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Intelligent agent-assisted adaptive order simulation system in the artificial stock market ☆

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ABSTRACT

Agent-based computational economics (ACE) has received increased attention and importance over recent years. Some researchers have attempted to develop an agent-based model of the stock market to investigate the behavior of investors and provide decision support for innovation of trading mechanisms. However, challenges remain regarding the design and implementation of such a model, due to the complexity of investors, financial information, policies, and so on. This paper will describe a novel architecture to model the stock market by utilizing stock agent, finance agent and investor agent. Each type of investor agent has a different investment strategy and learning method. A prototype system for supporting stock market simulation and evolution is also presented to demonstrate the practicality and feasibility of the proposed intelligent agent-based artificial stock market system architecture.

1. Introduction

The financial turmoil triggered by the US subprime mortgage crisis has swept the world since 2007. Many banks, real estate investment trusts (REIT) and hedge funds have suffered significant losses as a result of mortgage payment defaults or mortgage asset devaluation. Some even collapsed, such as Bear Stearns and Lehman Brothers (Sorkin, 2008; White & Anderson, 2008). Jan Hatzius estimates that in the past year, financial institutions around the world have already written down $408 billion worth of assets and raised $367 billion worth of capital (Hilsenrath, Ng, & Paletta, 2008). The crisis has severely shaken people's faith in traditional economic theory. "We have had a massive failure of the dominant economic model", Eric Weinstein said. In 2009, Nature journal published two articles on agent-based modeling to study the economics and prevent the financial crisis (Buchanan, 2009; Farmer & Foley, 2009). Agent-based computational economics (ACE) is the computational study of economies modeled as evolving systems of autonomous interacting agents (Wu, 2001). ACE is a bottom-up culture dish approach to the study of economic systems (Tesfatsion, 2011). It has been applied to research areas such as asset pricing, stock market simulation, industry dynamics, and macroeconomics.

China's economy has developed rapidly in the past 30 years. The healthy development of the stock market is very important for the national economy. However, changes in the stock trading mechanism may have a greater impact on the market. Thus, the Shanghai Stock Exchange launched China's first innovation R&D and experimental platform based on finance simulation and modeling technology in 2011. The short-term goal of the innovation experimental platform is to construct a table-top exercises environment for business innovation research. The long-term goal is to build an open and professional R&D experimental environment that can provide support and service for continuous trading mechanism innovation. To achieve this goal, we need to build an innovation experimental platform by designing an adaptive simulation system based on intelligent agents. In practice, some researchers have already developed agent-based simulation systems of the stock market in past years (LeBaron, 2002; Nadeau, 2009; Wang, Wang, Xu, Wan, & Vogel, 2004). However, there are still two limitations in today's practical simulation systems that need to be addressed. These are:

(1) The simulation of market news in the investment decision-making process. In general, investors make investment decisions through comprehensive analysis of various information in which the financial magazine is an important information source. However, little work has been done about the utilization of such information in the decision process of fundamentals investors. Thus, how to simulate the decision-making process of fundamentals investors based on financial information is one major challenge.

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(2) The learning mechanism of fundamentals investors. In the long practice of investing, each investor will continue to learn to improve their profitability. Investors improve and optimize their strategies based on investment return. Everyone is willing to believe information sources that have strong predictive power. Thus, the predictive ability evaluation of the various information sources is a key problem. How to design and implement the learning mechanism of fundamentals investors is another challenge.

To address these challenges, we studied the conceptual model of the stock market in-depth. It includes stocks, investors, financial information, trading mechanisms and other participants. We use a different agent to represent each type of participant. The relationships among the agents are embodied using the agent hierarchy. We describe in detail the design of the stock agent, investor and financial agent, which shows how market news is used in the decision-making process. We study the investment strategy and learning algorithm of fundamentals investors and other types of investors. Finally, we design and implement one system to simulate the real stock market, i.e., Intelligent Agent-assisted Order Simulation System (IAOSS), and evaluate the reasonableness of the system design through some technical indicators.

The rest of the paper is organized as follows. Section 2 discusses related work. Section 3 describes the system design, including the conceptual model, agent hierarchy, agent design, and system architecture. Section 4 describes system implementation, including agent implementation and the investor learning algorithm. Section 5 describes the application and evaluation of the system and conducts short selling experiments. Finally, we draw conclusions to end this paper.

