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Multi-agent based supply chain modelling with dynamic environment

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Abstract

Supply chain management (SCM) is not always concerned with optimal solutions conventionally in terms of product allocation. Virtual market based supply chain operation solves the product allocation problem by distributing the scheduled resources based on the agent interactions in the market. We formulate supply chain model as a discrete resource allocation problem under dynamic environment, and demonstrate the applicability of the virtual market concept to this framework. The proposed algorithm facilitates sophisticated SCM under dynamic conditions.

Keywords: Supply chain management; Market-oriented programming; Multi-agent; Dynamic utility; Resource allocation; Virtual market

1. Introduction

A supply chain is a network of facilities and distribution options that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers. Supply chains exist in both service and manufacturing organisations, although the complexity of the chain may vary greatly from industry to industry and firm to firm. Realistic supply chains have multiple end products with shared components, facilities and capacities. The flow of materials is not always along an arborescent network, various modes of transportation may be considered, and the bill of materials for the end items may be both deep and large.

Traditionally, marketing, distribution, planning, manufacturing, and the purchasing organisations along the supply chain operated independently. These organisations have their own objectives and these are often conflicting. Marketing's objective of high customer service and maximum sales conflict with manufacturing and distribution goals. Many manufacturing operations are designed to maximise throughput and lower costs with little consideration for the impact on inventory levels and distribution capabilities. Purchasing contracts are often negotiated with very little information beyond historical buying patterns. The result of these factors is that there is not a single, integrated plan for the organisation—there were as many plans as businesses. Clearly, there is a need for a mechanism through which these different functions can be integrated together. Supply chain management (SCM) is a strategy through which such an integration can be achieved (Fisher, 1994).

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SCM is typically viewed to lie between fully vertically integrated firms, where the entire material flow is owned by a single firm, and those where each channel member operates independently. Therefore coordination between the various players in the chain is key in its effective management. SCM, however, is conventionally based on simple theory of constraints (TOC) concept (Goldratt, 1983), and is not always concerned with optimal solutions on resource allocation in such a complicated supply flows.

Market price systems constitute a well-understood class of mechanisms that provide effective decentralisation of decision making with minimal communication overhead. In a market-oriented programming approach to distributed problem solving, the resource allocation for a set of computational agents is derived by computing competitive equilibrium of an artificial economy (Kaihara, 2001). Market mechanism can provide several advantages on resource allocation in SCM as follows:

(i) Markets are naturally distributed and agents make their own decisions about how to bid based on the prices and their own utilities of the goods.
(ii) Communication is limited to the exchange of bids and process between agents and the market mechanism.

In this paper, we formulate agent strategies in supply chain model, based on virtual market (VM) concept with multi-agent, and demonstrate the applicability of economic analysis to this framework by simulation experiments under dynamic environment.

2. VM with multi-agent paradigm

2.1. VM

There exists a market-oriented programming to construct a computational market (virtual market), which consists of several heterogeneous agents (Wellman, 1996). Agent activities in terms of products required and supplied are defined so as to reduce an agent's decision problem to evaluate the tradeoffs of acquiring different products in the market-oriented programming. These tradeoffs are represented in terms of market prices, which define common scale of value across the various products. The problem for designers of computational markets is to specify the mechanism by which agent interactions determine prices (Kaihara, 1999).

In economics, the concept of a set of interrelated goods in balance is called general equilibrium (Okuno et al., 1985). The general equilibrium theory guarantees a Pareto optimal solution at competitive equilibrium in perfect competitive market. The connection between computation and general equilibrium is not all foreign to economists, who often appeal to the metaphor of market systems computing the activities of the agents involved (Shoven and Whalley, 1992). Obviously SCM model is well-structured for market-oriented programming, and that means the proposed concept takes advantage of the theory, and a Pareto optimal solution, which is conducted by microeconomics, is attainable in resource allocation problem in SCM (Kaihara, 2001).

2.2. Market-oriented programming

Market-oriented programming is the general approach of deriving solutions to distributed resource allocation problems by computing the competitive equilibrium of an artificial economy (Wellman, 1996; Kaihara, 1999). It involves an iterative adjustment of prices based on the reactions of the agent in the market. General concept of the negotiation mechanism in market-oriented programming is shown in Fig. 1, and refer to (Kaihara, 2001; Wellman, 1996) about further detailed explanation about the market-oriented programming.

Supply/demand functions represent agent's willingness to sell/buy resources, respectively. They are defined as the relationship between price and quantity of the trading resource. Let $Pt(s)$ be the price of resource s at time t. $\alpha_t ms$ and $\beta_t ns$ represent the supply function of supplier m on resource s at time t and the demand function of