Optimizing Inventory Grouping Decisions: A Grouping Particle Swarm Optimization Approach

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***Abstract*—Inventory classification involving thousands of different items is of common occurrence in moderate to large scale organizations. Though widely applied in several industries, the classical ABC inventory analysis has limitations, including inability to handle qualitative criteria, inability to model multiple criteria, and sub-optimal solutions. This research presents an extension to the inventory classification problem. The proposed approach incorporates a multi-criteria grouping perspective based on a particle swarm optimization approach. First, we analyze the grouping structure of the inventory classification problem. Second, we model the problem from a multi-criteria perspective. Third, we present a particle grouping particle swarm optimization approach for the problem. The proposed multi-criteria inventory classification approach is promising. Finally, further research prospects are presented.**

***Index Terms*—Inventory grouping, ABC analysis, Particle Swarm Optimization, Grouping algorithm, Multi-criteria optimization**

I. Introduction

To effectively manage and control several inventory items, inventory managers often need to group the items into efficient categories. In most cases, the number of items is way too high, such that it becomes difficult to manage. Consequently, in practice, inventory mangers classify or group the items in order to simply the management and control of the items [1]. This problem is of common occurrence across several industry sectors, even in medium sized organizations. The well-known conventional ABC analysis has been used widely in industry [2].

Literature has shown that very few inventory grouping methods have been suggested before [2] [3] [4]. In addition, literature has shown that ABC analysis is the most common inventory grouping approach in industry [1] [5]. Basically, ABC analysis classifies inventory based on their transaction volumes or value. Three classes are obtained: A-class items, consisting of top 20% items, B-items comprising the next 30% of items, and C-items consisting of the rest [6] [7]. However, the ABC approach is not clear on service level optimization. Moreover, optimal decisions are usually not achievable [1].

In light of the above discussions, this research seeks to model the inventory grouping problem using particle swarm optimization approach. Therefore, the objectives of the research are as follows:

1) To define the generic grouping structure of the inventory grouping problem;
2) To analyze the inventory grouping problem from a multi-criteria view point; and,
3) To develop a multi-criteria grouping particle swarm approach for modelling inventory classification/grouping problems.

The rest of the paper is organized as follows: The next section presents a related literature. Section III provides a description of the generic inventory grouping problem. In Section IV, we present an overview of particle swarm optimization. Section V proposes a multi-criteria particle swarm optimization approach for inventory grouping. Finally, conclusions and further research are presented in Section VI.

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II. Related Literature

Apart from the basic ABC analysis method, related methods have been suggested in the literature [1] [3] [4]. A two-stage procedure was suggested in [2], incorporating optimization and statistical clustering techniques. A non-linear optimization model was suggested in [3] to optimize inventory costs. A model was also proposed to simultaneously optimize inventory classification and control decisions [4]. Furthermore, a multi-criteria optimization model was recently developed in [1] using mixed integer programming.

Table I presents a summary of related literature, indicating whether or not the criteria of number of groups, budget limit, and management cost were considered. It can be seen that past literature rarely considered these important

TABLE I
A SUMMARY OF RELATED LITERATURE

Authors	Groups	Budget	Cost
Ernst and Cohen [2]	√		
Guvenir and Erel [5]			
Partovi and Anandarajan [8]			
Ramanathan [9]			
Bhattacharya et al. [10]			
Ng [11]			
Hadi-Vencheh [12]			
Chen [13]			
Chen et al. [14]	√		
Tsai and Yeh [15]	√		
Crouch and Oglesby [16]			
Chakravarty [17]	√		
Aggarwal [18]	√		
Korevaar et al. [3]			
Teunter et al. [4]			
Milistein et al. [1]	√	√	√

criteria and most of the methods were linear programming approaches.

When inventory budget constraints are considered after ABC grouping infeasible solutions may arise. In practice, decision makers want fast and flexible solution approaches that provide a pool of near-optimal solutions from which they can make the final decision. Also, it is often desirable to model the problem from a multi-criteria point of view, including the number of groups, assignment of items to groups, desired service level, and allocation of inventory budget. This is more realistic.

