Three dimensional Bin Packing Problem applied to air transport

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Abstract

Packing boxes into containers is a daily process in many different fields and especially in transport. However, the particular case of air transport brings some new constraints such as the stability or the fragility of the cargo. The distribution of the weight has also to be considered. Moreover, this special case also brings some data such as the dimensions of the possible containers, called *Unit Load Devices*. This paper is concerned with the formulation of the three dimensional palletization which includes the main constraints met in the air cargo industry. It proposes a integer linear program for this combinatorial optimization problem.

Keywords: Bin-packing, unit load devices, 3D-BPP

1 Problem statement

Nowadays, packing boxes into containers is a daily process in many fields such as truck or air transport. This process has to be conducted as fast and profitable as possible. Indeed, it is important to pack a maximum number of boxes into a minimum number of containers such that the costs can be reduced. This minimization problem is called the *bin packing problem* (BPP) or *container loading problem*. There exist some variants of the BPP: it can be considered in one, two or three dimensions and with one or several containers. If there are several containers, they can have the same or different shapes (*Multi-Container Loading Problem*) and so do the boxes. There could be different constraints imposed by the operator or by the transportation. A more complete classification of the packing problem is developed in [6].

A lot of articles developed some models for the BPP on one and two dimensions while the three dimensional BPP (3D-BPP) is a more recent subject, the first models appeared less than twenty years ago. However, the application to the air transport still needs to be studied because of its particular constraints. Yet, since BPP is a NP-hard problem, some heuristics methods are developed to try to solve some particular cases of the BPP (see e.g. [1, 2, 7]).

2 Methodology

In this paper, 3D-BPP is considered in the particular case of air cargo. In this specific situation, containers are called *unit load devices* (ULD). A ULD is an assembly of components consisting of a container or of a pallet covered with a net, whose purpose is to provide standardized size units for individual pieces of baggage or cargo, and to allow for rapid loading and unloading [3]. Thus, how ULDs are filled in and their number has a significative impact on the loading of these ULDs into an aircraft. The boxes to pack are assumed stackable in a same container but with some conditions on the stability and the fragility of the contents of the boxes. Each box could also execute some 90°-rotations. Some limits on the total weight inside the ULDs are introduced as well as on the distribution of this one. These constraints will be usefull to optimize the loading of these ULDs in an aircraft [4, 5]. Since several identical ULDs are considered, the problem consists in determining in which ULD each box is assigned (as in the knapsack problem) and where it must be. Our objective is to minimize the unused volume respecting all these constraints.

All this work is in progress. Our first contribution is to propose a mathematical model to represent this complex problem. This step is almost over and will be presented at the conference. The model is already implemented in Java with the professional library IBM ILOG CPLEX 12. Since the model is a mixed integer linear program, we have used the classical branch-and-cut CPLEX solver with the default parameters. But, due to its complexity, this problem opens the way to heuristics. The next step will be to test this model on real data provided by our industrial partners.

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