Expert Systems with Applications 39 (2012) 5920–5934

Contents lists available at SciVerse ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

A multi-agent-based decision support system for bankruptcy contagion effects

Jinyu Zhang [a,*], Lin Cheng [b,c], Huaiqing Wang [c]

[a] Software Institute, Nanjing University, 22 Hankou Road, Gu Lou, Nanjing, Jiangsu, PR China
[b] USTC-CityU Joint Advanced Research Center, Suzhou, PR China
[c] Department of Information Systems, City University of Hong Kong, 83 Tat Chee Avenue, Kowloon, Hong Kong

ARTICLE INFO

Keywords:
Bankruptcy filing
Software agents
Multi-agent-based system
Ontology

ABSTRACT

With the increasing interdependence of marketing participants, distress experienced by a specific entity may cause other connecting firms to encounter financial difficulties, leading to a negative impact on their stock valuations. At the same time, individual investors have a great need to gain relevant information for portfolio risk management. The monitoring vision cannot be limited to investors' portfolios but must take into account any potential candidates affected. Based on the ontological knowledge model of inter-firm relationships, the proposed multi-agent decision support system continuously observes real-time news reports and forecasts their potential impact on the corresponding stock price. After identifying relating companies for which significant market reactions can be expected, a wireless push-based message service promptly supplies information. A case study is used to illustrate the multi-agent-based decision support system (MAB-DSS) implementation and its use. The example shows that the MAB-DSS can automate the solution for intricate and dynamic valuation effects among interdependent firms and provide constructive advice for individual investors.

1. Introduction

News articles usually contain rich and real-time information about companies and have a visible impact on the price of securities; thus, investors need to spend a significant amount of time in aiding investment decisions, especially for those companies in their portfolio. It is widely recognized that the global financial and economic system exhibits a tendency to become more and more remarkably intertwined with the continual increase in economic globalization, and this provided a diffusion path for the United States (US) subprime mortgage crisis. With this intensified interaction of various types among participants, it is far from adequate to simply 'keep an eye' on the companies in your portfolio basket. In this network economy, an event specific to one entity may have an immediate economic impact on other entities, since economic and financial systems are built on interdependencies and implemented through the close ties created between firms as a result of legal (parent–subsidiary), financial (trade–credit relationship), business (buy–supplier, competitor, partner, etc.) and other relationships. The phenomenon of the ripple effect caused by bankruptcy is widely explored in the literature (Carling, Rönnegård, & Roszbach, 2004). Based on the background of the Japanese slump in the 1990s, for example, Kiyotaki and Moore (2002) found that contagion is diffused through balance sheet effects, i.e. when a firm goes bankrupt, it cannot pay the debt to its creditors, which may lead its creditors into financial difficulties. Gatti, Gallegati, Greenwald, Russo, and Steglitz (2006) model a network economy with three sectors: downstream firms, upstream firms, and banks. Through agent-based simulations, they found that credit linkages among agents are a source of bankruptcy diffusion because the failure to fulfill debt commitments would lead to bankruptcy. The contagion effect is also severely felt in the stock market and characterized as stock correlation or co-movement. When the fourth largest US investment bank, Lehman Brothers, filed for bankruptcy protection in September 2008, the China Merchant Bank was among the first to disclose its holdings of US$70 million in Lehman Brothers bonds, the majority of which were in senior debt and the remainder in subordinate debt. In the days following Lehman Brothers' collapse, China Merchant Bank shares experienced a sharp depreciation in value. This kind of contagion effect is due to direct exposure to distressed US financial institutions and interaction with the fear of investors wanting to withdraw their money. We claim that truly effective portfolio diversification strategies should be achieved by investigating the underlying structure and inter-relationships among candidate firms to enhance risk management.

An important premise in financial investment is that a decision should be based on a reasonable amount of validated information. Online news has become an important source of information with the rapid development of the Internet, but because content on the web updates frequently, information overload becomes a

* Corresponding author. Tel.: +86 25 83621002 926; fax: +86 25 83621370.
E-mail address: zhjinyu@software.nju.edu.cn (J. Zhang).

0957-4174/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2011.11.112

significant problem for investors, especially individual investors who are not able to observe current developments all the time compared to their institutional counterparts. The empirical observations by Dey and Radhakrishna (2007), for example, provide evidence that individual investors react with significant delay to new information becoming available and therefore miss opportunities that institutional investors exploit because they react promptly. These opportunities have been observed by several intra-day event studies that analyze the impact of newly disseminated information on the financial market (Barclay & Litzenberger, 1988). Although tremendous systems have also been developed for analyzing, monitoring and predicting risk in financial investment, however, they have usually been limited to monitoring the news of one specific company of interest and neglecting some of the information that may have an indirect influence on the stock price of the focus company through inter-firm linkages. In this paper, based on the previous work of conceptual modeling of inter-firm relationships, we have developed a Multi-Agent-Based Decision Support System (MAB-DSS) to collect, process, and provide information in a way that supports individual investors in reacting faster to information news published by companies and identifying relevant events and affected shares.

