

An efficient heuristic algorithm for rectangle-packing problem

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Abstract

Rectangle-packing problem involves many industrial applications, such as shipping, timber cutting, very large scale integration (VLSI) floor planning, and so on. This problem has shown to be NP hard, and many algorithms such as genetic algorithm, simulated annealing and other heuristic algorithms are presented to solve it. Based on the wisdom and experience of human being, an efficient heuristic algorithm is proposed in this paper. Two group benchmarks are used to test the performance of the produced algorithm, 19 instances of first group and 3 instances of second group having achieved optimal solutions. The experimental results demonstrate that the presented algorithm is rather efficient for solving the rectangle-packing problem.

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1. Introduction

Rectangle-packing problem involves many industrial applications. For example, in shipping industry, various size boxes have to be loaded as many as possible in a larger container. In wood or glass industries, rectangular components have to be cut from large sheets of material. In very large scale integration (VLSI) floor planning, various chips have to be laid on the chip board, and so on. The rectangle-packing problem belongs to a subset of classical cutting and packing problems and has shown to be NP hard [1]. For more extensive and detailed descriptions of packing problem, please refer to [2,3]. Various algorithms based on different strategies have been suggested to solve this problem. In general, these algorithms can be classified into two major categories: non-deterministic algorithms and deterministic algorithms. The key aspect of non-deterministic algorithms, such as simulated annealing and genetic algorithm [4,5], is to design data structure that can represent the topological relations among the rectangles. The key aspect of deterministic algorithms is to determine the packing rules, such as *less flexibility first* principle [6].

Optimal algorithm for orthogonal two-dimensional cutting is proposed in [7], but it might not be practical for large problems. In order to improve the quality of solution, some scholars combine genetic

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algorithm or simulated annealing with deterministic method and obtain hybrid algorithms [8,9]. Some heuristic and meta-heuristic algorithms are presented in [10–13]. In recent years, some people began to formalize the wisdom and experience of human being and obtain the quasi-human heuristic algorithms [6,14–17]. The “quasi-human” tries to simulate the behavior of human being in related special work such as bricklaying.

In [17], the authors presented a heuristic algorithm based on two important concepts, namely, the corner-occupying action and caving degree. Based on [17], an efficient heuristic algorithm (HA) for rectangle-packing problem is proposed on the basis of the wisdom and experience of human being in this paper. The objective is to maximize the area usage of the box. The key point of this algorithm is that the rectangle packed into the box always occupies a corner, even a cave, if possible. Furthermore, the rectangle should occupy as many corners and overlap as many edges with other previously packed rectangles as possible. In this way, the rectangles will be close to each other wisely, and the spare space is decreased. As compared with reviewed literatures, the results from HA are much improved. For 21 rectangle-packing test instances taken from [11], optimal solutions of 19 instances are achieved by HA, and two and three ones by the algorithm in [6] and [12], respectively. For each of 13 random instances taken from [13], the container height obtained by HA is smaller than that by best fit (BF) heuristic [13]. Furthermore, optimal solutions of three instances are achieved by HA. Experimental results show that HA is rather efficient for solving the rectangle-packing problem.

2. Problem description

Given an empty box B_0 with width w_0 and height h_0 , and a series of rectangles R_i with width w_i and height h_i ($i = 1, 2, \dots, n$). The task is to pack as many rectangles into the box B_0 as possible, where the measurement of “many” is the total area of the already packed rectangles. The constraints for packing rectangles are:

1. Each edge of a packed rectangle should be parallel to an edge of the box.
2. There is no overlapping area for any two already packed rectangles, and any packed rectangle should not exceed the box boundary.
3. The rectangle should be packed horizontally or vertically.

Without significant loss of generality, it is usual to assume that all w_i and h_i ($i = 0, 1, \dots, n$) are integers.

3. Algorithm description

3.1. Main idea

If some rectangles have been packed into the box without overlapping, that is, the overlapping area is zero, the question is which rectangle is the best candidate for the remainder, and which position is the best one to be filled? There is an aphorism in ancient China: “*Golden corners, silvery edges, and strawy voids*”. It means that the empty corner inside the box is the best place to be filled, then the boundary line of the empty space, and the void space is the worst. And more, if the rectangle not only occupies a corner, but also touches some other rectangles, the action for packing this rectangle is perfect. We may call the corresponding action as cave-occupying action. Therefore, we can develop foresaid aphorism into “*Golden corners, silvery edges, strawy voids, and highly valuable diamond cave*”. In addition, we hope that the rectangle occupies as many corners and overlaps as many edges with previously packed rectangles as possible. Thus, the following packing principle is natural: The rectangle to be packed into the box always occupies a corner, and the caving degree of the packing action should be as large as possible, where the caving degree reflects the closeness between the rectangle to be packed and the previously packed rectangles, the details about caving degree will be described in Section 3.2(6). Furthermore, the rectangle should occupy as many corners and overlap as many edges with other previously packed rectangles as possible. Thus, the rectangles are close to each other wisely. Actually, this strategy describes a quasi-human idea, that is, to simulate the behavior of human being in related special work such as bricklaying.

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