Chapter 4
A Hybrid Genetic Algorithm for Optimization of Two-Dimensional Cutting-Stock Problem

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ABSTRACT

In this paper, the authors present a hybrid genetic approach for the two-dimensional rectangular guillotine oriented cutting-stock problem. In this method, the genetic algorithm is used to select a set of cutting patterns while the linear programming model permits one to create the lengths to produce with each cutting pattern to fulfill the customer orders with minimal production cost. The effectiveness of the hybrid genetic approach has been evaluated through a set of instances which are both randomly generated and collected from the literature.

INTRODUCTION

Cutting problems are encountered in several industries with different objectives and constraints. The ship building, textile and leather industry (Farley, 1988) are mainly concerned with the cutting of irregular shapes, whereas in the glass wood and paper industry, regular shapes are to be cut. In particular, rectangular shape which can be obtained through guillotine or non guillotine cut and oriented or non-oriented cut. A guillotine cut means that each cut must go from one side of a rectangle straight to the opposite. Then, each cut

produces two sub-rectangles. An oriented cutting means that the lengths of rectangles are aligned parallel to lengths of the stock sheet or roll. Hence, a piece of length l and width w is different from a piece of length w and width l when $l \neq w$.

In order to classify the types of constraints with other specifications such as types of pieces, types of containers and objectives, previous typologies were defined (Wascher, Haussner, & Schumann, 2007; Dyckhoff, 1990). Beside, extensive survey of two dimensional cutting problems can be found in Lodi, Martello, and Monaci (2002).

In this paper the two-dimensional rectangular guillotine oriented cutting-stock problem is considered, with the objective of minimizing the production cost. Before providing the details of this problem and the details of the elaborated algorithm, we briefly review the resolution techniques available in the literature.

The two-dimensional cutting-stock problem is NP-hard and a solution can be found either by exact methods that require large amounts of computational time (Martello, Monaci, & Vigo, 2003; Fekete, Schepers, & Veen, 2007) or by heuristic algorithms whose solutions can be very far from the optimal ones. Many heuristic algorithms have been developed, ranging from simple constructive algorithms to complex meta-heuristic procedures such as evolutionary algorithms, which are known as powerful tools for NP-hard problems. However, due to the complexity of these problems, special chromosome structures are needed. In Esbensen (1992) and Kado, Ross, and Corne (1995), chromosomes are used with some specific designed genetic operations. However, they, in turn generate many difficulties in handing the geometrical constraints of these problems and the efficiency of these algorithms is greatly affected.

In Leo and Wallace (2004), Jakops (1996), Gomez (2000) and Yeung and Tang (2004), a combination of genetic algorithms and constructive methods were proposed. By applying a constructive method such as Bottom Left (BL) and Lowest-Fit-Left-Right-Balanced (LFLRB)

heuristic methods, the cutting problem is transformed into a simple permutation problem, which can be effectively solved by genetic algorithms.

In this paper, a hybrid genetic approach which combines a genetic algorithm with a linear programming model is elaborated. The genetic algorithm is used to select a set of cutting patterns while the linear programming model allows us to determine the lengths to produce with each cutting pattern in order to satisfy the customer orders with the minimal production cost. This paper is organized as follows. The first section describes the problem and the mathematical formulation proposed. The hybrid approach with the details of the genetic algorithm is then presented and the experimental results are illustrated. Finally, concluding remarks are given.

PROBLEM FORMULATION

In this paper, we study the two-dimensional rectangular guillotine oriented cutting-stock problem. This problem can be stated as follows. N customer orders of rectangular pieces with dimensions $w_i\, l_i$ ($i=1,\ldots,N$) are requested with quantity d_i ($i=1,\ldots,N$). d_i is usually a very large number, greater than one hundred, and it is to be cut from K rolls of material with standard width W_k ($k=1,\ldots,K$), each in sufficient length to satisfy the entire demand.

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