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A hybrid heuristic to reduce the number of different patterns in cutting stock problems

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Abstract

We propose a hybrid procedure to obtain a reduced number of different patterns in cutting stock problems. Initially, we generate patterns with limited waste that fulfill the demands of at least two items when the patterns are repeatedly cut as much as possible but without overproducing any of the items. The problem is reduced and the residual problem is solved. Then, pattern reduction techniques (local search) are applied starting with the generated solution. The scheme is straightforward and can be used in cutting stock problems of any dimension. Variations of the procedure are also indicated. Computational tests performed indicated that the proposed scheme provides alternative solutions to the pattern reduction problem which are not dominated by other solutions obtained using procedures previously suggested in the literature.

Keywords: Pattern reduction; Cutting stock; Heuristics

1. Introduction

In many wood, paper and steel industries, the cutting process and/or the type of machines impose a setup cost every time a different pattern is cut. For instance, the positions of the cutting knifes in a machine must be adjusted or prepared for every new pattern that is cut. In these settings, it is desirable to have a cutting plan with a reduced number of patterns. On the other hand, keeping the waste of material as low as possible is always another desired objective in practice. Unfortunately, these are usually two conflicting

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objectives. In this work, we address this bi-criteria decision problem that is of relevance when machine costs are significant compared with the costs of material.

The minimization of waste and the number of patterns problem (P) can be formulated as

$$\text{Minimize} \quad (z_1, z_2) = \left(\sum_{i=1}^{n} x_i, \sum_{i=1}^{n} \delta(x_i) \right) \tag{1}$$

$$\text{Subject to} \quad \sum_{i=1}^{n} \underline{\boldsymbol{a}}_i x_i \geqslant \underline{\boldsymbol{d}}, \tag{2}$$

$$x_i \geqslant 0, \quad i = 1, 2, \ldots, n \text{ and integer}, \tag{3}$$

$$\delta(x_i) \text{ is equal to 1 for } x_i > 0 \text{ and is equal to 0, otherwise}, \tag{4}$$

where n is the total number of feasible patterns in the problem; $\underline{\boldsymbol{a}}_i$ is the cutting pattern i. Its element a_{ji}, $j=1, 2, \ldots, m$, is the number of items j contained in pattern i, m is the total number of different items in the problem; x_i is the run quantity (or frequency) of pattern i, $\underline{\boldsymbol{d}}$ is the customers' order requirements vector. Its element d_j, $j = 1, 2, \ldots, m$, is the amount required for item j.

We assume, without loss of generality, that $0 < d_1 \leqslant d_2 \leqslant d_3 \leqslant \cdots \leqslant d_m$, and any two items in the problem are different in size.

There seems to be a relative small number of published papers dealing with pattern reduction/controlling problems. In Haessler [1], a repeated pattern exhaustion technique is proposed to solve the cutting stock problem where a pattern is selected if it satisfies the aspiration levels of waste and frequency. Farley and Richardson [2] modeled a pattern minimization cutting stock problem as a fixed charge problem by considering a single objective composed of the sum of the cost of the patterns and the setup costs. The learned literature about fixed charge problems is vast since many other (practical) problems are modeled as such. However, some particularities of the cutting stock problem prevent us to apply, in most cases, the methods proposed to solve other fixed charge problems arising in other settings. In particular, the large number of columns in practical cutting problems is one of the difficulties that must be taken into account. Farley and Richardson [2] use simplex iterations to replace basic variables (the cutting patterns) by surplus variables to reduce the number of patterns. In Haessler [3], the basic ideas of some heuristics suggested in the literature that use the repeated pattern exhaustion technique are presented. Foerster and Wäscher [4] propose a pattern reduction method by iteratively combining 2, 3, 4 or more patterns, of a minimal input cutting plan generated in a first stage. They extend the idea suggested by Diegel et al. [5]. Umetami et al. [6] propose a heuristic that searches a solution that minimizes the quadratic deviation of the cut items from the requirements after the number of different patterns is fixed to a predefined value. They also review some other works that combine two patterns into one. Vanderbeck [7] proposes a quadratic integer programming formulation to minimize the number of setups in the unidimensional case. He proposes a decomposition method and a branch-and-bound algorithm procedure to solve the problem. Apparently, only small and moderate size problems could be solved to optimality in a reasonable amount of computational time (2 h).

The fact that mostly heuristics have been proposed in the literature to solve this problem can be explained by the fact that the pattern minimization in cutting stock problems is strongly NP-hard, even for the special case in which any two customer items fit into an object, but no three do [8]. Note that for