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Meta-heuristic algorithms for nesting problem of rectangular pieces

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Abstract

Nesting problems consist of placing multiple items onto larger shapes finding a good arrangement. The goal of the nesting process is to minimize the waste of material. It is common to assume, as in the present work, that the stock sheet has fixed width and infinite height, since in the real world a company may have to cut pieces from a roll of material.
The complexity of such problems is often faced with a two-stage approach, so-called "hybrid algorithm", combining a placement routine and a meta-heuristic algorithm. Starting from a given positioning sequence, the placement routine generates a non-overlapping configuration. The encoded solution is manipulated and modified by the meta-heuristic algorithm to generate a new sequence that brings to a better value of the objective function (in this case the height of the strip).
The proposed method consists in placing the rectangles inside a strip and in combining the meta-heuristic algorithms with the No Fit Polygon algorithm. The software has been developed in Python language using proper libraries to solve the meta-heuristic techniques (*Inspyred*) and the geometric problems (*Polygon*).
The results show the effectiveness of the proposed method; moreover, with regard to problems reported in literature employed as benchmark of the nesting algorithms, the degree of occupation values (Efficiency Ratio, ER) are shown to be higher than 90%.

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Keywords: Sheet metal optimisation; meta-heuristic algorithm; No Fit Polygon algorithm.

1. Introduction

In the field of nesting problems [1-2], a particular interest is focused on the frequent two-dimensional rectangular strip packing problem (2D-SPP), in which a given set of rectangular pieces have to be packed into a strip of given

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width and infinite length in order to minimize the required height of the packing [3]. The 2D-SPP occurs, e.g., in the cutting of rolls of paper or metal. Since the problem has NP-hard complexity, over the years many solutions have been proposed. In the literature meta-heuristics techniques have been considered more suitable for solving the 2D-SPP. These are mainly genetic algorithms (GA), but simulated annealing (SA) and other types of meta-heuristics algorithms have been also applied. Hopper et al. [4] and, recently Olivera et al. [5] and Delorme et al. [6] provide a large overview of the meta-heuristics techniques that have been developed for the different variants of the 2D-SPP.

In this work, it is propose to compare the use of different meta-heuristic methods for a 2D-SPP problem solution by the improvement of a suitable heuristic positioning technique (said Bottom Left Fill) combined with the concept of the No-Fit-Polygon previously developed [7].

The analysis was carried out by developing a suitable program in Python that, by using two libraries (*Polygon* [8] and *Inspyred* [9]), it is able to solve both the problems related to positioning and those related to the identification of the best solution for different types of meta-heuristic methods.

2. The employed methods

The nesting problem can be split into two main steps: the search of an optimal sequence of the shapes (rectangles) which have to be positioned and their allocation on the stock sheet. The placement technique is based on the intensive use of a nesting method which employ a particular polygon, called No-Fit-Polygon, shortly described in the next paragraph.

2.1. The Bottom Left Fill Algorithm

One of the placement routine often used in nesting problems is the Bottom Left Fill algorithm (BLF). This algorithm is a adaptation of the Bottom Left one proposed by Jakobs [10] that consists in placing sequentially the pieces in the position as far as possible to the bottom-left place in the examined strip, without overlapping them with those previously positioned. The routine is modified with the so-called technique Bottom Left Fill (BLF) in which, using the NFP computation, the piece can be positioned even in the existing empty spaces, in order to determine better packing, even if this increases computation complexity.

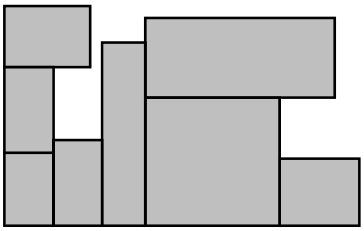

Fig. 1. An example of Bottom Left Fill positioning.

2.2. The No Fit Polygon Algorithm

A great number of nesting of two-dimensional irregular shapes use a particular polygon called No-Fit-Polygon (NFP) [11]. The NFP is described in the following terms (Fig. 1):

"*Given two polygons A and B such that the position of A and the orientation of B are all fixed, then the NFP of B relative to A (denoted with NFP_{AB}) completely describes all those positions where a reference point of B polygon (say orbiting polygon) can be placed in order to have B touching A polygon (say stationary polygon) without overlapping*".

The main advantage of the NFP is that it can be employed both for regular shapes and non-regular ones. The NFP is obtained by fixing the position of a reference point of orbiting polygon that moves around the perimeter of stationary polygon (fig. 2a). A relevant feature of the NFP is that the points located inside it are associated to an