

Multi-objective Optimization of Supply Chain Problem Based NSGA-II-Cuckoo Search Algorithm

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Abstract. A hybrid Cuckoo search algorithm and NSGA-II algorithm called NSGA-II-Cuckoo is proposed and applied to find a set of non-dominated solutions for multi-objective supply chain problem. In NSGA-II-Cuckoo, the cuckoo search algorithm is applied to generate the initial population that considers as a good start for another algorithm to reduce the time, avoids the local optima entrapment so its effect on the accuracy of the final solutions obtained by the NSGA-II algorithm. The presented results clarify the enhanced performance for the NSGA-II-Cuckoo algorithm, which provides a sufficient stability and robustness for solving multi-objective supply chain problem.

1. Introduction

The optimization is a critical requirement in the world with a wide range of applications, the problem in these requirements is how to achieve many objectives under complex constraints in short time, by maximizing or minimizing desired and the undesired parameters that involved in the problem. However, with the increase of complexity in the economic world, due to several factors such as the expansion of the market, 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, the multi-objective optimization has become a wide area of research interest.

Meta-heuristic algorithms can be defined as a useful tool that can be used to solve specific optimization problems [1]. The developed metaheuristic algorithms have three main purposes: solving problems faster, solving large problems, and obtaining robust algorithms [2]. There are many metaheuristic algorithms has proposed for solving multi-objective optimization problems like multi-objective genetic algorithm (MOGA), strength Pareto evolutionary algorithm (SPEA), Pareto-archived evolution strategy (PAES), etc. NSGA-II is a well-known, fast sorting and elite multi-objective genetic algorithm which proposed by [3] in 2002. However, the new metaheuristic search algorithm is cuckoo search (CS) which proposed by Yang and Deb [4] in 2009.

Over the past a few years various researchers have used meta-heuristic techniques to solve multi-objective optimization for supply chain cases. Bhattacharya and Bandyopadhyay (2010) [5] presented NSGA II [3] to choose facility location for achieving two contradictory objectives. Also, there are several researches applied NSGA II to solve multi-objective optimization for supply chain [6, 7]. Mastrocinque et al. [8] used bees algorithm for supply chain network with multi-delivery destinations and multi-products to decrease lead-time and total cost. Yuce et al. [9] improved Bees Algorithm to



reduce the total lead-time and total cost and find the optimal solution for the given supply chain problem.

There are many studies concerning on multi-objective optimization applied Ant Colony Optimization (ACO) algorithm for SC problem with different configurations and frameworks. Zhao et al. [10] 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 [11] 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 [12] designed SC to provide a satisfactory level of service to customers with minimizing total cost of SC. Xin-She Yang and Suash Deb[13] developed Cuckoo search algorithm (CS) which enhanced by Lévy flights [14] 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 to lay their eggs so increase the hatching probability.

In this article, the power of the proposed algorithm is increased through integrating the Cuckoo search algorithm and NSGAII algorithm to develop a hybrid algorithm for a multi-objective supply chain to achieve speed up convergence of the heuristic algorithms. We tested this algorithm by comparing it with the other algorithms like Bee (bee colony algorithm) and GA(Genetic Algorithms), and the solutions obtained for the proposed algorithm is better than the other algorithms like Bee and GA. These algorithms are applied to Engineering Optimization.

The remainder of this article is organized as follows. Section 2 presents a case study of Multi-objective optimization for supply chain design. After that, Section 3 presents Hybrid NSGA-II-Cuckoo search algorithm followed by Section 4, which describes Results and discussion. Section 5 provides the summary and conclusions.

2. Multi-objective optimization of supply chain design

In this paper, the multi-objective supply chain problem, obtained from[11] that interests the optimal choice of resource options to minimize TC and TLT.

In this study, the given supply chain is formed of M activities. Each activity i can be achieved by a various number of resource options (M_i), and each resource option j has its cost (C_{ij}) and processing lead-time (T_{ij}).

The cumulative lead-time (LT_i) at activity i denoted by Equation (1), is the sum of the processing lead-time of the activity and the maximum delivery lead-time for the set of activities S_i that input to activity i .

