stock trading data from Tehran Stock Market, stores the raw data to stock database, calculates various technical indicators, identifies various price and trading volume patterns, and gives the output to fuzzy recommendation agent (through the coordination agent).
The fundamental analysis agent gathers the fundamental information of the listed companies in Iran, opinions of the market commentators or experts, and some relative news, integrates the information, makes recommendations to the fuzzy recommendation agent, and puts this information into stock database.
The industry agent interacts with Iran's industries and recognizes their investment opportunities. Then specifies the best industries and through the coordination agent report this information to the fuzzy recommendation agent and save them in stock database.

6.4 Market maker agents

This group composes the fuzzy agents system that acts according to the following steps in order to complete the decision making procedure in Tehran Stock Market:
Step 1: Fuzzifier agent takes the inputs and determines the degree to which they belong to each of the appropriate fuzzy sets via membership functions.
Step 2: Inference agent, applies fuzzy operator, implication method, and at the end aggregates all outputs in order to analyses inputs with the aid of fuzzy rules (exist in fuzzy rule base data base) and sends the fuzzy output to defuzzifier agent.
Step 3: Rule discovering agent processes the outputs after each recommendation by fuzzy interface agent to extract the new rules and updates the fuzzy rule based database based on the new extracted rules.
Step 4: The input for the defuzzification process is a fuzzy set (the aggregate output fuzzy set from interface agent) and defuzzifier agent produces the output as a single number and sends all of the defuzzified outputs to the fuzzy recommendation agent.
Step 5: Fuzzy recommendation agent with the aid of customer pattern identification, risk management agent, industry agent, and fundamental and technical analysis agent (through the coordination agent) and according the recommendation database (to use last experiences) make a recommendation and deliver it to the coordination agent to conscious the user and save the new result in recommendation database.

7. Fuzzy Agent Interactions

Fuzzy multi agent based framework performs following actions:

i) *Query all share's quotation on the current day*
ii) *Query a given share's quotation on the current day*
iii) *Query a given share's real-time trading chart*
iv) *Query a given share's history price chart over a period*
v) *Query a given share's price and technical indicator chart over a period*
vi) *Query a given share's fundamental analysis data*
vii) *Query the market statistic information over a period*

A user delegates the task to the human decision making agent, which then passes the request to the coordination agent. The coordination agent will distribute the task to the relevant task-specific agent. Then the related agent finds the answer and sends to the coordination agent. Afterwards the coordination agent passes the answer to the human decision making agent; in the meantime, the coordination agent will update the blackboard status and delete the relative messages associated with this conversation session in the private message area of the blackboard, since the conversation (or task) is complete. Finally, the human decision making agent presents the results in a readily

understandable format to the user. The fuzzy multi-agent-based framework automatically monitors the market status of the given shares. Based on the share's market status and monitoring actions given by the users, any abnormal status will be reported to the users. The monitoring actions include: 1) Monitoring abnormal price fluctuation, 2) Monitoring abnormal trading volume, 3) Monitoring abnormal technical indicator's status, and 4) Monitoring abnormal price chart pattern. Furthermore, fuzzy multi agent based framework will provide profits and risks management, including calculation of profits/risk ratio based on shares' market status and user's investment, and reminders of the stop-loss level.

Having discussed earlier, the agents act as a dynamic blackboard in the system. Every agent can watch the information change (or an event) on the blackboard, and an agent will react to or ignore the event according to its responsibility. The monitoring agent requests the user database to get the share codes needed for monitoring and the user's monitoring instruction through coordination agent. According to the monitoring instruction, the monitoring agent will ask the technical analysis agent to help in finding out the current value of the given shares. The technical analysis agent interacts with the stock database and calculates the value of the technical indicators on behalf of a monitoring agent and then returns the results to the monitoring agent. The monitoring agent compares the value obtained from the technical analysis agent with the predefined appraisal thresholds of abnormal technical indicators that are obtained from the user database. If an abnormal event occurs, the monitoring agent will immediately send a message to the coordination agent to notify the user of abnormal indicators by means of the interface agent.

For the buying and selling share process in Tehran Stock Market, the scenarios of agent interaction are variable. It largely depends on the buying and selling fuzzy rules defined by the users stored in fuzzy rule based database. Fuzzy multi agent based framework help the user to set up fuzzy rules (strategies) which can be altered by users. As an instance the user delegates the task of finding the best share to buy the next trading day to the human decision making agent through mouse clicks. The human decision making agent passes the task to the communication agent. Communication agent decides to assign the task to the fuzzy recommendation agent. The fuzzy recommendation agent needs to request the defuzzifier agent to get the crisp buying rules through inference agent. The records in the fuzzy rule based database are the buying and selling strategies that are stored by rule discovering agent. Therefore, the inference agent together with the fuzzifier agent fuzzifying the users' input parameters, acting as a dynamic blackboard to find the fuzzy answer. Accordingly, direct communication between the agents makes the dynamic exchange of facts, knowledge, and commands more flexible and transparent in this framework.