The ontology-based analysis and design of the decision support system can be loosely divided into three phases. Firstly, domain ontology is developed by the business analyst (BA) to capture the specifications of the functionality that the target MAS should provide. Different functionalities need to be integrated to provide appropriate support for developing a multi-agent-based system. One prominent approach is the use of ontology on multi-agent-based systems (Fuentes, Carbo, & Molina, 2006; Lavbič, Vasilecas, & Rupnik, 2010; Soo, Lin, Yang, Lin, & Cheng, 2006). Ontology provides significant benefits for the interoperability and reusability of multi-agent systems, as well as support for multi-agent system (MAS) development activities (such as system analysis and agent knowledge modeling) and MAS operation (such as agent communication and reasoning). The system analyst (SA) designs the system by transforming the conceptual model into an operational solution, and the system is implemented by choosing related techniques.

The remainder of the paper is organized as follows. An overview of related literature is given in Section 2. Section 3 presents a system development approach and combines its application with our application. In Section 4, we introduce a multi-intelligent decision support system for bankruptcy contagion effects with emphasis on system architecture and the roles of agents. As a prototype, the MAB-DSS system is focused on customer–supplier and trade credit relationships in the application domain. By utilizing wireless communication technologies, we push a risk alerting message. After presentation of the system architecture and agents, the decomposition of ontologies in the MAB-DSS is presented in detail. Section 5 elaborates the implementation of a case study in detail. Finally, some advantages and limitations of our developed multi-agent-based system are discussed in the last section.

2. Background research

2.1. Multi-agent-based system

According to Wooldridge and Jennings (1995) and Wooldridge (2002), an agent is a software program which is capable of autonomous action within its environment in order to meet its design objectives. Software agents have autonomy and are social; they communicate, coordinate, and cooperate with each other to achieve goals (Bradshaw, 1997; Jennings, Sycara, & Wooldridge, 1998; Weiss, 1999), and enjoy the following characteristics: autonomy, the ability to operate without direct human intervention or the intervention of other agents; social ability, which is the capacity to interact, communicate and cooperate with other agents (and possibly humans) via a kind of agent-communication language; reactivity, which is the ability to monitor their environment and respond to changes that occur in it; and proactiveness, the ability to take initiatives when necessary and to exhibit goal-oriented and opportunistic behavior.

Software agents in a system have the ability to cope with very different levels of representation of 'individuals' and 'groups', ranging from reactive agents to cognitive agents. Reactive agents are simple entities that just have reflexes, whereas cognitive agents are those that can form plans for their behaviors (Ferber, 1999). Ferber (1999) has shown that both approaches can converge in the end-user, while emphasizing different aspects. Multi-agent-based systems are composed of a collection of decision-makers (autonomous agents), which interact and collaborate with each other by means of communication and prescribed rules to solve problems that are beyond individual capabilities or knowledge (Farmer & Foley, 2009; Sycara, 1998; Vicente et al., 2005). The multi-agent-based paradigm is therefore considered to be well suited to explaining and understanding the phenomena associated with the complex phenomena of the financial system (Axtell, 2000; Lebaron, 2000; Mentges, 1999), even in a dynamic distributed environment in time and space (Jennings et al., 1998).

There is some promising research about multi-agent-based systems for small portions of the real-world economy (Farmer & Foley, 2009); for example, the models of the financial market built by Blake LeBaron of Brandeis University provided a plausible explanation for bubbles and crashes, and SimStockExchange (http://www.simstockexchange.com/index.htm) by Hoffmann, A.O.I of Maastricht University, is a multi-agent simulation model used to simulate trading behavior and investigate stock market dynamics. There are also others, such as the credit sector model of Mauro Gallegati's group at the Marche Polytechnic University, and the monetary model developed by Robert Clower of the University of South Carolina and Peter Howitt of Brown University. In recent years, there has been a growth in the interest in software agent applications, and practical programming languages and techniques are proposed to guide system development, e.g. Jason (Bordini et al., 2005), JACK (Busetta, Ronnquist, Hodgson, & Lucas, 1999), Jade (Bellifemine, Caire, & Greenwood, 2007), and Jadex (Braubach, Pokahr, & Lamersdorf, 2004; Pokahr, Braubach, & Lamersdorf, 2005). A survey on programming languages and platforms for multi-agent-based systems can be found in Bordini et al. (2006).

2.2. Ontology

According to the most popular definition, ontology is an explicit specification of a conceptualization (Gruber, 1993) in which 'conceptualization' is an abstracted view of a domain world that we wish to represent. Therefore, ontology has become popular as a paradigm for knowledge representation and engineering by domain experts (Qiu, 2006) by providing a methodology for the shared understanding of a domain of interest. Related research on using ontology has attracted a great deal of interest and is extensive. The sharing and understanding of the knowledge in a given domain is a central role of the ontology. Ye, Wang, Yan, Wang, and Miao (2009), for example, proposed three kinds of ontology to understand the crisis contagion in financial institutions and enhance knowledge sharing among related entities from static, dynamic and social perspectives. Vasilecas and Bugaite (2006) applied ontology for ontology-based system development and defined the major problem of automation of information processing rules. In other literature, several authors shared similar opinions to address ontology as knowledge representation