III. The Inventory Grouping Problem Description

Multi-criteria inventory classification problem is defined by N items, where each item i (i = 1,…, N), with an average monthly demand of d_i with a standard deviation σ_i [1]. The demand for each item is normally distribution, N(di, σi). Assume that the lead time of item is l_i time units, each item has a profit π_i, the inventory holding cost per item is c_i, and the inventory budget limit is set at B.

The aim is to classify N items into M groups and set an inventory policy for each group, so that overhead costs are minimized.

The inventory classification assumes that inventory performance is measured using multiple criteria, k = 1, 2,…, K, which is either quantitative, such demand volume, lead time, and unit cost [1], or qualitative, such as replaceability and criticality [1] [5] [9]. Let s_{ik} be the performance score of item i based on criterion k with weighting w_k, so that $\sum w_k = 1$. The weighted performance score for each item i is formulated as follows:

$$f_i = \sum_k w_k s_{ik} \tag{1}$$

where, s_{ik} denotes the performance score of item i based on criterion k, and w_k, is the weighting of criterion k such that $\sum w_k = 1$.

Therefore, the overall inventory grouping performance can be evaluated using a multi-criteria optimization approach [1], typically, according to the following expression,

$$F_i = \sum_i \sum_j f_i d_i \alpha_j x_{ij} \tag{2}$$

where, x_{ij} = 1 if item i is assigned to group j, and 0 otherwise; d_i is the mean demand of item i; α_j is the service level required for group j.

For specific problem situations, specific constraints are added to ensure solution feasibility solutions. For instance, it may be important to ensure that each item is assigned to at most one group, and that the budget B is not exceeded.

In the next section, we present a multi-objective particle swarm optimization algorithm for modelling the inventory grouping problem.

IV. Particle Swarm Optimization: An Overview

According to Kennedy and Eberhert [19], particle swarm optimization (PSO) is a stochastic optimization technique that was motivated by the social behavior of fish schooling and bird flocking [19] [20]. The swarm of particles flies through the search space. While flying, each particle adjusts its position based on its own experience and that of the most successful particle. The PSO mechanism uses a velocity vector to update the current position of each particle in the swarm. The velocity v_i and the position x_i of each particle i are updated, respectively, follows:

$$\begin{aligned} v_i(t+1) = v_i(t) + c_1 \cdot \eta_1 \cdot (pbest_i(t) - x_i(t)) \\ + c_2 \cdot \eta_2 \cdot (gbest(t) - x_i(t)) \end{aligned} \tag{3}$$

$$x_i(t+1) = x_i(t) + v_i(t+1) \tag{4}$$

where, $v_i(t)$ and $x_i(t)$ are, the velocity component and the location component of particle i at iteration t, respectively; $v_i(t+1)$ and $x_i(t+1)$ are, respectively, the velocity component and the location component of particle i at iteration t + 1; $pbest_i$ is the best location of particle i, and $gbest_i$ is the global best location of the whole swarm; c_1 and c_2 are, respectively, the cognitive and social parameters, and η_1 and η_2 are uniform random numbers in the range [0, 1]. Fig. 1

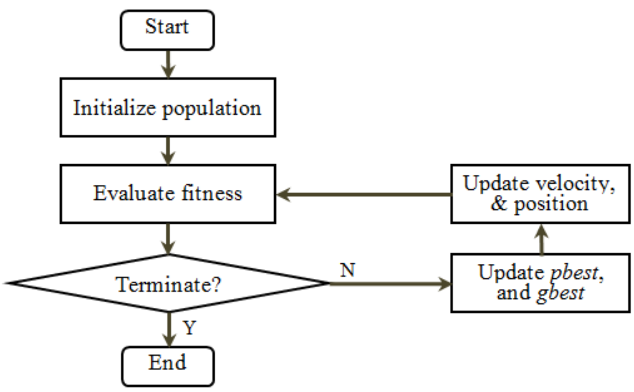

Fig. 1. Flowchart for the proposed GPSO

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presents a summary of the PSO procedure.

