A

Hybrid Genetic Metaheuristic for Two-Dimensional Constrained Guillotinable Cutting Problems

Hamza Gharsellaoui
National Institute of Applied Sciences and Technologies (INSAT), Carthage University, Tunisia

Hamadi Hasni
National School of Computer Science, ENSI, University of Manouba, Tunisia

INTRODUCTION

The packing problems have been widely studied during the last three decades, as they are often faced in industry. The rectangular pieces packing problem, cutting also from rectangular board, is one particular case of this set of problems. The aim is often to achieve the minimum trim loss (Teng & Liu, 1999). In this book article we propose two approaches for the construction of algorithms for optimization problems such as packing problems whose involve constructing an arrangement of items that minimizes the total space required by the arrangement. This is mainly due to the constraints imposed by the industrial applications, e.g. textile, wood, steel and metal industry. A recent survey on packing problems is given in (Ntene & van Vuuren, 2009). In this book article, we specifically consider the two-dimensional (2D) rectangular strip packing problem based on a new hybrid approach, named hybrid genetic algorithm. The input is a list of n rectangles with their dimensions (length and width). The goal is to pack the rectangles without overlap into a single rectangle of width W and minimum height H. We further restrict ourselves to the oriented, orthogonal variation, where rectangles must be placed parallel to the horizontal and vertical axes, and the rectangles can be rotated. This book article is organized as follows. In Section 2, we provide the backgroundwhere we describe a brief literature review, and some known concepts in the genetic algorithmstheory. In Section 3, we present the resolution methods which use the bottom left algorithm and the guillotine constraint. Section 4 presents some major problems in industry. In Section 5, we show howour two hybrid algorithms can be adapted for solving the general 2DC problem. In Section 6, we undertake a comparative study of our proposed algorithms and evaluate their performance for the2DC problem using benchmark problems from the literature. Finally, in Section 7, we summarize thecontributions of this book article and explain their possible extensions.

BACKGROUND

Literature Review

Further background packing problems in general are important in manufacturing settings; for example, one might need n specific rectangular pieces of glass to put together a certain piece offurniture, and the goal is to cut those pieces from the minimum height fixed-width piece of glass. The more general version of the problem allows for irregular shapes, which is required for certain manufacturing problems such as clothing production. Indeed, there are three key components of the problem under consideration; bin packing, guillotine cuts and regular shapes (rectangular form). To our knowledge there are no papers that tackle these three together with a hybrid genetic algorithm.

In this work all pieces are regular with a rectangular form; instead the key challenge arises in modeling efficiently continuous rotation of the pieces, which is not commonly dealt with in the literature. A side from the geometry, solution approaches to irregular packing are almost all heuristic and can be divided into those that build up to a final solution through sequentially adding to partial solutions, and those that

DOI: 10.4018/978-1-4666-5888-2.ch017

work with complete solutions and search by making small changes to the incumbent solution. The latter approach can be subdivided into representing the solution by a sequence, or packing order, that is decoded by a construction heuristic, or by the co-ordinate positions of the pieces in the layout. For a review of solution approaches to the irregular packing problem see Bennell and Oliveira in (Bennell et al., 2010). The rectangle bin packing problem with guillotine constraints has the most similarities to the problem we are tacking in this work. In (Lodi & Martello, 1999) the authors create the shelves by solving a series of 0-1 knapsack problems improving on the performance of the finite first fit andfinite best strip heuristics (Berkley & Wang, 1987). Instead of assigning pieces to bins and then packing, Alvelos et al. in (Alvelos et al., 2009) define a sequence for packing the pieces while keeping a list of candidate locations forthe next piece. The solution is improved using variable neighborhood descent where moves are made within the packing sequence. We adopt methodologies for efficiently processing the geometry of irregular convex shapes with free rotation using some classic concepts andphi-functions. We follow the common theme of construction methodologies for generating patterns while meeting guillotine constraints, and for the two-stage strategies we directly use the approach of Charalambous and Fleszar (2011). However, the rectangular case has many industrial applications (Hifi-Mhand, 1997). The 2D rectangular strip packing problem has been the subject of a great deal of research, both by the theory community and the operations-research community (Morabito & Arenales, 1994). One focus has been on heuristics that lead to good solutions in practice.

Known Concepts in the Genetic Algorithms Theory

Genetic Algorithm (GA)

Genetic Algorithms (an interesting introduction to GA's and other evolutionary algorithms may be found in (Degraeve & Vandebroek, 1998) are optimization algorithms which are frequently cited as ''partially simulating theprocess of natural evolution." Indeed, a genetic algorithm (GA) is a procedure used to find approximate solutions to search problems through application of the principles of evolutionary biology. In one hand, the genetic algorithm was developed at first by Holland (Glover, 1989) for optimization problemsin difficult domains. Difficult domains are those with both enormous search spaces and objectivefunctions with many local optima, discontinuities and high dimensionality. On the other hand, genetic algorithms use biologically inspired techniques such as genetic inheritance, natural selection, mutation, and sexual reproduction (recombination, or crossover). For this problem, members of a space of candidate solutions, called individuals, are represented using abstract representations called chromosomes.

Selection Operator

Selection is a genetic operator that chooses a chromosome from the current generation's populationfor inclusion in the next generation's population. Before making it into the next generation's population, selected chromosomes may undergo crossover and/or mutation (depending upon the probabilityof crossover and mutation) in which case the offspring chromosome(s) are actually the ones that makeit into the next generation's population. There are many types of mutation (Roulette, Tournament, Top Percent, Best, and Random).

Mutation Operator

Mutation is a genetic operator that alters one or more gene values in a chromosome from its initialstate. This can result in entirely new gene values being added to the gene pool. With these new gene values, the genetic algorithm may be able to arrive at better solution than was previously possible.

Mutation is an important part of the genetic search as help helps to prevent the population from stagnating at any local optima. Mutation occurs during evolution according to a user-definable mutation probability. This probability should usually be set fairly low (0.01 is a good first choice). If I tis set to high, the search will turn into a primitive random search.

Crossover Operator

Crossover is a genetic operator that combines (mates) two chromosomes (parents) to produce a newchromosome (offspring). The idea behind crossover is that the new chromosome may be better thanboth of the