8. Conclusion

In this paper, we presented a fuzzy multi-agent-based framework that can be used instead of basic trader roles (investor, broker, and market maker participant) to make decisions in stock trading and supporting the most typical market structures (including continuous trading sessions) based on Tehran Stock Market structure. We have briefly described how to integrate the quantitative analysis and qualitative judgment, and model the situation of stock market, by use of fuzzy agents.

In this architecture the coordinator agent plays an integral role in maintaining the appropriate communication protocol (it decomposes system-level tasks to subtasks and distributes the subtasks to related task specific agents). We have introduced a framework in which agents can exchange knowledge in a dynamic environment. Knowledge can be exchanged among the agents by using a combination of facts, rules and commands being transferred. The obvious advantages of this framework are understanding fuzzy if-then rules which exist in stock market, the elimination of redundant knowledge and hence the improved utilization of the system memory capacity.

It is important to note that the multi-agent-based system should focus on supporting, rather than replacing, human judgments. Human mind is itself a very powerful, flexible, creative, agile problem solving and decision-making 'machine'. There should be inter-play between the decision-maker and the agent based stock trading system which can contribute to a greater total effort than the power attained by the independent human decision-maker and the operating computerized system. Both analysis and human inputs should guide final decisions.

References:

[1] Yap, M.; Sam-Yuan Sung; Hung-Keng Pung, "Agent managed multi database system design for the stock broking domain," Database and Expert Systems Applications, pp. 471 – 476, September 2000.

[2] R.D. Edward, J. Magee, "Technical Analysis of Stock Trends," eighth ed., AMACOM St. Lucie Press, 2001.

[3] Yuan Luo, Kecheng Liu, Darryl N. Davis, "A multi-agent decision support system for stock trading," IEEE Network, vol. 16, no. 1, pp. 20-27, January/February 2002.

[4] Leigh Tesfatsion, "Introduction to the special issue on agent-based computational economics," Journal of Economic Dynamics and Control, vol. 25, pp.281–293, 2001.

[5] T. Selker, "A teaching agent that learns," communications of the ACM, vol. 37(7), pp. 92-99, 1994.

[6] Bui, T., & Lee, J., "An agent-based framework for building decision support systems," Decision Support Systems, vol. 25, pp. 225–237, 1999.

[7] N. Jennings and M. Wooldridge, "software agents," IEEE Review, pp. 17-20, January 1996.

[8] Jaco van der Merwe and S. H. von Solms, "Electronic commerce with secure intelligent trade agents," computers & security, Vol. 17, No. 5, pp. 435-446, 1998.

[9] Wong FS, Wang P.Z., T.H. Goh, "Fuzzy neural systems for decision making," *IEEE International Joint Conference on*, vol. 2, pp. 1625-1637, November 1991.

[10] Riza C. Berkan, Sheldon L. Trubath, "fuzzy systems design principles," IEEE press, 1997.

[11] M. C. S. Wong, "Fund management performance, trend-chasing technical analysis and investment horizons: a case study," Omega, vol. 25, Issue 1, pp. 57-63, February 1997.

[12] Amir Albadvi, S. Kamal Chaharsooghi, Akbar Esfahanipour, "Decision making in stock trading: An application of PROMETHEE," European Journal of Operational Research, In Press, Corrected Proof, Available online 8 February 2006.

[13] H. Kwas´nicka, M. Ciosmak, "Intelligent Techniques in Stock Analysis," in: Proceedings of the International Symposium "Intelligent Information Systems X," Zakopane, Poland, Physica-Verlag, A Springer-Verlag Company, pp. 195–208, June 2001.

[14] Chi, R. T., & Turban, E., "Distributed intelligent executive information systems," Decision Support Systems, vol.14, pp. 117–130, 1995.

[15] Katalin Boer and Uzay Kaymak, "Microsimulation of artificial stock markets based on trader roles," International Workshop on Data Mining and Adaptive Modelling Methods for Economics and Management (IWAMEM-03), Porto, Portugal, pp. 61–72, September 2003.

[16] Benos, A. and Tzafestas, E., "Alternative distributed models for the comparative study of the stock market phenomena," Information Sciences, vol. 99, no. 3-4, pp. 137-157, 1997.