Hindawi
Mathematical Problems in Engineering
Volume 2021, Article ID 2864607, 17 pages
https://doi.org/10.1155/2021/2864607

Research Article

Different Transfer Functions for Binary Particle Swarm Optimization with a New Encoding Scheme for Discounted {0-1} Knapsack Problem

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Received 27 June 2020; Revised 8 April 2021; Accepted 9 April 2021; Published 24 April 2021

Academic Editor: Luigi Rodino

The discounted {0-1} knapsack problem (DKP01) is a kind of knapsack problem with group structure and discount relationships among items. It is more challenging than the classical 0-1 knapsack problem. In this paper, we study binary particle swarm optimization (PSO) algorithms with different transfer functions and a new encoding scheme for DKP01. An effective binary vector with shorter length is used to represent a solution for new binary PSO algorithms. Eight transfer functions are used to design binary PSO algorithms for DKP01. A new repair operator is developed to handle isolation solution while improving its quality. Finally, we conducted extensive experiments on four groups of 40 instances using our proposed approaches. The experience results show that the proposed algorithms outperform the previous algorithms named FirEGA and SecEGA . Overall, the proposed algorithms with a new encoding scheme represent a potential approach for solving the DKP01.

1. Introduction

The discounted 0-1 knapsack problem (DKP01) is a new kind of knapsack problem proposed by Guldan [1]. This problem has an important role in the real-world business process. It is a part of many key problems such as investment decision-making, mission selection, and budget control. An exact algorithm based on dynamic programming for the DKP01 is first proposed in [1]. An approach combining dynamic programming with the core of the DKP01 to solve it is studied in [2]. Two algorithms based on genetic algorithm for DKP01 are named FirEGA and SecEGA in [3].

Assume that there are n groups. Each group contains three items. Consider a given set of 3^*n items; each of them has an integer weight w_i and an integer profit p_i. The problem is to select a subset from the set of 3^*n items in n groups such that the overall profit is maximized without exceeding a given weight capacity C. We cannot choose more than 1 item in each group. It is an NP-Hard problem and hence it does not have a polynomial time algorithm unless $P = \text{NP}$. The problem may be mathematically modelled as follows:

$$\text{maximize} \quad f(X) = \sum_{i=0}^{n-1} \left(x_{3i} p_{3i} + x_{3i+1} p_{3i+1} + x_{3i+2} p_{3i+2} \right), \tag{1}$$

$$\text{subject to} \quad x_{3i} + x_{3i+1} + x_{3i+2} \le 1, \quad i \in \{0, \ldots, n-1\}, \tag{2}$$

$$\text{subject to} \quad \left(x_{3i} w_{3i} + x_{3i+1} w_{3i+1} + x_{3i+2} w_{3i+2} \right) \le C, \tag{3}$$

$$x_{3i}, x_{3i+1}, x_{3i+2} \in \{0, 1\}, \quad \forall i \in \{1, 2, \ldots, n-1\}, \tag{4}$$

where x_{3i}, x_{3i+1}, and x_{3i+2} represent whether the items $3i, 3i+1$, and $3i+2$ are put into the knapsack: $x_j = 0$ indicates that the item $j\,(j = 0, 1, \ldots, 3n-1)$ is not in knapsack, while $x_j = 1$ indicates that the item j is in knapsack. It is worth noting