PERGAMON

Expert Systems with Applications 25 (2003) 589–602

Expert Systems with Applications

www.elsevier.com/locate/eswa

Intelligent policy recommendations on enterprise resource planning by the use of agent technology and data mining techniques

Andreas L. Symeonidis[a,b,*], Dionisis D. Kehagias[a,b], Pericles A. Mitkas[a,b]

[a]*Department of Electrical and Computer Engineering, Aristotle University of Thessaloniki, Panepistimioupoli, 54124 Thessaloniki, Greece*
[b]*Laboratory of Intelligent Systems and Software Engineering, Informatics and Telematics Institute/CERTH, Thessaloniki, Greece*

Abstract

Enterprise Resource Planning systems tend to deploy Supply Chain Management and/or Customer Relationship Management techniques, in order to successfully fuse information to customers, suppliers, manufacturers and warehouses, and therefore minimize system-wide costs while satisfying service level requirements. Although efficient, these systems are neither versatile nor adaptive, since newly discovered customer trends cannot be easily integrated with existing knowledge. Advancing on the way the above mentioned techniques apply on ERP systems, we have developed a multi-agent system that introduces adaptive intelligence as a powerful add-on for ERP software customization. The system can be thought of as a recommendation engine, which takes advantage of knowledge gained through the use of data mining techniques, and incorporates it into the resulting company selling policy. The intelligent agents of the system can be periodically retrained as new information is added to the ERP. In this paper, we present the architecture and development details of the system, and demonstrate its application on a real test case.

Keywords: Supply Chain Management; Customer Relationship Management; Data mining; Multi-agent systems; Agent training

1. Introduction

In a typical supply chain, raw materials are procured, items are produced at one or more company sites, shipped to warehouses for intermediate storage, and then sent to retailers or customers. Consequently, effective Supply Chain Management (SCM) strategies are applied at various stages of the process, in order to reduce cost and improve service levels (Levi, Kaminsky, & Levi, 2000).

On the other hand, Customer Relationship Management (CRM) techniques are frequently applied to enable companies to master the basics of building customer focus, i.e. move from a product orientation to a customer orientation and define their market strategy from outside-in instead of inside-out. Customer orientation can be fostered through the integration of CRM across the entire customer experience chain, by leveraging technology to achieve real-time customer management (Rygielski, Wang, & Yen, 2002).

These two technologies have mainly been employed separately due to their increased complexity (Barbuceanu & Fox, 1994; Patterson, Grimm, & Corsi, 2003; Shen, Xue, & Norrie, 1998; Zeng & Sycara, 1999) and slight scope declination. Nevertheless, there have been some efforts to integrate them and exploit the advantages of such a coalition (Choy, Lee, & Lo, 2002; Choy, Lee, & Lo, 2003; Heikkila, 2002). These systems use the basic concepts of SCM and CRM and try to combine them, in an effort to produce a more sophisticated quality of services. Efficient may they be, the already developed systems are neither versatile nor adaptive, since newly discovered customer trends and changes in company policy cannot be easily incorporated into the system's backbone. In addition, the notions of synergy and collaboration, which are compulsory to such kinds of expert systems are not properly met, whereas their corresponding architecture is not always optimal.

Such systems facilitating Supply Chain and Customer Relation primitives (SC-CR systems) can be viewed as networks of collaborative, yet autonomous, units that

* Corresponding author. Address: Department of Electrical and Computer Engineering, Aristotle University of Thessaloniki, Panepistimioupoli, Thessaloniki 54124, Greece. Tel.: +30-2310-99-6349; fax: +30-2310-99-6398.

E-mail addresses: asymeon@iti.gr; asymeon@ee.auth.gr (A.L. Symeonidis).

0957-4174/03/$ - see front matter © 2003 Elsevier Ltd. All rights reserved.
doi:10.1016/S0957-4174(03)00099-X

regulate, control and organize all distributed activities involved in procurement, manufacturing, order processing, order transaction and product distribution. Research literature on intelligent agent system architectures has proven that problems that are inherently distributed or require the synergy of a number of distributed elements for their solution can be efficiently implemented as a multi-agent system (MAS) (Jennings, Sycara, & Woolridge, 1998; Ferber, 1999). Thus, multi-agent technology constitutes a powerful technology for developing SC-CR systems.

