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Goodwill, inventory penalty, and adaptive supply chain management

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ABSTRACT

Information visibility is generally useful for decision makers distributed across supply chains. Availability of information on inventory levels, price, lead times, demand, etc. can help reduce uncertainties as well as alleviate problems associated with bullwhip effect. A majority of extant literature in this area assume a static supply chain network configuration. While this was sufficient a few decades ago, advances in e-commerce and the ease with which order processing can be performed over the Internet necessitates appropriate dynamic (re)configuration of supply chains over time. Each node in the supply chain is modeled as an actor who makes independent decisions based on information gathered from the next level upstream. A knowledge-based framework is used for dynamic supply chain configuration and to consider the effects of inventory constraints and 'goodwill,' as well as their effects on the performance dynamics of supply chains. Preliminary results indicate that neither static nor dynamic configurations are consistently dominant. Scenarios where static configurations perform better than the modeled system are identified.

1. Introduction

Information visibility resulting from advances in information technology as well as the availability of timely data and the willingness of nodes to share such data with other nodes in the network has spurred increased interest in supply chain management. A supply chain ideally facilitates the availability of the right amount of the right product at the right price at the right place with minimal inventory across the network. Information visibility across the supply chain has facilitated reduction of inventory while improving demand forecast through reduction of certain types of uncertainties.

The advent of the Internet and related technologies that enable fast transfer of huge amounts of data have tangibly affected supply chains in how both data and items are moved between nodes in a supply chain network. Such information visibility increases the potential for every node in a supply chain network to make decisions with more relevant and useful information. A side effect of this dynamic is the expanded visible availability of choices of nodes that any node in the supply chain network has, and the ease with which a node can switch among nodes with which it does business. The need to switch among nodes (e.g., suppliers) arises simply because one (or a fixed set of a few) node(s) cannot be optimal under all circumstances due to several reasons (e.g., physical distance, relative order fulfillment urgency, cost, timely availability of needed quantity).

Despite such changes in reality, a majority of extant supply chain literature assume a static supply chain network (e.g. Shao and Ji, 2009). Assuming information transparency (e.g. Agrawal et al., 2009), where all nodes in the supply chain network are willing to share their information, this study incorporates the facility to dynamically switch among nodes in a supply chain network. We use a generic knowledge-based framework to study the dynamics that occur in a supply chain and consider cases where (1) excess inventory is penalized, and (2) presence of 'goodwill' is considered. 'Goodwill' is assumed to accumulate through repeated transactions with the same vendor. Each node in the supply chain is modeled as an independent actor that interacts with other actors in the supply chain since, in the absence of vertical integration, supply chains are generally owned and/or associated with several firms. Moreover, each of these firms has its own goals and objectives and make myopic decisions based on locally available information (e.g. Graves et al., 1993; Lee and Whang, 2000).

A majority of recent work in supply chain configuration involves using multi-agent systems (e.g. Kimbrough et al., 2002; Nagarajan and Sosic, 2008; Strader et al., 1998), heuristics (e.g. Wang, 2009), and/or auctions (Fan et al., 2003) in some form. Each of the players in the supply chain is modeled as an agent who negotiates with its immediate neighbor in pushing/pulling the part or product through the chain. GE has developed a trading process network that allows several suppliers to bid on jobs based on part specifications that are displayed on the Web. SAP's (2002) initiative on adaptive supply chain networks is a step in automating the

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supply chain networks using new technologies including agent-based, RFID, and Web services.

We consider a multi-stage (echelon) supply chain where each actor (node) has learning capability, whereby it learns to use its (local) knowledge to make decisions regarding choice of nodes in the next level with which to interact (i.e., place order). The knowledge-base in these nodes are independently updated as and when necessary to keep them current.

This paper, an extension of Emerson and Piramuthu (2004), addresses the following specific questions with example scenarios modeled incorporating knowledge-based actors (nodes): (1) Does dynamically switching among appropriate nodes in a stage always improve (a) overall revenue, (b) effectively serving the customer based on the percentage of orders fulfilled as desired by the customer? (2) How does 'goodwill' affect performance in these systems? (3) What effect does inventory restrictions and penalty for high as well as low inventory have on performance?

The framework for automating supply chain configuration is discussed in the next section. The dynamics of multi-stage supply chains with and without inventory penalties and the presence/absence of 'goodwill' is illustrated using examples in Section 3. The final section (Section 4) concludes the paper with discussion of results, policy implications, and extensions to this study.

