Bottom-Left and Sequence Pair for Solving Packing Problems

T. Rolich*, D. Domović *, M. Golub **

* University of Zagreb, Faculty of Textile Technology, Zagreb, Croatia

** University of Zagreb, Faculty of Electrical Engineering and Computing, Zagreb, Croatia

*{tomislav.rolich, daniel.domovic}@ttf.hr, ** marin.golub@fer.hr

Abstract - Nesting problem is a combinatorial optimization problem with a goal of placing a set of polygons within container boundaries without overlapping. If polygons in shape of cutting patterns are used, and the container has a fixed width, the problem is defined as a strip packing problem. In this paper two methodologies are described: Bottom-Left (BL) and Sequence Pair (SP). Bottom-left is order based strategy which can solve strip packing problem. It moves each polygon as far as possible to the bottom of the temporary layout and then as far as possible to the left until a stable position is found. In this paper, BLDP version was used with genetic algorithm. Sequence pair is an abstract representation method for nesting problem that creates a relationship model between bounding box approximations of polygons instead of direct placement. The goal of the research is to compare the methodologies, as well as layout density obtained during experiments. Experiments have been conducted on benchmark datasets: Albano (24 parts), Dagli (30 parts), Mao (20 parts) and Marques (24 parts) in MATLAB environment, with GA-BLDP performing 78.23, 70.15, 70.70 and 77.63 percent respectively (in average), and SP-BL performing 76.28, 63.10, 68.52 and 75.60 percent respectively (in average).

I. Introduction

Packing problems are combinatorial optimization problems where a set of items $I = \{i_1, i_2, \ldots, i_n\}$, $n = |I|$, need to be placed within the container C so that no pair of items i_i and i_j do not overlap ($i_i \cap i_j = 0$) and items do not exceed the boundaries of a container ($i_i \cap C = i_i$) [1]. If defined in a two-dimensional space, the container and items may be regular or arbitrary shaped polygons.

A packing (often referred to as a placement or a layout) is a set of positions where polygons are placed within a container. Since polygons are usually defined with coordinates of its vertices and a reference point, polygon placement is defined with a position of its reference point.

The 2D packing layout may be normalized or semi-normalized (Fig. 1). A layout is normalized if each polygon cannot be moved more down or to the left without causing an overlap. A layout is semi-normalized if each polygon that is added to the layout is placed as bottom-left as possible regarding the current packing contour. In this paper algorithms that create normalized layouts have been constructed.

The significance of packing problems lies in real world applications. In most manufacturing processes it is desirable to reduce the amount of waste, and hence maximize the utilization of material. In this paper, experiments on datasets from textile industry have been performed. In textile industry, a set of cutting patterns needs to be optimally allocated on a material in order to minimize waste, and utilize the material.

In computer science this problem is addressed to as the *strip packing problem* [2], but is also known as the marker making problem. Since polygons are irregularly shaped the problem is often referred to as *nesting problem*, also.

The two-dimensional packing problems can be classified as: (1) *knapsack problems* with a goal of finding optimal subset of items in a container, (2) *bin-packing problems* with a goal of minimizing the number of containers used, and (3) *area minimization problems*, with a goal of optimally allocating polygons in a container to minimize the occupied container area.

In this paper two hybrid algorithms using metaheuristics and bottom-left strategies have been used. In the first approach, *a strip packing problem* is solved using genetic algorithm and BLDP method. A set of irregular polygons are placed within the rectangular area with a fixed width and unlimited length. The goal is to minimize the length, i.e. minimize the waste area between polygons.

The second approach is an *area minimization problem*, where the size of both width and the length is arbitrary, but the goal is to obtain the enclosing rectangular of irregular polygons with a minimal area. Simulated annealing is combined with a sequence pair to perform this task.

One of the greatest challenges in solving packing problems is the overlapping detection methods. Many methods are used in the literature: raster method, no-fit polygon, phi-functions etc. In this paper an abstract representation method is used that prevents overlapping by determining relationships between polygons and

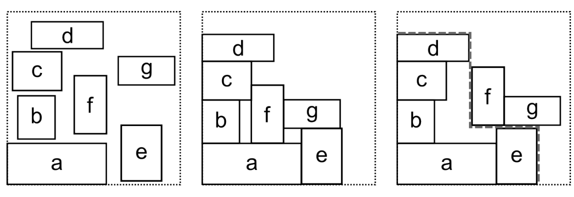

Figure 1. Polygons (a) in a normalized layout (b) and semi-normalized layout (c)