Université Polytechnique Hauts-de-France
Institut National des Sciences Appliquées Hauts-de-France **2023-2024**

Master CDSI Semestre Pair

Sujet de TP

1 Introduction

L'objectif de ce travail est de compléter l'initiation aux notions abordées pendant les séances de cours du module autour de l'intérêt d'utiliser des heuristiques et/ou des métaheuristiques lorsque le problème à résoudre est "*difficile*".

Pour cela vous allez travailler en équipe.

Une équipe est, par définition, composée de plusieurs individus. Il ne s'agit pas d'un travail individuel mais bien d'une collaboration qui doit notamment contribuer à renforcer vos compétences organisationnelles au sein d'un groupe.

L'organisation au sein de l'équipe n'est pas du ressort de l'équipe enseignante qui peut néanmoins intervenir en cas de difficultés ou problèmes. Il est **très important** que chaque membre de l'équipe puisse mettre en avant son rôle et ses contributions dans la réalisation du projet et son aboutissement. Ces éléments seront pris en compte dans la notation et pourront déboucher sur une note différente pour chacun.

2 Description du problème

Given n rectangular items, each characterized by a height h_j and a width w_j, $j \in 1, 2, \dots n$, and an unlimited number of identical rectangular bins, each having height H and width W, the Oriented Two-Dimensional Bin Packing Problem (2D-BPP) is to pack each item into a bin so that no two items overlap and the number of required bins is minimized. We assume that the items cannot be rotated. We also assume, without loss of generality, that all input data are positive integers and that $h_j \leq H, w_j \leq W (j = 1, 2 \dots n)$. The following picture extracted from Lodi et al. (1999b) illsutrates the problem.

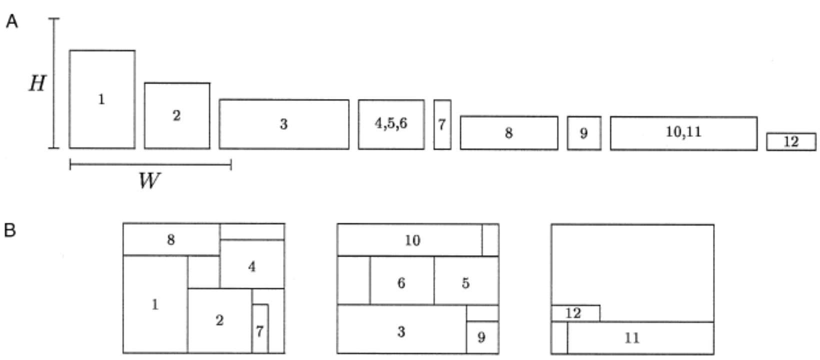

Figure 4. *A*, Two-dimensional bin packing instance with n = 12; *B*, solution found by Algorithm AD_{OF}.

3 Travail attendu - tâches à réaliser

3.1 Constructive heuristic- *Finite Best Strip*

First task is to construct a feasible solution of the problem. Although many constructive heuristics do exist for the problem, you need to develop ***Finite Best Strip (FBS)*** heuristic. The FBS heuristic initially sorts the items by non-increasing height and consists of two phases. First the items are packed into an infinite height strip using a best-fit algorithm to select the level for each item : the resulting strip packing is made up of "shelves", each corresponding to a different level, having width equal to the strip width and a different height. In the second phase the shelves are packed into finite bins using again best-fit heuristic. The best-fit algorithm in the first phase works as follows : if the current item does not fit into any existing shelf(level), then a new shelf is initialized for it ; otherwise the current item is packed onto the shelf whose resulting residual horizontal space is minimum. In the second phase, the resulting shelves are packed into finite bins using the best-fit decreasing heuristic : the next (highest) shelf is packed into the bin whose resulting residual vertical space is minimum, or into a new one, if no bin can accommodate it. Some examples of the heuristic may be found at Figure 3 in Berkey and Wang (1987) at Figures 2A and 2B in Lodi et al. (1999b).

In what follows for a given subset S of items, $\texttt{FBS}(S)$ will denote, the number of $H \times W$ bins used by algorithm FBS to pack all items from S.

3.2 Local search

The next step is to develop a local search to possibly improve the inital solution provided by $\texttt{FBS}(S)$. Let z denote the number of bins used in the current solution and let S_i denote the set of items that, in the current solution, are packed into bin $i, (i = 1, 2, \dots z)$. The weakest bin b is then defined as the one which minimizes the quantity :

$$\phi(i) = \alpha \frac{\sum_{j \in S_i} h_j w_j}{HW} - \frac{|S_i|}{n}$$

that gives an estimate of the difficulty of emptying bin i. α is a predefined non-negative parameter, which needs to be empirically set. For example, in Lodi et al. (1999a) it is set to 5, while in Lodi et al. (1999b) it is set to 20.

The local search to be implemented explores neighborhood obtained by determining the weakest bin b and by considering, in turn, each item j currently packed into b and other bins : $\texttt{FBS}(S_i \cup \{j\})$ is then iteratively computed for bins $i \neq b$. As soon as a bin i^* is found for which $\texttt{FBS}(S_{i^*} \cup \{j\}) = 1$, item j is moved to this bin, and the next item of b is considered. Whenever the weakest bin becomes empty, the new weakest bin is determined and the search continues in the same manner. As soon as none item can be moved, the search stops.

3.3 Shaking/Diversification procedure

The shaking procedure to be implemented has two parameters : current solution (current packing) and parameter k which controls level of diversification. It consists of choosing k items and packing each item separately to a new bin.

3.4 Basic Variable Neighborhood Search

The above procedure present main ingredients for a basic variable neighborhood search. Your task is to develop one and test. For testing purposes you should use test instances available on the `Moodle` page.

4 Dépôt et modalités

Un rapport (compte-rendu étendu de TP) sera à fournir par équipe. Ce rapport doit, à minima, présenter le problème, présenter et expliquer les algorithmes développés (en donnant le pseudo-code des procédures), présenter et commenter les expériences numériques réalisées et les résultats obtenus, donner une conclusion et des pistes d'amélioration. Il doit aussi clairement indiquer les contributions de chacun.

Le rapport et le code source devront être déposés sur `Moodle` avant la date limite.

Il est fortement conseillé de ne pas attendre la dernière minute pour déposer votre travail, afin de limiter les risques liés à un problème de réseau par exemple.

Le dépôt se fera sous la forme d'une archive au format `.zip, .rar ou .7z`.

Références

Berkey, J. O. and Wang, P. Y. (1987). Two-dimensional finite bin-packing algorithms. *Journal of the operational research society*, 38(5) :423–429.

Lodi, A., Martello, S., and Vigo, D. (1999a). Approximation algorithms for the oriented two-dimensional bin packing problem. *European Journal of Operational Research*, 112(1) :158–166.

Lodi, A., Martello, S., and Vigo, D. (1999b). Heuristic and metaheuristic approaches for a class of two-dimensional bin packing problems. *INFORMS Journal on Computing*, 11(4) :345–357.