A Less Flexibility First Based Algorithm for the Container Loading Problem

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Abstract.

This paper presents a Less Flexibility First (LFF) based algorithm for solving container loading problems in which boxes of given sizes are to be packed into a single container. The objective is to maximize volume utilization. LFF, firstly introduced in [An effective quasi-human heuristic for solving the rectangle packing problem, European Journal of Operations Research 141 (2002) 341], is an effective deterministic heuristic applied to 2D packing problems and generated up to 99% packing densities. Its usage is now extended to the container loading problem. Objects are packed according to their flexibilities. Less flexible objects are packed to less flexible positions of the container. Pseudo-packing procedures enable improvements on volume utilization. Encouraging packing results with up to 93% volume utilization are obtained in experiments running on benchmark cases from other authors.

1. Introduction

Profit is a major concern in running business. One way to maximize profit is to minimize the cost. Transportation costs may greatly affect the overall costs. Effective management of transportation by maximizing the utilization of containers can contribute to an obvious reduction of costs. Various algorithms for container loading address this problem. A good algorithm can achieve high volume utilization of containers and in turn reduce the number of containers being used.

Many researchers have studied several variants of this problem. Classification of 3D packing problems can be done by types of boxes and by objective. The former classifies the problem into three types. In homogeneous cases, a single type of boxes (all with the same dimensions) is to be packed. A weakly heterogeneous box set refers to a few number of box types with a lot of individual boxes

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in each type. A strongly heterogeneous box set refers to a large number of box types with a few individual boxes in each type [1]. For objective classification, strip packing, bin packing and knapsack loading [6] are considered. The emphasis of this paper is on knapsack loading which is usually applied to the loading of cargoes into a container.

In knapsack loading problem, boxes are to be packed into a single container with fixed dimensions. A subset of these boxes is packed in an arrangement which maximizes a pre-defined profit. Some boxes can be left unpacked. When the profit is set to be the utilized volume, the objective will be minimization of wasted space. Volume utilization is calculated by: *Volume of occupied space / Total volume of the container* (V_o / V_t). Given a set of n rectangular-shaped boxes $\{b_1, b_2, b_3, \ldots, b_n\}$, with known dimensions l_i x h_i x d_i for the i^{th} box, and a single rectangular-shaped container B with fixed dimensions L x H x D, a subset of the boxes should be packed without violating the following criteria:

- All edges of the packed boxes should be parallel to the container edges.
- No overlapping of boxes is allowed.
- All packed boxes must be completely stowed inside the container
- Orientation Constraint: Orientation defines horizontal or vertical placement of the box's surfaces. Orientation constraints states which sides of the box cannot be placed vertically. This restricts the rotation of the box and reduces the number of possible packing positions.
- Stability Constraint: Stability constraints require every packed box to be supported in a stable and balanced manner. Support can be provided by other packed boxes or by filling all empty space with foam rubber [6]. The former should ensure that *Area supported by underneath layer / Total base area >= a predefined value.* The latter method saves time for computing the area ratio and increases the number of possible packing positions. As the volume utilization is quite high, the space to be filled is not much. This approach is practical and is adopted in this paper for handling stability constraints.

Container loading problem is proven to be NP-hard [2]. No existing algorithms are able to give optimal solutions in polynomial time. Heuristics are mostly adopted in this kind of problems. Several heuristics using layering approach are developed. The advantage is mainly on balancing of load inside the container. [5] presents several ranking rules for selection of the most promising layer depths. [1] introduces a hybrid genetic algorithm based on layering. Genetic algorithms on non-layering methods are presented in [7]. Other methods include an integer programming model [4] and a parallel tabu search algorithm which increases diversity by exchanging local solutions [2].

We present a Less Flexibility First algorithm for this problem. Boxes are packed according to their flexibilities. Less flexible boxes are packed to the less flexible position of the container. By a series of pseudo-packing and greedy-packing process, a box is always packed to a position with the highest Fitness Cost Function Value (FFV). Final packing result is promising.