Cuckoo search algorithm for multi-objective supply chain problem

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Abstract. A meta-heuristic algorithm called, the cuckoo search algorithm is proposed in dealing with the multi-objective supply chain model to find the optimum configuration of a given supply chain problem which minimizes the total cost and the total lead-time. The supply chain problem utilized in this study is taken from literature to show the performance of the proposed model; in addition, the results have been compared to those achieved by the bee colony optimization algorithm and genetic algorithm. Those obtained results indicate that the proposed cuckoo search algorithm is able to get better Pareto solutions (non-dominated set) for the supply chain problem.

1 Introduction

Nowadays, the complexity of the business environment is rapidly increasing due to several factors such as the expansion of the market, a wide range of suppliers, increased competition and customers demands on the performance of a companies that requires to continuously evaluate, configure their Supply Chains (SCs) and provide customers with high-quality products/ services at the lowest cost within the shortest time.

According to this work, minimization the total cost (TC) and delivery lead time (TLT) are considered the two main objectives for multi-objective supply chain problem. However many researchers use various objectives for multi-objective supply chain problem such as minimize total cost, minimize lead time, minimize environmental impact, maximize profit, maximize service level, etc. There are different types of optimization techniques developed and improved for solving multi-objective optimization (MOO) problems. Donoso and Fabregat[1] classify optimization methods for MOO into two classes, i.e., Classical and meta-heuristic methods.

Classical techniques deal with MOO as a single objective problem, i.e., optimize the most significant objective and transform other objectives as constraints or aggregate objective functions. There are several classical methods such as goal programming, weighted sum, ϵ -constraint, etc.

Meta-heuristic is utilized to obtain the optimal value or the set of optimal values for the single-objective case or the multi-objective case respectively[1]. There are some meta-

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heuristic methods that used to solve MOO for supply chain cases such as evolutionary algorithms, bee colony algorithm, ant colony algorithm, etc.

Bhattacharya and Bandyopadhyay[2] presented NSGA II[3] to choose facility location for achieving two contradictory objectives. Also, there are several types of research applied NSGA II to solve MOO for supply chain[4-17].

Mastrocinque et al.[18] used bees algorithm for supply chain network with multi-delivery destinations and multi-products to decrease TC and TLT. Yuce et al. [19] improved Bees Algorithm to reduce TLT and TC and find the optimal solution for the given supply chain problem.

There are many studies concerning on MOO applied Ant Colony Optimization(ACO) algorithm for SC problem with different configurations and frameworks. Zhao et al.[20] applied ACO algorithm for optimization SC design with a different business environment, and different customer demands to reduce total cost and total lead-times. Monkayo Martinez and Zhang [21] developed SC for a family of the product containing a complex hierarchy of sub-assemblies and components to satisfy two objectives (cost and time). Monkayo Martinez and Chang[22] designed SC to provide a satisfactory level of service to customers with minimizing total cost of SC.

2 Multi-objective supply chain design case study

In this paper, the multi-objective supply chain problem obtained from interesting the optimal choice of resource options which minimize TC and TLT[23].

The given supply chain formed of M activities. Each activity achieved by a various number of resource options (M_i), and each resource option had its cost (C_{ij}) and processing lead-time (T_{ij}).

Equation (1) represents the cumulative lead-time (LT_i) at each activity which, is the sum of the processing lead-time and the maximum delivery lead-time.

$$LT_i = \sum_{j=1}^{M_i} T_{ij} X_{ij} + \max_{a_k \in S_i} (LT_k) \quad (1)$$

Since there is no preceding input, the second term of Equation (1) will be zero for the sourcing activities.

$$X_{ij} = \begin{cases} 1 & \text{if } j \text{ is selected} \\ 0 & \text{otherwise} \end{cases} \quad \text{for } i \in M \quad (2)$$

$$\sum_{j=1}^{M_i} X_{ij} = 1 \quad \text{for } i \in M \quad (3)$$

The cumulative lead-time will be LT_{a_d} for delivery of a product to its destination at activity each a_d .

Equation (4) represented the maximum lead-time amongst delivery nodes

$$TLT = \max_{a_d \in D} LT_{a_d} \quad (4)$$

The total supply chain cost expressed by Equation (5):

$$TC = \omega \sum_{i=1}^M \left(\mu_i \sum_{j=1}^{M_i} C_{ij} X_{ij} \right) \quad (5)$$

where μ_i is the average demand per unit time at the activity i and ω denote the period of interest depending on the unit time.

