International Journal of Applied Metaheuristic Computing
Volume 15 • Issue 1 • January-December 2024

An Artificial Bee Colony Algorithm for the Multidimensional Knapsack Problem:
Using Design of Experiments for Parameter Tuning

Niusha Yaghini
Iran University of Science and Technology, Iran

Mir Yasin Seyed Valizadeh
Iran University of Science and Technology, Iran

ABSTRACT

The Multidimensional Knapsack Problem (MDKP) stands as a prominent challenge in combinatorial optimization, with diverse applications across various domains. The Artificial Bee Colony (ABC) algorithm is a swarm intelligence optimization algorithm inspired by the foraging behavior of bees. The aim of this paper is to develop an ABC with the goal of improving the solution quality in comparison to previous studies for the MDKP. In the proposed ABC algorithm, a heuristic method is presented to make employed bees. The roulette wheel and k-tournament methods are investigated for selecting employed bees by onlooker bees. For crossing over, two methods including one-point and uniform are studied. To tune the parameters, the Design of Experiment (DOE) method has been applied. The well-known benchmark test problems have been used to evaluate the proposed algorithm. The results show the absolute superiority of the solutions generated by the proposed algorithm in compared with the previous studies.

KEYWORDS

The Multidimensional Knapsack Problem, The Artificial Bee Colony Algorithm, The Design of Experiments, Metaheuristics

1. INTRODUCTION

The Multidimensional Knapsack Problem (MDKP) is an extension of the classic knapsack problem, where instead of a single constraint, there are multiple constraints to consider. Each item has multiple attributes or dimensions, and the goal is to maximize the total value of the items selected while staying within the constraints for each dimension. The MDKP is recognized as an NP-Hard integer programming problem (1). The problem can be mathematically defined as equations (1)-(3).

$$\max z = \sum_{j=1}^{n} c_j x_j, \tag{1}$$

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i, \quad i \in M = \{1,2,\ldots,m\}, \tag{2}$$

DOI: 10.4018/IJAMC.350225

$$x_j \in \{0,1\}, \ j \in N = \left\{1,2,\ldots,n\right\} \quad . \tag{3}$$

In Kellerer et al. (2004) study, a set of items n with profits $c_j \geq 0$ needs to be packed into a knapsack with m dimensions, each having capacities $b_i \geq 0$. Each item j consumes $a_{ij} \geq 0$ from each dimension i and binary variables x_j determine the selection of items to maximize overall profit while adhering to knapsack constraints.

The MDKP is significant because it can represent a variety of real-world applications including resource allocation, intelligent transportation systems, logistics, Quality of Service (QoS), web service composition, energy-efficient offloading in mobile edge computing, medicine, budgeting problems, hardware design, and cloud computing. As a highly complex multi-constraint Combinatorial Optimization Problem (COP) with binary decision variables, and extensive research has been dedicated to the MDKP (Mkaouar et al., 2020).

Solving the MDKP is generally more complex than the classic knapsack problem due to the additional dimensionality. The most effective exact algorithms primarily utilize the branch-and-bound method. However, as the size of the MDKP increases, the time required for the branch-and-bound method grows exponentially, making it inefficient for large-scale MDKP instances. This inefficiency is a common drawback of exact algorithms. Various algorithms, such as dynamic programming, greedy algorithms, and metaheuristics can be adapted or extended to address the multidimensional version. Solving the MDKP is considered as a challenge in the field of optimization discussions (Chu & Beasley, 1998).

The ABC algorithm is a swarm intelligence optimization algorithm inspired by the foraging behavior of bees. ABC is widely used for solving optimization problems. ABC has been widely applied in various fields such as engineering design, data mining, and machine learning, due to its simplicity and ability to find high-quality solutions efficiently. Its versatility and effectiveness make it a popular choice for addressing diverse optimization challenges (Karaboga & Basturk, 2007).

The ABC algorithm is widely used due to its simplicity and high efficiency in various fields such as transportation, communications, engineering design, data mining, and machine learning. In transportation, ABC optimizes transportation routes and reduces associated costs (Karaboga et al., 2007). In communications, it optimizes resource allocation and manages wireless networks (Karaboga & Ozturk, 2011). In engineering design, ABC solves complex design and optimization problems (Akay & Karaboga, 2012). In data mining and machine learning, it is used for feature selection, clustering, and parameter optimization of machine learning models (Karaboga & Basturk, 2008). In distributed computing, ABC optimizes resource allocation and load management (Gao et al., 2012).

The aim of this article is to develop a metaheuristic algorithm with the goal of improving the solution quality in comparison to the published sources in literature. In this study, the Beasley (2017) dataset has been employed for the implementation of the proposed algorithm. A total of 30 problems, each comprising 100 items and 5 knapsacks, has been selected for evaluating the performance of the proposed algorithm. The contributions presented in this article can be summarized as follows:

(1) designing an Artificial Bee Colony (ABC) algorithm for MDKP,
(2) developing a heuristic method to make employed bees (solutions),
(3) investigating the roulette wheel and *k*-tournament methods for selecting employed bees by onlooker bees,
(4) evaluation of two uniform and one-point crossover methods,
(5) applying the Design of Experiments (DOE) method for parameter tuning,
(6) improving the quality of solutions in comparison with the previous studies.

Hybrid Swarm Intelligence-Based Biclustering Approach for Recommendation of Web Pages

R. Rathipriyaand K. Thangavel (2015). *Emerging Research on Swarm Intelligence and Algorithm Optimization (pp. 161-180).*

www.irma-international.org/chapter/hybrid-swarm-intelligence-based-biclustering-approach-for-recommendation-of-web-pages/115303