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An agent based approach for exception handling in e-procurement management

Sherry X. Sun *, Jing Zhao, Huaiqing Wang

Department of Information Systems, City University of Hong Kong, Hong Kong, China

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ABSTRACT

E-procurement has become an important function of enterprise information systems. The process of e-procurement includes the automatic definition of product requirements, search and selection for suppliers, negotiation and contracting with suppliers. However, the adoption of e-procurement encounters various exceptions from internal and external environments such as sharply increased demand, delivery delay and inventory failure. In this paper, we have proposed an agent and Web service based architecture for exception handling in e-procurement. Agent technology is applied to deal with the complex, dynamic, and distributed e-procurement process, while Web service technology is applied to provide scalability and interoperability. In this architecture, different tasks in the e-procurement process, such as searching, negotiating, supplier selection, contracting, monitoring, and exception handling, are assigned to different agents, which are wrapped as Web services. A set of rules for detecting and handling the exceptions is defined based on a basic inventory model and a genetic algorithm is utilized for supplier selection. To evaluate our exception handling approach, we have developed a prototype system, through which a simulation has been conducted to verify the effectiveness of our approach.

1. Introduction

Electronic procurement (e-procurement), which has been widely adopted to facilitate the acquisition of commodities through the Internet (Barua, Konana, Whinston, & Yin, 2001), mainly focuses on automating the major steps of a purchasing process, such as definition of product requirements, search and selection for suppliers, negotiation and contracting with suppliers (Lancioni, Schau, & Smith, 2003). Companies apply e-procurement technologies for the purpose of reducing administrative costs, cutting down the order fulfillment cycle time, lowering inventory levels and the price paid for goods, and preparing organizations for collaboration with others (Croom, 2000). Through an e-procurement system, the suppliers' product descriptions and prices can easily be communicated to buyers. Buyers can also submit purchase orders electronically to suppliers through e-procurement. Given the great potential of e-procurement, it is important to study both business and technical issues in implementing e-procurement (Rajkumar, 2001).

Challenges still remain in the application of e-procurement, however, since uncertainties resulting from demand, process, and supply, such as demand fluctuation, delivery delay, and inventory failure, can cause exceptions in the procurement process (Chopra & Meindl, 2003; Ho, Chi, & Tai, 2005; Mason-Jones & Towill, 1998). When such exceptions occur, an e-procurement system should be able to automatically gather relevant information and respond to the exceptions by identifying appropriate alternative suppliers. Thus, the flexibility to handle exceptions is critical for any e-procurement system. Although the existing research has investigated the impact, risks, and uncertainties for adopting e-procurement in an enterprise environment, limited support is offered to handle exceptions in e-procurement management.

Agent technology can automate the execution of complex tasks and has been proposed as a technology for computer-based decision support in the procurement domain (Nissen & Sengupta, 2006). In this paper, we propose a multi-agent based approach to deal with the uncertainties encountered in a procurement process. In our architecture, different tasks in the procurement process, such as searching, negotiating, contracting, supplier selection, exception monitoring and handling, are delegated to a number of both autonomous and collaborative agents. Given that agents can reason using specific knowledge and then react to different situations accordingly, our approach provides a more intelligent, flexible, and autonomous solution to exceptions handling in e-procurement management. Moreover, by wrapping each agent as a Web service, our architecture provides greater scalability and interoperability.

The rest of this paper is organized as follows. Section 2 briefly reviews the relevant literature on e-procurement, intelligent agent, Web service, and agent based applications in e-procurement. In Section 3, we propose an agent based architecture for e-procurement exception management. In Section 4, we develop a prototype and in Section 5 we evaluate our exception handling approach. Finally, Section 6 concludes this paper with our contributions and future research directions.

* Corresponding author. Tel.: +852 3442 8697; fax: +852 3442 0370.
E-mail addresses: sherry.sun@cityu.edu.hk (S.X. Sun), jingzhao@student.cityu.edu.hk (J. Zhao), iswang@cityu.edu.hk (H. Wang).

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2. Literature review

2.1. E-procurement

Most research in e-procurement management focuses on the business value of the implementation of e-procurement in an organization. Croom (2000) shows that low-value, high-variety goods and services can be obtained by strategically adopting Web-based procurement systems. A study has been conducted to explore buyer–supplier relationships and participants' behaviors in e-reverse auctions (e-RAs) and the results indicate that the management of e-RAs had a positive impact on the buyer–supplier relationship (Lösch & Lambert, 2007). Hartley, Lane, and Hong (2004) introduce reverse auctions into the e-procurement process. Through the reverse auctions, suppliers can compete for a buyer's orders. This study (Hartley et al., 2004) reports increased annual sales by suppliers who participate in the reverse auctions.

The risks and uncertainties involved in e-procurement have also been investigated. Kauffman and Mohtadi (2004) analyze the e-procurement adoption behavior of firms in the presence of transaction costs, agency costs, and information uncertainty. Yen and Ng (2003) propose a four-phase migration model to adopt Web-based procurement in order to minimize the related risks. Chang, Wang, and Chiu (2008) examine the fit between business and the IT environment in adopting e-procurement through a multiple-case study and discuss the challenges and barriers resulting from various uncertainties from internal and external business environments.

