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Abstract

Supply chain management critically affects businesses' abilities to obtain and sustain competitive advantages. The bullwhip effect, however, presents a challenge for successful supply chain management by amplifying demands in the supply chains. This paper presents a systematic approach to tackle the issue of bullwhip effect. Firstly, we define the supply chain under a multiagent framework. Secondly, the group problem solving paradigm, which is a rule learning approach, is proposed to enhance the decision making process within the supply chain framework. The group problem solving paradigm is also suggested as a means to alleviate the bullwhip effect. The paper concludes with a discussion on the possible implication of this research and future research directions.

Introduction

Competition and globalization are changing the paradigm of traditional logistics strategy. A successful logistics strategy has moved from an internal focus emphasizing integration with other enterprise functions (i.e., production and marketing) and linking the various enterprise functions to the overall corporate strategy, to an external focus of integrating supply chains and cycle time compression. Supply chain management directly affects an organization's competitive position. According to Cooke (1993), the Efficient Consumer Response (ECR) estimated a potential $30 billion saving from efficiently streamlining the grocery supply chain. One factor that can impact on the effectiveness of a supply chain is the bullwhip effect (Lee *et al.*, 1997a, 1997b). According to Lee *et al.*, 1997b, "the bullwhip effect refers to the phenomenon where orders to the supplier tend to have larger variance than sales to the buyer (i.e., demand distortion), and the distortion propagates upstream in an amplified form (i.e., variance amplification)". The bullwhip effect has a major negative impact on the performance of the manufacturing function. For instance, Metters (1997) reported that a major manufacturer of chicken noodle soup increased its production by 11% based on the retailers' information in the high demand weeks. However, the company cut back its production by more than 10% in the low demand weeks, due to the overstock position of the retailers.

A number of solutions have been proposed to contain the bullwhip effect. Lee *et al.* (1997a) proposed the vendor-managed inventory (VMI) or a continuous replenishment program (CRP) to counteract the bullwhip effect. Swaminathan *et al.* (1998) used a simulation approach to reduce the uncertainties in supply chains.

This research attempts to tackle the bullwhip effect using artificial intelligence techniques. In this paper, group problem solving (GPS) strategy is suggested as a technique to control the information distortion in supply chains. The research proposes a genetic algorithm (GA) approach to simulate the GPS situation. This research is ongoing and thus, the computational experience of the GPS approach is not reported.

Literature Review

The bullwhip effect is not a new phenomenon and numerous researchers from different academic disciplines have noted it. The first piece of work undertaken to understand the dynamic behavior of simple linear supply chains was carried out by Forrester of MIT (Forrester, 1961). Forrester (1961) presented a practical demonstration of how various types of business policy create disturbance, which were often blamed on conditions outside the system. He stated that random, meaningless sales fluctuations could be converted by the system into apparently annual or seasonal production cycles thus sub-optimizing the use of capacity and generating swings in inventory. A change in demand is amplified as it passes between organizations in the supply chain. Sterman (1989) provided the evidence of the bullwhip in the "Beer Distribution Game," a classroom supply chain experiment. Towill and Naim (1993) further expanded Forrester's work. They explored ways of reducing demand amplification and illustrated the impact of current supply chain strategies such as just-in-time philosophy, vendor integration, and time-based management on reducing the amplification. Contribution to the understanding of the bullwhip phenomenon was also made by a group of economists (e.g., Holt *et al.*, 1960; Blinder 1982). More recently, Lee *et al.* (1997a, 1997b) described and modeled the four causes of the bullwhip effect -- demand signal processing, rationing game, order batching, and price variations. Metters (1997) tried to quantify the bullwhip effect from profitability standpoint.

These remedies proposed in previous research, however, were not systematic approaches to alleviate the bullwhip effect. In this work, we attempt to use artificial intelligence techniques to provide a systematic approach to alleviate the bullwhip effect.

Artificial Intelligence Techniques Proposed

Group Problem Solving

In a GPS system, information (the data set) is divided among the different agents that infer a set of hypotheses based on their individual data subsets. The agents then engage in group interaction based on their individual solutions to reach a consensus on a group solution. Figure 1 depicts the group problem solving paradigm. First, the problem (data set) is decomposed into different subproblems P_1, P_2 • • • P_n , which are then allocated to different inductive learning programs (agents). Each agent solves its subproblem independently from the other agents. The individual solutions are then synthesized into a final solution.

Multiagent supply chain paradigm

Swaminathan (1998) extended the use of knowledge-based multiagent framework to the domain of supply chain management. He proposed a supply chain consisting of different agents (e.g. manufacturer agents, transportation agents, supplier agents, distribution center agents, retailer agents, and end-user agents). Different agents in the multiagent framework communicate with each other through messages.

In the multiagent supply chain paradigm, the downstream supplier agents traditionally obtain the demand information from the agent a step ahead of him/her. This practice resembles the single-agent learning technique in conventional rule learning. The multiagents supply chain paradigm underlines the foundation for successful implementation of the GPS approach. Because supply chain management is fundamentally concerned with coherence among multiple decision makers, a multiagent framework based on explicit communication between constituent agents (such as manufacturers, suppliers, distributors, and customers) is a natural choice. The conventional supply chain model uses a sequential approach in dealing with information flow in supply chains. In this traditional approach, the process itself becomes one of the key sources of the bullwhip effect. A multiagent structure that involves parallel decision making rather than sequential is more apt for addressing the bullwhip effect.