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

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

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

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

The cumulative lead-time at the activity a_d will be the LT_{a_d} for delivery of a product to its destination. The maximum lead-time amongst delivery nodes represented by Equation (4) which is used in this work:

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

The total supply chain cost can be 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 denotes the period of interest depending on the unit time.

3. Hybrid NSGA-II-Cuckoo search algorithm

Heuristic and meta-heuristic algorithms is widely used for solving multi-objective supply chain problem because of their significant advantages, but long computational time is the common drawback of these methods, especially when the solution space is hard to discover. The newest meta-heuristic algorithms is a Cuckoo search (CS) algorithm proposed in 2009 by Yang and Deb[4], it is very easy to understand, implement, apply and requires simple mathematical pre-processing. Comparing with other population based algorithms such as PSO, GA and other popular algorithms[15], which can solve general N-dimensional, linear and nonlinear optimization problems. Cuckoo search algorithm introduced to solve multi-objective supply chain problem[16], compared it with genetic algorithm and bee colony algorithm, and obtain better Pareto solutions (non-dominated set) for the supply chain problem.

Many efforts have been already done to speed up convergence of the heuristic algorithms. Most of these works are concentrated on improving selection, mutation and crossover operators and adaptive controlling of parameter settings. However, the initial population has a vital role in evolutionary algorithms, for example, NSGA-II algorithm, where affects the quality and the accuracy of the final result and also the convergence speed, because it helps to reduce the time of those algorithms needs to reach an optimal result. Therefore, we create a hybrid NSGA-II-Cuckoo search algorithm for solving the multi-objective supply chain problem to generate the set of non-dominated solutions. So in this work, we utilized cuckoo search algorithm described in [13,15] to find fast, high-quality initial solutions that used as initial population for the NSGA-II algorithm in order to provide fast convergence to the set of non-dominated solutions with less number of iterations which reduce the algorithm overall execution time. In the following, we present a pseudo-code, which presented that solving multi-objective supply chain problem by the NSGA-II algorithm with initial population created by the cuckoo search algorithm. See all details in Figure 1.

4. Results and discussion

The non-dominated solutions for multi-objective supply chain problem which generated by cuckoo search algorithm, bee colony algorithm, genetic algorithm and NSGA-II with maximum iterations equal to 100, the used parameters are duplicated in table 1, are presented in the figures 2-4. The black circle, Black Square, red star, and blue points respectively represent the set of non-dominated solutions created by cuckoo search algorithm, bee colony algorithm, NSGA-II algorithm and genetic algorithm.

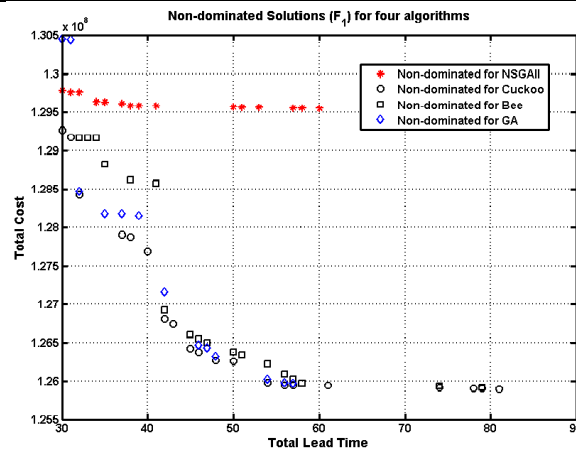
From the Figure 2, we observe that the set of solutions which generated by cuckoo search algorithm dominates the three sets of solutions generated by other algorithms. Also, the set of solutions which generated by the NSGA-II algorithm is dominated by the three sets of solutions generated by other algorithms because of the NSGA-II algorithm, in this case, start with random initial population. So that, the initial population has a worse effect on the quality of the final result and the convergence speed.

