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A hybrid of genetic algorithm and particle swarm optimization for solving bi-level linear programming problem – A case study on supply chain model

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ABSTRACT

The main goal of supply chain management is to coordinate and collaborate the supply chain partners seamlessly. On the other hand, bi-level linear programming is a technique for modeling decentralized decision. It consists of the upper level and lower level objectives. Thus, this paper intends to apply bi-level linear programming to supply chain distribution problem and develop an efficient method based on hybrid of genetic algorithm (GA) and particle swarm optimization (PSO). The performance of the proposed method is ascertained by comparing the results with GA and PSO using four problems in the literature and a supply chain distribution model.

1. Introduction

Bi-level linear programming problem (BLPP) has the hierarchical relationship between upper and lower levels. It is developed for decentralized planning systems in which the upper level is termed as the leader and the lower level pertains to the objective of the follower. Thus, many researches applied it to make the best decision with the upper-and-lower hierarchical relationships in the organizations. Thus, the first effort of this study is made to use collaboration function of supply chain systems to obtain the best resources distribution. This can result in reducing production, inventory and distribution costs and increasing the efficiency and the coordination of supply chain partners.

On the other hand, metaheuristics, like genetic algorithm (GA) and particle swarm optimization (PSO), are the generic computational technique espoused from the progression of biological life in the natural humanity [1]. GA is a global optimization algorithm by simulating heredity and process of evolution in environment. It uses three operating process that are selection, crossover and mutation to be survival of the fittest. Additionally, PSO can mimic cooperation between individuals in the same group by using swarm intelligence and exchange experiences from generation to generation [2]. There are some advantages to exploit and explore the hyperspace global optimum with PSO method, especially the fast convergence. Because of the characteristics of GA and PSO, it is feasible to make use of the crossover and mutation of algorithm process into PSO. Moreover, it can effectively integrate the characteristic of global search in GA and the capability of local search in PSO to avoid converging ahead of time and to raise the accuracy of problem solving. Therefore, the second effort of this study is to develop three hybrids of GA and PSO (HGAPSO) for solving BLPP and apply them to the area of supply chain management with pattern of hierarchy.

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Four problems adopted from the literature are employed to validate the proposed methods' feasibility. The results demonstrate that the proposed three hybrid methods are able to provide better performance than GA and PSO. Additionally, this study also employs the three proposed hybrid methods to solve the BLPP for the supply chain. The main purpose is to collaboratively arrange the inventory between distribution centers and manufacturers. The experimental results show that the proposed methods also have better performance than GA and PSO.

The rest of this paper is organized as follows. Section 2 describes basic concept of supply chain management, BLPP, GA and PSO, while the proposed hybrid methods for solving BLPP are explained in Section 3. Sections 4 and 5 make a thorough discussion on computational experiences for four problems from literature and supply chain distribution model, respectively. Finally, the concluding remarks are made in Section 6.

2. Background

This section will provide general backgrounds regarding supply chain management, bi-level linear programming problem, genetic algorithm, particle swarm optimization and integration of genetic algorithm and particle swarm optimization.

2.1. Supply chain management and distribution management

Supply chain management (SCM) is defined as a set of approaches used to efficiently integrate suppliers, manufacturers, warehouses, and stores so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time in order to minimize system-wide costs while satisfying service-level requirements [3]. SCM is widely used by companies to improve their responsiveness to changing market requirements. SCM encompasses the planning and management of all activities involved in sourcing, procurement, conversion, and logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, SCM integrates supply and demand management within and across companies.

Distribution management in supply chain is the process of getting goods or services from their source to the end user. Academically speaking, a channel distribution is a set of people that perform all the functions necessary to move a product or service from its producer or provider to customers and prospective clients. Distribution management encompasses the fields of marketing, operations, management, sales, logistics and distribution.

2.2. Bi-level linear programming problem (BLPP)

Bi-level linear programming problem (BLPP) is a special case of multi-level linear programming problem which is based on the decomposition principle for linear programs [4]. BLPP assumes that the higher-level decision-maker has control over X and lower-level decision-maker has control over Y. Then, we have $x \in X \subset R^n$, $y \in Y \subset R^m$ and $F: X \times Y \to R^1$. The BLPP can be stated as follows:

$$\mathrm{P}_1: \quad \min_{x \in X} \quad F(x,y) = c_1 x + d_1 y \tag{1}$$

$$\mathrm{P}_2: \quad \min_{y \in Y} \quad f(x,y) = c_2 x + d_2 y \tag{2}$$

$$\text{s.t.} \quad A_2 x + B_2 y \leqslant b, \tag{3}$$

where c_1, $c_2 \in R^n$, d_1, $d_2 \in R^m$, $b \in R^p$, $A \in R^{p\times n}$, $B \in R^{p\times m}$. P_1 and P_2 are the higher-level decision-maker and lower-level decision-maker, respectively. Based on the practical applications, there may be some extra limitations for x and y. These are the model constraints. For examples, the limitations of integers or the limitations of upper and lower bound. For solving this problem, once the leader has chosen an x, the x of the follower's objective function has become a constant. Therefore, the objective function of follower can be simplified to $\min_{y\in Y} f(y) = d_2 y$.

Wen and Hsu [5] have treated the way for finding the efficient compromise solution at the situation of non-degeneracy. It implies when solving the BLPP and the solution is non-Pareto optimal, the efficient compromise solution can be found according as the advice of the authors. The upper level decision maker can retain the original rewards, and the lower one can get the extra profits. Shih [6] advanced that it cannot assure that BLPP could get the Pareto-optimal or the efficient solution only when the objectives of both levels are the same. In other words, it may get the Pareto-optimal when they cooperate absolutely with each other.

There have been different methods for solving BLPP, like methods based on vertex enumeration, methods based on Kuhn–Tucker conditions, fuzzy approach [7], and methods based on metaheuristics [8]. Next, the methods based on metaheuristics will be discussed more detailed. Mathieu et al. [9] proposed a GA-based bi-level programming algorithm (GABBA) for solving BLPP. Hejazi et al. presented a GA-based method for BLPP. The results are compared with those of Gendreau et al. method [10]. Oduguwa and Roy [11] developed a bi-level GA, which is an elitist optimization algorithm developed to encourage limited asymmetric cooperation between the two players, to solve different classes of the BLPPs within a single framework. Yin proposed another GA-based approach for solving two BLPPs, road pricing and reserve capacity of signal-controlled road network. Wang et al. [12] proposed an evolutionary algorithm for solving nonlinear bi-level programming problem. Recently,