Genetic Algorithms

Genetic algorithms are general-purpose search algorithms that use principles inspired by natural population genetics to evolve solutions to problems (Holland, 1975). The basic idea is that over time, evolution will select the “fittest species.” Applying this idea to supply chain involves optimizing the solutions using genetic operators (i.e., crossover, mutation) to obtain the best solutions. In our approach, the genetic algorithms will be used in the solution phase of the group problem solving approach.

Research Methodology

According to Smith *et al.* (1981), GPS involved four steps -- (1) problem decomposition, (2) subproblem allocation, (3) sub-problem solution, (4) solution synthesis. The bullwhip effect will first be decomposed into different subproblems (Dantzig, 1961). The decomposed problems are then distributed to different agents. Each agent in the supply chain solves its subproblem individually. The independent solutions are then synthesized into a final solution using genetic algorithms. According to Sikora *et al.* (1996), each agent’s solution was an alternative hypothesis suggested by the agent. The final step corresponds to the group decision-making process where every agent proposes a solution and the group deliberates on the strengths and weaknesses of each alternative. Each agent then refines its solution and repeats above process until all the group members reach a consensus.

Figure 1depicts the proposed framework. First, the bullwhip problem is divided into subproblems. Second, the subproblems are disseminated to the relevant players in different layers (Tier II suppliers, Tier I supplies, and Customers) of a supply chain. Third, each player (agent) solves its subproblem independently. Finally, the bullwhip effect is solved by synthesizing the individual solutions.

Research Procedure

Our ongoing research lies in four areas. First, we will gather a data set from the supply chain practice to conduct an empirical analysis. The most likely candidates in our study are consumer electronic and grocery retailing. Second, we will report the computational experience of the GPS method as compared to the traditional single-agent problem solving approach. The aim is to show the advantages of the GPS in dealing with the bullwhip effect in supply chains. Third, an experimental study will be conducted to identify the factors influencing the GPS method. The effect of these factors on the performance of the GPS approach will also be tested. Finally, we will attempt to extend the GPS approach to other business areas such as business process reengineering.

Conclusion and Potential Contribution

One of the major sources of the bullwhip effect in supply chains is the traditional supply chain framework itself. In this research, we propose replacing the traditional supply chain framework (sequential decision making) with the multiagent supply chain framework (parallel decision making).

This study will make contribution in three ways. First, this study presents a new approach for alleviating the bullwhip effect in supply chains. Second, this study enriches the contemporary literature on supply chain by considering the supply chain as a multiagent structure. Third, the multiagent approach provides the practitioners with an alternative tool to reduce the bullwhip effect in their supply chains.

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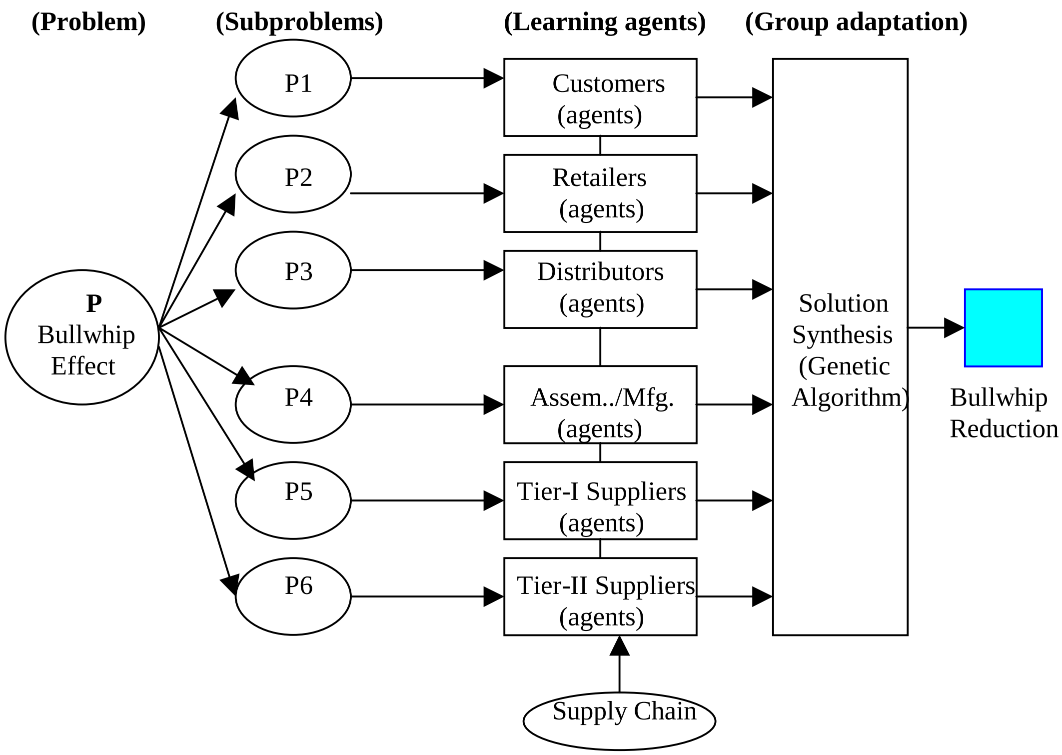

Figure1 Group Problem Solving Approach in Supply Chain Management