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Supply chain management with market economics

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Abstract

Supply chain management (SCM) is now recognised as one of the best means by which enterprises can make instant improvements to their business strategies and operations. SCM, however, is generally based on the simple theory of constraints (TOC) concept, and is not always concerned with Pareto optimal solutions in product distribution. Since market price systems constitute a well-understood class of mechanisms that under certain conditions provide effective decentralisation of decision making with minimal communication overhead, we propose SCM based on market-oriented programming in this paper. In market-oriented programming, we take a metaphor of economy computing multi-agent behaviour literally, and directly implement the distributed computation as a market price system. We define the agent activities to negotiate the tradeoffs of acquiring different resources, so as to realise the multi-echelon optimisation. Several simulation experiments on the supply chain model with multi-echelon structure clarify the market dynamics that emerge through the agent negotiations. It is confirmed that careful constructions of the decision process according to economic principles can lead to Pareto optimal resource allocations in SCM, and the behaviour of the system can be analysed in economic terms.

Keywords: Supply chain management; Market-oriented programming; Product distribution; Multi-agent paradigm; Distribution system

1. Introduction

During the last few years the focus has shifted from factory level to enterprise level due to the increasing global presence of the companies. Supply chain management (SCM) is now recognised as one of the best means by which enterprises can make instant improvements to their business strategies [1]. Manufacturers and suppliers have to decide if they would like to form close relationships not to have partial solutions. Real benefits can only be attained by sincere commitment from each of the partner to use what is proposed. Sharing of information is central to the optimisation of resource allocation (i.e., product distribution) in the supply chain. SCM is generally based on the simple theory of constraints (TOC) with throughput-based costing method, and conducts effective strategies in the enterprise level by DBR (Drum, Buffer and Lope) concept [2].

The management of physical flow of products amongst the nodes of the supply chain comes under the intensive study of effective operation in SCM. Since supply chains consist of several layers of business units, resource allocation is a quite important operational criterion at workshop level in

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SCM. As the number of potential business units in the supply chain increases, an effective management on product distribution (i.e., multi-echelon optimisation) plays a more important role in dynamic environment. Current SCM concept does not deal with the problem, because TOC does not handle combinatorial optimisation problem in the resource allocation.

Recently the use of multi-agent system in large-sized complex system is increasing [3]. The multi-agent paradigm has several characteristics, such as autonomy, pro-activeness, social ability, and emergence. In this paradigm, a global goal of the whole system is achieved as the aggregation of their local objectives with their negotiation. In supply chain networks, each business unit behaves independently and autonomously with simple goals of achieving local optimum. The situation is quite similar to the distributed decision making mechanism in multi-agent paradigm, and it is natural to model supply chain networks through multi-agent programming. In such an environment, each agent represents the independent business unit with conflicting and competing individual requirements, and may possess localised information relevant to their utilities. To recognise this independence, we treat the business units as agents, allowing each of them to decide autonomously how to deploy resources under their control in service of their interests.

Within this model, a distributed SCM can be analysed according to the following properties:

- Self-interest agents can make effective decisions with local information, without knowing the private information and strategies of other agents.
- The method requires minimal communication overhead.
- Solutions do not waste resources. If there is some way to make some agent better off without harming others, it should be done. A solution that cannot be improved in this way is called Pareto optimal.

Assuming that a resource allocation problem in SCM must be decentralised in considering a practical application, market concept can provide several advantages:

(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 particular settings, it can be shown that price systems minimise the dimensionality of messages required to determine Pareto optimal allocation.
(iii) Since agent must back their representations with exchange offers, some mechanism can elicit the information necessary to achieve Pareto and system optima in some well-categorised situations.

Market-oriented programming is a multi-agent-based concept to facilitate distributed problem solving. In the market-oriented programming, we take the metaphor of an economy computing multi-agent behaviour literally, and directly implement the distributed computation as a market price system. In the market-oriented programming approach to distributed problem solving, the resource allocation for a set of computational agents is derived by computing competitive market of an artificial economy [4–6].

In this paper, we formulate supply chain model as a discrete resource allocation problem with supply/demand agents, and demonstrate the applicability of economic analysis to this framework by simulation experiments. Finally, we prove that the market mechanism can provide several advantages on resource allocation in SCM. Needless to say, the term 'resource allocation' in this paper corresponds to 'product distribution' at workshop level in practical SCM.

2. Market-oriented programming

2.1. Market-based approach

In economics, the concept of a set of interrelated goods in balance is called general equilibrium. The general equilibrium theory guarantees a Pareto optimal solution at competitive equilibrium in perfect