2. Automated supply chain configurer framework

The automated supply chain configurer (ASCC) framework used in this paper is given in Fig. 1. Each node in the supply chain, except the final node upstream, is modeled by this framework. Each node comprises an ASCC, among other functionalities. The nodes in the last stage upstream is assumed to generate the necessary "raw materials" that go into the production of the final product, and are therefore not modeled in this study. Each node in this network act independently in deciding the node one level upstream that they are associated with for any given order. Clearly, for a node at any level till the penultimate level upstream, the node it corresponds (i.e., place an order) with need not be the same for any two consecutive orders.

The decentralized scenario considered is realistic under most circumstances since a centralized control scenario is not natural in this context. A centralized scenario is perhaps realistic in a vertically integrated market mechanism. Given that additivity of profits across levels is assumed, a decentralized scenario is reasonable. Of course, the dynamic may be different under centralized scenario assumptions.

Five components comprise the ASCC framework: sampler, Learning, knowledge-base, performance element, and dispatcher. The sampler component is used to generate samples of input data on the dynamics of the system. These data are used as input to the learning component, which extracts the essence or patterns that are present in data and represents them in the form of decision rules. These decision rules constitute stored knowledge in the system. The knowledge itself are stored in the knowledge-base. The knowledge thus generated are periodically evaluated for "staleness" by the performance element. When the quality of knowledge (i.e., generated and stored decision rules) decreases below a predefined threshold, as measured by the node's performance, knowledge update occurs by generating appropriate new samples and incrementally updating the knowledge-base. The dispatcher is essentially a pattern-matcher as it matches the pattern present in an incoming order to the most appropriate decision rule, which is then instantiated.

We use C5.0 (Quinlan, 2002) in the learning component because of its excellent characteristics including classification performance and knowledge representation in the form of decision rules. C5.0 is a variant of C4.5 and ID3 which were both developed by Quinlan (1987, 1993). The details of these algorithms are not directly relevant to this paper, and are hence omitted. The cited Quinlan

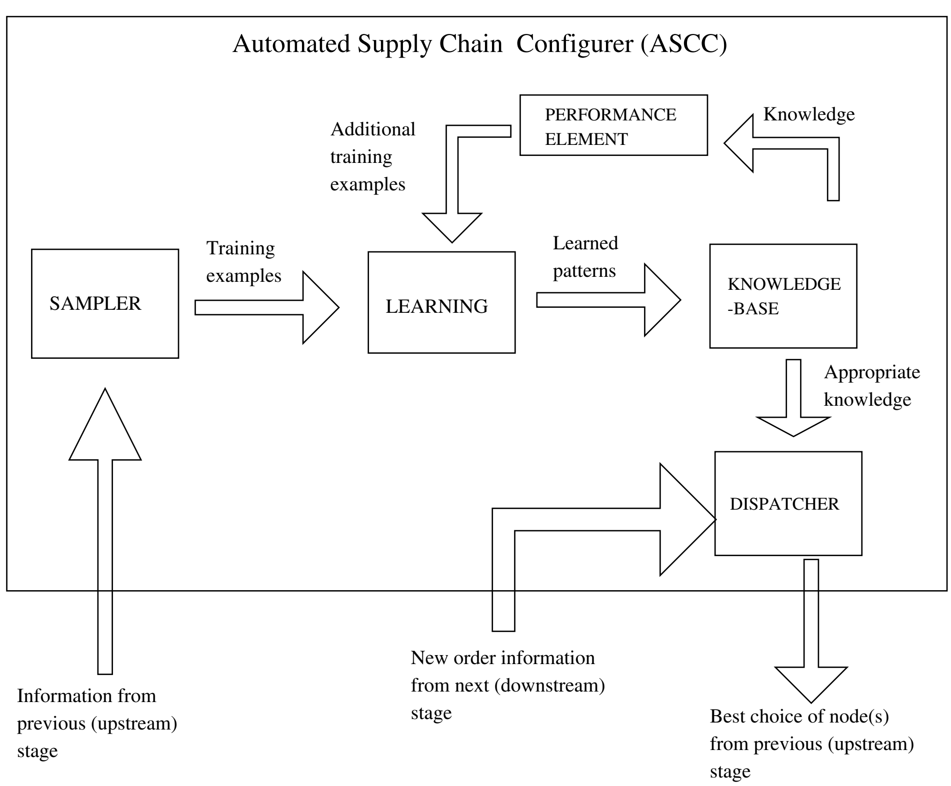

Fig. 1. Automated supply chain configurer (ASCC) framework.