2. Background and related work

The research of stock market simulation originated from the first artificial stock market established by the Santa Fe Institute. Many researchers have subsequently undertaken very effective work. These efforts are concentrated in several areas: agent-based stock market model, investor trading strategies, market trading mechanisms, etc. The related work is reviewed below.

2.1. Intelligent agent and artificial stock market

Intelligent agents can be seen as software agents with intelligent behavior, that is, they are a combination of software agents and intelligent systems. Intelligent agents have been successfully applied to many domains, such as decision support systems (Wang, 1997), e-Learning (Xu, Wang, & Wang, 2005), supply chain management (Wang, Liu, & Wang, 2008), and personnel finance (Gao, Wang, Wang, Shen, & Yeung, 2005).

The artificial stock market originated from Holland's complex adaptive system (Holland, 1992), which posited that a finance system is also a complex adaptive system. Various researches have been conducted into applying intelligent agent-based technology to the artificial stock market. For example, the Santa Fe Institute used intelligent agents to build the first artificial stock market in the world (Arthur, Holland, LeBaron, & Palmer, 1997), which introduced "incomplete rationality", "non-linearity", "non-equilibrium", "non-effective" and enabled the modeling to be closer to the real market. LeBaron also developed an agent-based model of the stock market (LeBaron, 2002). In his model, several hundred agents attempt to profit by buying and selling stock, basing their decisions on patterns they perceive in past stock movements. Because the agents can learn from and respond to emerging market behavior, they often shift their strategies, leading other agents to change their behavior in turn. As a result, prices do not settle down into a stable equilibrium, as predicted by standard economic.

In the late 1990s, the NASDAQ stock exchange planned to cease listing its stock prices as fractions such as 12 1/4 and instead to list them as decimals (Buchanan, 2009). Before making this risky change, NASDAQ hired the BiosGroup to develop an agent-based model of the market to test the idea. The tests revealed that if the stock exchange reduced its price increment too much, traders would be able to exploit strategies that would make them quick profits at the expense of overall market efficiency. Thus, when the exchange went ahead with the changeover in 2001, it was able to take steps to counter this vulnerability. Such work in designing and implementing practical stock simulation system is crucial to our research in the sense that their results provide solid pragmatic technology. However, not all existing work considers the specific effect of financial information on investors. In this paper, we design a finance agent and investor agent, and proposed the corresponding fundamentals investment strategy.

2.2. Investor trading strategy

In finance, a trading strategy is a predefined set of rules for making trading decisions. An investor uses trading strategy to assist in making wiser investment decisions and eliminating the emotional aspect of trading. Generally, the trading strategy styles include technical analysis, fundamentals analysis, quantitative trading, trend following, mean reversion, and more. Chen proposed trading strategy based on genetic programming design (Chen, 2001). Yang proposed trading strategy in an artificial double auction stock market with neural learning agents (Yang, 2002). Zhu et al. proposed strategic learning in a sealed-bid bargaining mechanism by particle swarm optimization algorithm (Zhu, Wang, & Yu, 2006). Lu and Li proposed the mixed tactics-based dynamic offering algorithm (Lu & Li, 2006). Most existing work concerns technical analysis strategy. However, less work has been done in fundamentals analysis strategy and other strategies. In this paper, we not only consider the trading strategies of fundamentals investors, but also take into account the trading strategies of noise investors and momentum investors.

2.3. Stock market trading mechanism

China's stock market is still an emerging market. Many trading mechanism are not the same as those of other countries. There is much controversy in academia and industry about whether China should adopt international practices or not. Short selling is a typical example. In finance, short selling is the practice of selling securities that have been borrowed from a third party with the intention of buying identical securities back at a later date to return to the lender. It is a form of reverse trading. Mathematically, it is equivalent to buying a "negative" amount of the assets.

One view about short selling is that allowing short selling affects the stability of the stock market and increases market volatility (Allen & Gale, 1991). Allen and Gale found that in the case of restricted short selling, the market is perfectly competitive and balanced. However, in allowing unrestricted short selling, the market is not perfectly competitive and permitting short selling will therefore affect economic stability. Bemardo and Welch studied the relationship between finance crisis fears and crisis (Bernardo & Welch, 2004). They believe that once investors have concerns about liquidity, they will tend to immediately sell the stock on hand to prevent them being the last people to stay in the market. To limit short selling helps prevent public panic caused by a small group of investors, thereby reducing the incidence of financial crisis and stabilizing financial markets.