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On solving the double loading problem using a modified particle swarm optimization

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A B S T R A C T

We consider in this paper a double loading problem (DLP), an NP-hard optimization problem of extreme economic relevance in industrial areas. The problem consists in loading items into bins, then stowing bins in a set of compartments. The main objective is to minimize the number of used bins. We state the mathematical model as well as a modified binary particle swarm optimization with FFD initialization that outperforms state-of-the-art approaches carried out on a large testbed instances.

1. Introduction

In the manufacturing and distribution industries the efficient use of transportation devices is of extreme relevance. A high utilization of the transportation capacities offers a significant cost saving as well as a protection of natural resources. During the last decades packing problems have received a great deal of attention due to the wide number of related practical applications as the bin ship loading [26], the plane cargo management [4] and the transportation planning [28].

The modeling of different practical problems of the optimal employment of transportation devices brings to life numerous variants of packing problems. The compartmentalized Knapsack Problem (CKP), a packing problem version introduced by Hoto et al. [7], splits the packing into two main steps: *clustering* and *compartmentalized packing* of items. In spite of the importance of the problem, few studies have dealt with it. Malthouse et al. [18] applied the CKP in the marketing area to select media vehicles for marketing campaigns then, to determine the depth of purchase from each vehicle. Leão et al. [16] and Marques and Arenales [5] proposed different mathematical formulations to handle the constrained CKP.

Numerous metaheuristics were adopted to solve such relevant class of NP-hard problems. More recently, swarm intelligence-based methods have attract more consideration, e.g., Particle Swarm Optimization (PSO) [8], Artificial Bee Colony (ABC) [24] and Ant Colony Optimization (ACO) [23]. Due to the simplicity and robustness of the PSO, it has increasingly gained popularity.

Specifically, the Particle swarm optimization (PSO) is a bio-inspired method developed by Kennedy and Eberhart [13] to handle combinatorial optimization problems. It is a population-based evolutionary algorithm simulating the social behavior of bird flocking. A lot of emphasis has been laid on enhancing the conventional PSO to yield a computationally efficient algorithm. In view of the shortcomings of the conventional PSO algorithm, numerous variants have been proposed. Luan

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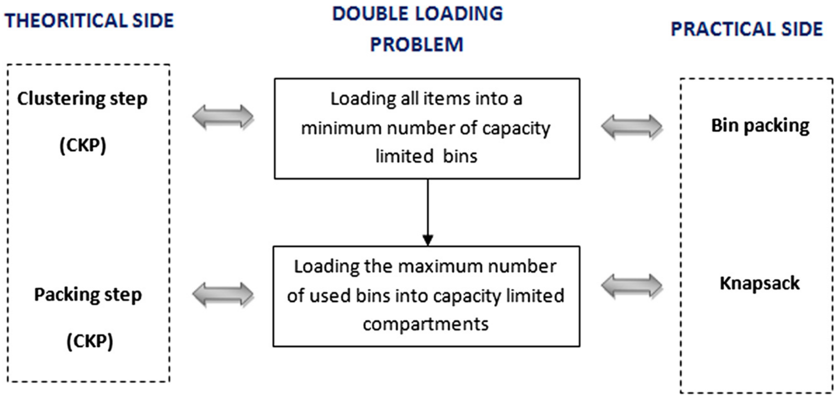

Fig. 1. DLP definition.

et al. [17] introduced the Robust Particle swarm Optimization (RPSO), in which an optimal solution tolerates the small perturbation on solving robust optimization problems. Chen et al. [3] proposed a Set-Based Particle Swarm Optimization (S-PSO) that defines the position and velocity using the concept of set and possibility. Modiri and Kiasaleh [20] suggested a modification of the velocity by either omitting the personal best coefficient or changing the initial velocity. This PSO variant were shown to give better results for benchmark mathematical optimizations.

In this paper, we investigate a variant of the CKP named the double loading problem (DLP). Theoretically spoken, in the DLP, *clustering* step corresponds to regrouping and packing items into bins while respecting the bin's capacity. The *compartmentalized packing* step refers to packing used bins into capacity limited compartments. In practice, the DLP, can also be viewed as a two-step problem: the bin packing problem and the knapsack problem.

We develop, as a solution approach, a modified variant of the PSO proposed by Modiri and Kiasaleh [20] based on changing the velocity for a fast convergence to best solutions. Since no DLP benchmark is available, first, we test the performance of the proposed method on the first step (bin packing). Second, we generate some classes, inspired by the bin packing instances, to test the entire DLP.

The present paper is organized as follows: Section 2 describes in details the DLP. In Section 3, a mathematical model is stated. Section 4 is a basic version statement of the PSO metaheuristic. The adapted new approach MBPSO is denoted in Section 5, we also present the solution encoding and the evaluation standards in this same section. Experimental investigations are drawn in Section 6 where a set of tests are carried out to measure the efficiency of MBPSO method and a dataset of Benchmark instances are performed to carry on a comparison between our results and some other heuristics from the literature.

2. Problem statement

We are specifically concerned with the DLP, where the number of used bins is to be minimized and system constraints are to be satisfied. The DLP is also considered as a two-step optimization model expressed by a combination of a bin packing subproblem and a knapsack subproblem. The bin packing concerns the step of items loading into bins and the knapsack consists on stowing a maximum number of used bins in compartments of a mean of transport or a pallet. Fig. 1 explains clearly the DLP showing the theoretical and the practical sides of the problem.

The main objective of the DLP is to minimize the number of used bins while respecting the bin's capacity and the compartment's capacity.

3. Mathematical formulation

3.1. Sets and notation

N	The total number of items to be packed
M	The total number of bins available
P	The total number of compartments
w_i	The weight of item i
v_i	The volume of item i
C_j	The maximum capacity of bin j
V_j	The volume of bin j
T_k	The maximum capacity of compartment k