In a MAS realizing a SC-CR system, all requirements collected by the end users are perceived as distinguished roles of separate agents, acting in close collaboration. All agents participating in MAS communicate with each other by exchanging messages, encoded in a specific Agent Communication Language (ACL). Each agent in the MAS is designated to manipulate the content of the incoming messages and take specific actions/decisions that conform to a particular reasoning mechanism designed by the agent programmer.

Another technology that has been widely used for solving CRM problems is data mining (DM). DM, which is defined as the extraction of interesting (non-trivial, implicit, previously unknown and potentially useful) information or patterns from data in large databases (Fayyad, Piatetsky-Shapiro, & Smyth, 1996). DM has been recognized by many researchers as a key research topic in database systems and machine learning and considerable effort has been spent on the development of a large class of AI applications to exploit DM techniques. Market-basket analysis and customer segmentation (Amir, Feldman, & Kashi, 1997; Chen, Han, & Yu, 1996; Ganti, Gehrke, & Ramakrishman, 1999; Han & Kamber, 2001; Hong, Kuo, & Chi, 1999) are major CRM areas data mining has been applied on.

In this context, the presented work is focused on developing not only a DM framework for the identification of CRM and SCM patterns, but also on the design and implementation of a multi-agent system for exploiting the results of the DM procedure. More specifically, the developed multi-agent architecture combines multi-agent and data mining technologies in order to provide intelligent and adaptive policy recommendations, created on knowledge extracted through the use of data mining techniques. IPRA (Intelligent Policy Recommendation multi-Agent system) is an add-on to existing ERP systems, providing the ERP operator with customer/inventory/supplier useful recommendations, based Customer/Supplier Clustering and on Association Rule Extraction on item transactions. In particular, an agent that represents the current customer transaction collects all necessary information that concern the details of an order and contacts the appropriate IPRA agents, in order to finally get a set of recommendations by the system. These recommendations are tailored to each customer and his/her order, since clustering on selected customer data and transaction history is performed. In an analogous manner, supplier added value is discovered, whereas ordering habits are discovered and exploited through the system.

The main objective of IPRA is the optimization of the quality of services provided by the existing ERP, which provides a robust means for storing and manipulating a large amount of data on company transactions. The choice of developing IPRA as a MAS, provides the advantage of untroubled modification and extension of the system, according to altering company requirements. It should be mentioned that IPRA can extend any existing legacy database, containing customer and supplier data, and therefore increase the added value of the system.

It can be thought of as an intelligent system, since it increases its intelligence by embedding knowledge to the intelligent agents of the system. This knowledge is extracted by applying DM techniques on enterprise data in order to identify and exploit specific patterns among customers, suppliers and inventory items. Special care has been given to the agents that are designed to produce the recommendations of the system.

IPRA has been primarily tested on an existing ERP (over 25,000 of data records concerning transactions, over 8000 customers, over 500 suppliers) and the results seem quite promising. The IPRA approach seems that it can significantly increase the enterprise service level, in terms of delivery time, discount and correlated recommendations.

The rest of this paper is organized as follows: Section 2 introduces the implemented multi-agent system in detail and describes the functional characteristics of the different types of agents that comprise IPRA. In Section 3 the data mining methodology that is used in order to augment the agent decision quality, both in terms of intelligence and autonomy is presented. Finally, Section 4 illustrates the basic functional operations of IPRA and outlines the test case developed in the real enterprise environment, while Section 5 summarizes the work described and concludes this paper.

2. System architecture

2.1. IPRA use case description

The implemented MAS is illustrated in Fig. 1. Thin arrows represent messages exchanged between agents, while thick arrows correspond to data transfer from/to the MAS.

Upon receiving an order, an agent representing the customer collects all the necessary information, in order to provide the other IPRA agents with input. Collected data include the customer name and id, his/her geographic location, the list of items ordered and the corresponding quantity, as well as the customer's preferred payment terms, i.e. cash, by check, by credit card etc. Customer info are sent to an agent responsible for customer segmentation, which decides on the discount to be made to the particular customer.