Procedure of hybrid NSGA-II-Cuckoo search algorithm is presented as follow:	
1:	Create an initial population P0 of size N by Cuckoo search algorithm
2:	Set t =0.
3:	Apply genetic operators on P0 to create new population Q ₀ of size N
4:	While stop criteria is not satisfied
5:	Apply genetic operators on P _t to create new population Q _t of size N
6:	Create R _t = P _t ∪ Q _t .
7:	Rank all individuals in R _t and identify the non-dominated fronts F ₁ , F ₂ , ..., F _R

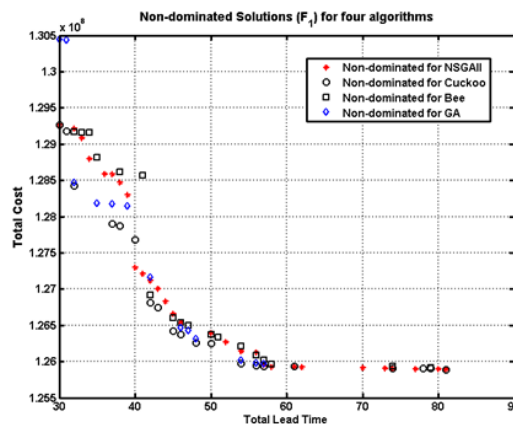
8:	by fast non-dominated sorting algorithm.
9:	For each objective function k , sort the solutions in F_j in the ascending order.
10:	Let $l = F_j $, Assign $cd_k(x_{[l,k]}) = \infty$ for $i = 1, 2, \dots, l - 1$.
11:	Calculate crowding distance for each objective function $cd_k(x)$
13:	Calculate the total crowding distance $cd(x) = \sum_k cd_k(x)$ of a solution x .
14:	End
15:	Stop and return Pt.

Figure 1. Pseudo code of NSGA-II -Cuckoo search algorithm.**Table 1.** Used parameters for GA, NSGA-II, Bee colony, Cuckoo search algorithms

GA/NSGA-II		Bee colony				Cuckoo
Crossover rate	Mutation rate	N of scout Bee	N of selected positions	N of selected elite positions	N of recruited Bees	Probability (pa)
0.64	0.1	20	10	4	4	0.25

**Figure 2.** Non-dominated solutions by three algorithms and NSGA-II with the random initial population.

From the Figure 3, the set of solutions which generated by cuckoo search algorithm dominates the three sets of solutions generated by other algorithms. The initial population which contains the ideal solution for each objective function has a significant effect on improving the set of solutions which generated by the NSGA-II algorithm. Therefore, NSGA-II algorithm results better than bee colony algorithm.

**Figure 3.** Non-dominated solutions by three algorithms and NSGA-II with improve initial population.

From Figure 4, the set of solutions which generated by NSGA-II-Cuckoo search algorithm dominates the three sets of solutions generated by other algorithms. The initial population which created by cuckoo search algorithm has the best effect on the quality of the final result and the convergence speed. Therefore, NSGA-II-Cuckoo search algorithm results better than other algorithms.

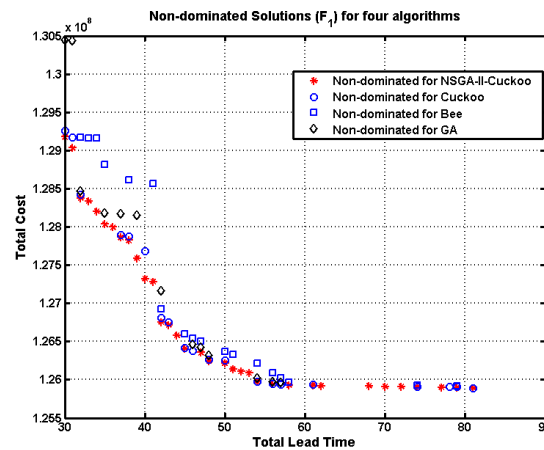


Figure 4. Non-dominated solutions by three algorithms and NSGA-II-Cuckoo search algorithm.

5. Conclusion

This paper presented the integration of the Cuckoo search algorithm and NSGA-II, which called NSGA-II-Cuckoo to solve multi-objective supply chain problem and comparing it with a genetic algorithm, bee colony algorithm, and cuckoo search algorithm. We applied it to find set of non-dominated solutions for multi-objective supply chain problem. In NSGA-II-Cuckoo, we applied the cuckoo search algorithm to generate the initial population that considers as a good start for another algorithm to reduce the time and avoids the local optima entrapment. Also, its effect on the accuracy of the final solutions obtained by the NSGA-II algorithm. The presented results clarify the enhanced performance for the NSGA-II-Cuckoo algorithm, which introduced sufficient stability, and robustness for solving multi-objective supply chain problem.

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