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Using pattern matching for tiling and packing problems

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Abstract

This paper describes a new placement method based on pattern matching for 2D tiling problems. Tiling problem can be considered as a special case of bin packing. In the proposed method, the representation of the figures and the board is based on directional chain codes. Contrary to other works that the area has been used for the board and the figures, the proposed method is based on usage of their boundaries instead. With this representation, consideration of the area has been replaced with that of the exact string matching. With the proposed knowledge representation, rotation and reflection of the figures can be considered easily. The results of a hybrid approach of genetic algorithm and simulated annealing have been shown. This new method, introduces a novel approach for handling and solving a variety of 2D-packing problems.

Keywords: Tiling; Direction code; Pattern matching; String matching; 2D cutting and packing; Genetic algorithm

1. Introduction

The tiling problem is to pack a checkerboard (bin) with small pieces. In doing so, the figures must not overlap and they must stay within the confines of the board. In this study, we consider a special case of these sorts of problems i.e., Tiling with polyminoes. Each polymino is a rectilinear polygon that, the length of each edge is a multiple of some predefined unit length.

Most of the previous works make some restrictions on the problem. Many of them use rectangular figures [1], whereas some others use specified or congruent polygons [2]. Tiling problem can be considered as a bin packing or cutting stock problem that the global minima are required. Bin packing and cutting stock problem

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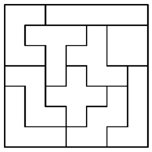

Fig. 1. The only solution for a 7×7 problem without rotation or reflection.

are the famous problems in combinatorial optimization problems and have received considerable amount of attention in the literatures [1,3].

In the next section, we explain two parallel algorithms among the reported algorithms on tiling and packing based on the modified McCulloch–Pitts neuron model [4,5] and a genetic algorithm based algorithm [6]. The first two algorithms are applicable for solving a 7×7 tiling problem with 10 polyminoes; which is the problem to find a single solution among 1.3×10^{14} possible candidates where there exists one and only one solution in the problem without rotation or reflection. Fig. 1 shows this solution of the problem. In the last paper, Pargas and Jain [6] proposed a stochastic approach, based on genetic algorithm and simulated annealing, for 2D-bin packing.

A common point in most of the algorithms on 2D-bin packing with irregular pieces, is the use of surface of the pieces for figures representation in their placement algorithm [4–9]. In this work instead of the surface, boundary of the figures and the bin has been used for their representation. The concept of direction code in image processing field has been used for boundary representation in the literatures. Anand et al. used the boundary of figures, but not for placement [10]. Hochstättler et al. used the boundary information for creating convex polygons [11]. To the best of our knowledge it is the first time that the circumference of the figures and pattern matching are used directly for placement. With this representation, working in the area (2D space) is transformed to working with the strings (1D space); in other words two-dimensional problem reduces to one-dimensional ones.

The rest of this article is organized as follows. In Section 2, we have a review on the related previous works. Section 3 contains a detailed explanation of how we applied pattern matching to the tiling problems. Section 4 gives an overview of the experimental results. The last section concludes with a summary of the paper and a quick look at our work in progress on this subject.

2. Related works

Takefuji and Lee [4] used a Hopfield neural network with optimization approach to solve this problem without rotation or reflection of figures. They defined an energy function that its value equals to zero, in solution state. As an optimization problem, energy function should be minimized. According to Hopfield and Tank [12], they update input of neurons to reach global minima. They reach to global minima in 100% of runs for the 7×7 problem shown in Fig. 1. This problem, can be solved by the three-dimensional $10 \times 7 \times 7$ neural network array, illustrated in Fig. 2.

Asai et al. [5] proposed a modified version of Takefuji and Lee approach. They add a new term (fitting violation function) to the energy function proposed by Takefuji and Lee and used an analog neural network array [5]. Their energy function is given by Eq. (1).

$$E = \frac{A}{2}\sum_{i=1}^{l}\left(\sum_{q=1}^{m}\sum_{r=1}^{n}V_{iqr}-1\right)^2 + \frac{B}{2}\sum_{i=1}^{l}\sum_{j=1}^{m}\sum_{k=1}^{n}f(i)V_{ijk}^2 + \frac{C}{2}\sum_{i=1}^{l}\sum_{j=1}^{m}\sum_{k=1}^{n}g(i)V_{ijk}^2 + \frac{D}{2}\sum_{i=1}^{l}\sum_{j=1}^{m}\sum_{k=1}^{n}V_{ijk}(1-V_{ijk}), \quad (1)$$

where m, n are width and length of the checkerboard, l is the number of figures, $f(i)$ is overlap violation function and $g(i)$ is fitting violation function for ith polymino. A, B, C and D are adjustable parameters, that obtained with experience and trial and error methods. Their method found the global minima for five examples illustrated in Fig. 3.