When applied to grouping problems, the classical PSO approach suffers redundancy in its solution encoding and context insensitivity since it cannot preserve the group structure of candidate solutions. This is common to other meta-heuristic approaches such as genetic algorithms [21] [22], when applied to grouping problems. The next section explains the grouping PSO algorithm for inventory classification problem.

V. Grouping Particle Swarm Optimization for Inventory Grouping

A. Group Encoding

As in grouping genetic algorithm [23], solution encoding is a key issue for improving the efficiency of the grouping PSO (GPSO) algorithm. The purpose of the group encoding scheme is to code permissible permutations of objects (or items) and to utilize a decoding procedure that considers the actual assignment of items into their respective groups [23] [24]. This concept is extended to the inventory grouping problem. We consider a candidate solution (particle) that consists of three groups g_1, g_2 and g_3, where each group contains inventory items {1,7}, {2, 3,6}, and {4,5}, respectively. A group encoding scheme for this solution is illustrated as shown in Fig. 2.

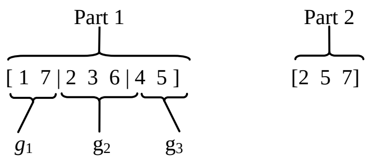

Fig. 2. GPSO particle solution coding scheme

The structure of the particle solution consists of two parts, that is, (i) part 1 which represents the assignment of groups of items {1,7}, {2, 3,6}, and {4,5}, to groups g_1, g_2, and g_3, respectively, and (ii) part 2 which represents the delimiter ("|") positions, that is 2, 5 and 7, respectively. Thus, code 2 records the position of the delimiter which separates item groups.

B. Initialization

An initial population of size p is created by random assignments of items to groups of random sizes, where the assigned items represent the coordinates (positions) of each particle. The GPSO algorithm can assign items to the groups by generating continuous position values using the expression,

$$x_i = X_{\min} + round\left(\left(X_{\max} - X_{\min}\right) \times U\left(0,1\right)\right) \quad (5)$$

where, X_{min} and X_{max} are the pre-defined range of position values, U(0, 1) is a uniform random number in the range [0,1]; *round*() is a rounding function that converts the continuous position values to integer positions.

C. Fitness Evaluation

The fitness of each particle solution in the population should be evaluated. To calculate the particle solution fitness, each solution is evaluated according to equation (2) presented Section IV.

D. Generating a New Particle Solution

Having constructed the grouping encoding scheme for the inventory classification problem, equations (3) and (4) are used for updating the particle solutions. It is important to note that the solutions may not contain integer item numbers. As such, the items are converted to integers using a suitable heuristic rounding function.

VI. Concluding Remarks and Further Research

The extended inventory grouping problem is a difficult problem that requires solution approaches that can capture the grouping structure of the problem, handle multiple optimization criteria, and offer a pool of good solutions in a fast computation time. When applied to the problem, conventional metaheuristic approaches have the following drawbacks, including redundancy and inefficiency.

In this paper, we observed that the ABC inventory classification problem is a grouping problem whose grouping structure can be modelled using grouping algorithm approaches. Consequently, we proposed and presented a multi-criteria GPSO approach for modelling inventory grouping problems for a wide range of possible groups. The proposed GPSO approach offers useful advantages when compared to other metaheuristic approaches. In summary, the proposed approach has the following advantages: (i) it has an efficient group encoding scheme which avoids time-consuming redundancies, which improves the efficiency of the algorithm, (ii) it avoids disruption of essential information encoded in the grouping structures which improves computational effectiveness, (iii) it can search for an optimal solution of the number of groups over a wide range of group sizes, and (iv) it can model multi-criteria inventory classification problems.

Further research should focus on the experimental applications of the GPSO approach to related real-world problems.

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