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An agent-based approach for e-manufacturing and supply chain integration

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Abstract

A major problem facing manufacturing organisations is how to provide efficient and cost-effective responses to the unpredictable changes taking place in a global market. This problem is made difficult by the complexity of supply chain networks coupled with the complexity of individual manufacturing systems within supply chains. Current systems such as manufacturing execution systems (MES), supply chain management (SCM) systems and enterprise resource planning (ERP) systems do not provide adequate facilities for addressing this problem. This paper presents an approach that would enable manufacturing organisations to dynamically and cost-effectively integrate, optimise, configure, simulate, restructure and control not only their own manufacturing systems but also their supply networks, in a co-ordinated manner to cope with the dynamic changes occurring in a global market. This is realised by a synergy of two emerging manufacturing concepts: Agent-based agile manufacturing systems and e-manufacturing. The concept is to represent a complex manufacturing system and its supply network with an agent-based modelling and simulation architecture and to dynamically generate alternative scenarios with respect to planning, scheduling, configuration and restructure of both the manufacturing system and its supply network based on the coordinated interactions amongst agents.

Keywords: Supply chain integration; Multi-agent system; Agile manufacturing; E-manufacturing

1. Introduction

A major problem facing manufacturing organisations is how to provide efficient and cost-effective responses to unpredictable changes that take place in a global market. This problem can be addressed at three different levels: at the process, system and enterprise levels. At the process level, solutions may be sought through responsive processes (Jendrzejewski et al., 1999) and modular/reconfigurable machines (Kota, 1999; Rogers &

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Bottaci, 1997). At the system level, the problem may be addressed through dynamic optimisation, reconfiguration, restructuring and adaptation of manufacturing systems within an enterprise. The enterprise level seeks solutions through the integration, optimisation and alignment of operations across a supply chain (Kanet, Faisst, & Mertens, 1999). A complete and ideal solution would integrate these three levels into a coherent framework. However, it is very costly for manufacturers to replace their existing manufacturing machinery with new reconfigurable ones, even if they are available. On the other hand, supply chain issues are important in attempting to achieve responsiveness, but it would not be sufficient to achieve supply chain responsiveness alone without achieving responsiveness within an enterprise's own manufacturing system. Thus, a pragmatic approach is to provide an efficient and effective integration of operations at both enterprise and system levels for improved responsiveness. Current systems for such integration include supply chain management (SCM) systems, enterprise resource planning (ERP) systems and manufacturing execution systems (MES). However, the individualistic manner in which these systems are implemented makes it difficult for coordinated interactions to exist amongst them. This situation is made more difficult by the fact that interfaces are developed to enable communication amongst the modules that make up these systems, and with a plethora of tools and a huge range of vendors, adequate interfacing that would facilitate coordination amongst these modules is usually too difficult or impractical. What is needed is a unified decision support framework that would facilitate concurrent evaluation and coordinated interactions of decisions across different levels. This is achieved in this work by harnessing the strengths of two manufacturing paradigms: agent-based agile manufacturing systems and e-manufacturing. Agile manufacturing aims at providing manufacturers with the methodologies and systems for responding rapidly and cost-effectively to changes that take place in the manufacturing environment. On the other hand, e-manufacturing aims at providing Internet-based strategies and systems that would facilitate co-ordination between suppliers, manufacturers and customers for more efficient procurement, production and distribution. In recent years, multi-agent systems (MAS) have been recognised as one of the technologies that would facilitate agile and e-manufacturing by providing manufacturing enterprises with the capabilities to meet the ever-increasing needs for flexibility, robustness and adaptability to the rapid changes that occur in the manufacturing environment. MAS technology provides such capabilities by abandoning central control and establishing co-ordinated intelligent decision-making at the local levels. As a result, the investigation of the applicability of MAS technology in the modelling and control of manufacturing systems and supply chains has received significant attention in the research community as would be shown in the next section.

2. Related work

Supply chain management and integration is an area that has indeed received a lot of attention amongst researchers in the past two decades. Multi-agent systems have been proven suitable to represent domains such as supply chain networks which involve interactions amongst manufacturing organisations, their customers, suppliers, etc. with different (possibly conflicting) individual goals and propriety information (Stone & Veloso, 1997). Turoski (2002) and Ghiassi and Spera (2003) developed agent-based techniques for coordinating activities of e-commerce and internet-based supply chain system for mass customisation markets. Li and Fong (2003) and Choy and Lee (2002) proposed agent-based architectures to facilitate the formation and organisation of virtual enterprises for order management. Bo and Zhiming (2003) developed a multi-agent system supply chain management tool to evaluate various scheduling algorithms for orders allocated to different suppliers. Sadeh, Hildum, Kjenstad, and Tseng (1999) developed the MASCOT decision-making tool; a reconfigurable, multilevel, agent-based architecture for coordinated supply chain planning and scheduling. Swaminathan, Smith, and Sadeh (1998), Zeng and Sycara (1999), and Valluri and Croson (2003) adopted agent technology to develop frameworks to evaluate and improve the performance of supply chain structures. These works did not consider the details of the operations of the individual enterprises' manufacturing systems and how these operations affect the operation of the entire supply chain.

Nonetheless, a number of works have made efforts to integrate manufacturing activities with supply chain activities. Peng et al. (1998, 1999) present the CIIMPLEX framework for integrating manufacturing activities with customer services. CIIMPLEX uses functional agents with specialised expertise to integrate existing manufacturing scheduling, planning, analysis and execution systems. This integration facilitates information