In order to facilitate the adoption of e-procurement, Wei (2002) has provided guidelines for enterprises to develop an appropriate strategy for using e-procurement. Ordanini, Micelli, and Maria (2004) analyzed business models of active e-marketplaces to show the features that differentiate the successful initiatives from the failures. Based on an analysis of direct and indirect procurement practices of sample organizations in Australia, Hawking, Stein, Wyld, and Foster (2004) have studied drivers and barriers in the adoption of e-procurement. Angeles and Nath (2007) studied the success factors and challenges in e-procurement implementation. Hardy and Williams (2007) have empirically investigated how to apply public e-procurement policies in e-government.

While the managerial perspective of e-procurement has attracted much attention, several studies have shed light on the technical issues in developing e-procurement. Chang, Markatsoris, and Richards (2004) have discussed the design principles of an e-procurement system and explained the overall development processes including generic procurement processes, data entities used in the system, functional diagram and technical architecture.

2.2. Agent and Web service

The concept of "agent" has become significant in artificial intelligence, computer science and e-commerce (Dugdale & Keynes, 1996; Wang, 1997). Intelligent agents are autonomous individuals that enjoy the following properties (Woodridge & Jennings, 1995):

- Autonomy: agents can operate autonomously without the direct intervention of humans.
- Co-operability: agents can co-operate with other agents to achieve certain objectives.
- Reactivity: agents can perceive their environment and make a timely response to changes that occur.
- Pro-activity: agents do not simply respond to their environment but also exhibit goal-directed behaviors by taking the initiative.

The basic components of an agent usually include reasoning facilities to achieve certain goals, a knowledge-base about its environment, and communication functions to interact with other agents. In order to achieve its goals, an agent needs to use its knowledge to reason about its environment and other agents' behaviors, to generate plans and to execute these plans. A multi-agent system consists of a number of agents interacting with one another to achieve their goals. Agents can overcome their inherent bounds of intelligence by absorbing other agents' knowledge and capabilities (Jennings & Wooldridge, 1998).

Web services are self contained, self-describing applications that can be published, located, and invoked across the Internet using standard protocols such as Simple Object Access Protocol (SOAP), Web Services Description Language (WSDL) and Universal Description, Discovery and Integration (UDDI) (Curbera et al., 2002). Through Web services, companies can publish applications as services, search for other services, and encapsulate existing services. Web services enable business process integration by utilizing existing applications to form a composite business application. While business environments are changing rapidly from centralized and closed to distributed and open, mainly due to the proliferation of the World Wide Web (WWW), it is crucial to develop systems with scalability and interoperability. Among current Web technologies, Web services are promising for distributed and open business applications because of their scalability and interoperability.

Both intelligent agents and Web services are able to perform certain functions independently. However, they suffer from different problems which limit their functionality when applied separately. A Web service knows about itself, whereas agents are aware of other agents. A Web service, as currently defined and used, is not autonomous, while autonomy is a characteristic of agents. Agents are inherently communicative, while Web services are passive until invoked. Agents can cooperate with each other to provide high-level and more comprehensive service, while current standards for Web services do not provide for composing functionalities (Huhns, 2002). In this paper, we try to integrate agent technology with Web services for the purpose of overcoming such limitations and enabling them to complement each other. By so doing, we can take advantage of the interoperable and extensible Web services and the autonomous and flexible agents.

2.3. Intelligent agents in e-procurement

In recent years, there has been considerable growth of interest in the design of a distributed, intelligent society of agents in e-commerce applications (Guttman, Moukas, & Maes, 1998; He, Jennings, & Leung, 2003; Ye, Liu, & Moukas, 2001). It has been suggested that intelligent agents can function on behalf of buyers to search for products in a procurement process (Hadikusumo, Petchpong, & Charoenngam, 2005; Lau, Wong, Pun, & Chin, 2003). Raghavan and Prabhu (2004) designed and developed a software agent-based framework for a typical e-procurement process by decomposing the procurement process into three steps: e-negotiations, reverse auctions, and e-settlement. Cheung, Wang, Lo, and Lee (2004) proposed an agent-oriented knowledge-based system for strategic e-procurement through capturing real time information to generate dynamic business rules. Hadikusumo et al. (2005) developed a decentralized database system equipped with electronic agents for material procurement, in which several tasks are assigned to electronic agents. Lee, Lau, Ho, and Ho (2009) proposed an agent based e-procurement system, in which the intelligent agents take responsibility for searching the potential suppliers, negotiating with the short-listed suppliers and evaluating the performance of suppliers based on the selection criteria.

Despite the existing research on applying intelligent agents for e-procurement, the challenge remains of how to deal with exceptions in the procurement process caused by different uncertainties from internal and external environments. In this paper, we propose