3 Cuckoo search algorithm for multi-objective supply chain problem

Almost all modern meta-heuristics(MH) algorithms have two main components of exploration and exploitation. It used a certain trade-off of randomization and local search. Evolutionary computation-based MH algorithms successfully applied to hard optimization problems. In research area, one of the newest algorithms is a Cuckoo search (CS)[24-26]which solved general N-dimensional, linear and nonlinear optimization problems. Ever since its foundation in 2009, CS algorithm drew the attention of many researchers all over the world.

The important advantage of this algorithm is simplicity, compared with other population-based algorithms such as PSO, GA and other popular algorithms[26]. There is only a single parameter for CS (apart from the population size n). Therefore, it is easy to understand, implement, apply and require simple mathematical pre-processing.

Xin-She Yang and Suash Deb [25, 26] developed Cuckoo search algorithm (CS) which enhanced by Lévy flights instead of simple random walks. They got the idea from brood parasitism of some cuckoos. Cuckoos have a beautiful sound, however, their aggressive reproduction strategy through removing others' eggs in the nest of other host birds then lay their eggs so increase the hatching probability.

4 Results

Extended simulation presented experiments for evaluating the proposed algorithm performance. A case study utilized to evaluate the proposed algorithm effectiveness, feasibility and compare its performance with genetic algorithm and the bee colony algorithm through the experimental framework.

Simulation experiment applied for testing the algorithm performance using MATLAB programming tool for a multi-objective supply chain case study by personal computer Pentium(R) Dual-Core CPU T4440 @ 2.20GHz, 2 GB of RAM.

Figure 1 represents the ideal solution for the first objective function(Minimum value for Total Cost) and the second objective function(Minimum value for Total Lead Time)that generated by Cuckoo search algorithm after a number of iterations equal to 100.

Fig. 1. Minimum value for Total Cost and Total lead time by Cuckoo search algorithm.

A genetic algorithm one of the most important heuristic algorithms. Initially, the collection of solutions (population) generated randomly and at each iteration, a new generation of solutions formed by applying genetic operators (crossover, mutation, selection). Each solution evaluated using an objective function called a fitness function and this process is repeated until some forms of convergence in fitness is achieved.

Figure 2 presented the dominated and non-dominated solutions for multi-objective supply chain problem which generated by a genetic algorithm with maximum iterations

equal to 100 in addition to crossover probability and mutation probability equal to 0.64 and 0.1 respectively. The red points represented the set of non-dominated solutions for two objectives (Total Cost, Total lead Time). The blue star points are the set of dominated solutions.

Figure 3 presented the dominated and non-dominated solutions for multi-objective supply chain problem which generated by Bee colony algorithm with maximum iterations equal to 100. There are some parameters for this algorithm such as the number of Scout Bee, number of selected positions, number of selected elite positions, number of recruited bees for selected positions and number of recruited bees for elite positions equal to 20,10,4,4 and 8 respectively. The red square points represented the set of non-dominated solutions for two objectives (Total Cost, Total lead Time) in addition to the blue star points are the set of dominated solutions.

Fig. 2. Non-dominated solutions F1 by GA algorithm.

Fig. 3. Non-dominated solutions F1 by Bee algorithm.

Figure 4 presented the dominated and non-dominated solutions for multi-objective supply chain problem which generated by cuckoo search algorithm with maximum iterations equal to 100. There is one parameter for cuckoo search algorithm which the nests are discovered with a probability (pa) equal to 0.25. The red circle points represented the set of non-dominated solutions for two objectives (Total Cost, Total lead Time) and the blue plus points are the set of dominated solutions.

Figure 5 presented the non-dominated solutions for multi-objective supply chain problem which generated by cuckoo search algorithm, bee colony algorithm and genetic algorithm with maximum iterations equal to 100. The black circle points represented the set of non-dominated solutions created by cuckoo search algorithm, the blue square points are the set of non-dominated solutions created by genetic algorithm and the red points represent the set of non-dominated solutions created by bee colony algorithm. From this Figure, the set of solutions which generated by cuckoo search algorithm dominates the two set of solutions generated by other algorithms.

Fig. 4. Non-dominated solutions F1 by Cuckoo search algorithm.

Fig. 5. Non-dominated solutions by three algorithms(GA, Bee and Cuckoo search algorithm).

5 Conclusion

This paper proposed and applied Cuckoo search algorithm to solve multi-objective supply chain problem. This problem deals with the resource options selection for a multi-product and multi-delivery supply chain to minimize the total cost and total lead-time of the network. The results showed the efficiency of the proposed algorithm. The Pareto solutions of the proposed algorithm have been compared with those obtained by a bee colony algorithm and genetic algorithm. So that the cuckoo search algorithm is the more powerful tool for finding better Pareto solutions (non-dominated set) for supply chain problems.

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