Chapter 2
An Improved Generalized Quantum-Inspired Evolutionary Algorithm for Multiple Knapsack Problem

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ABSTRACT

This article describes how the 0/1 Multiple Knapsack Problem (MKP), a generalization of popular 0/1 Knapsack Problem, is NP-hard and harder than simple Knapsack Problem. Solution of MKP involves two levels of choice – one for selecting an item to be placed and the other for selecting the knapsack in which it is to be placed. Quantum Inspired Evolutionary Algorithms (QIEAs), a subclass of Evolutionary algorithms, have been shown to be effective in solving difficult problems particularly NP-hard combinatorial optimization problems. QIEAs provide a general framework which needs to be customized according to the requirements of a given problem to obtain good solutions in reasonable time. An existing QIEA for MKP (QIEA-MKP) is based on the representation where a Q-bit collapse into a binary number. But decimal numbers are required to identify the knapsack where an item is placed. The implementation based on such representation suffers from overhead of frequent conversion from binary numbers to decimal numbers and vice versa. The generalized QIEA (GQIEA) is based on a representation where a Q-bit can collapse into an integer and thus no inter conversion between binary and decimal is required. A set of carefully selected features have been incorporated in proposed GQIEA-MKP to obtain better solutions in lesser time. Comparison with QIEA-MKP shows that GQIEA-MKP outperforms it in providing better solutions in lesser time for large sized MKPs. The generalization proposed can be used with advantage in other Combinatorial Optimization problems with integer strings as solutions.

1. INTRODUCTION

0-1 Multiple Knapsack Problem (MKP) is a generalization of the standard 0-1 Knapsack Problem (KP) where multiple knapsacks are required to be filled instead of one.

Given a set of n items with their profits p_j and weights w_j, $j \in \{1,\ldots,n\}$ and m knapsacks with capacities c_i, $i \in \{1,\ldots,m\}$ the MKP is to select a subset of items to fill given m knapsacks such that the total profit is maximized and sum of weights in each knapsack i doesn't exceed its capacity c_i.

$$\text{maximize:} \quad \sum_{i=1}^{m}\sum_{j=1}^{n} p_j x_{ij} \tag{1}$$

$$\text{subject to:} \quad \sum_{j=1}^{n} w_j x_{ij} \leq c_i, \ i \in \{1,\ldots,m\}, \tag{2}$$

$$\sum_{i=1}^{m} x_{ij} \leq 1, \ j \in \{1,\ldots,n\}, \tag{3}$$

$$x_{ij} \in \{0,1\}, \ \forall i \in \{1,\ldots,m\}, \ \forall j \in \{1,\ldots,n\}, \tag{4}$$

where $x_{ij} = 1$ if item j is assigned to knapsack i, $x_{ij} = 0$ otherwise and coefficients p_j, w_j and c_i are positive integers.

In order to avoid any trivial case, the following assumptions are made

1. Every item has a chance to be placed at least in largest knapsack:

$$\max_{j \in N} w_j \leq \max_{i \in \{1,\ldots,m\}} c_i. \tag{5}$$

2. The smallest knapsack can be filled at least by the smallest item:

$$\min_{i \in \{1,\ldots,m\}} c_i \leq \min_{j \in N} w_j. \tag{6}$$

3. There is no knapsack which can be filled with all N items:

$$\sum_{j=1}^{n} w_j \geq c_i, \ \forall i \in \{1,\ldots, m\} \tag{7}$$

The subset sum variant of MKP having $p_j = w_j$, $j \in \{1,\ldots,n\}$, is known as Multiple Subset Sum Problem (MSSP).

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