International Journal of Engineering, Mathematical and Physical Sciences
ISSN: 2517-9934
Vol:1, No:11, 2007

Optimizing Allocation of Two Dimensional Irregular Shapes using an Agent Based Approach

Ramin Halavati, Saeed B. Shouraki, Mahdieh Noroozian, and Saman H. Zadeh

Abstract**—**Packing problems arise in a wide variety of application areas. The basic problem is that of determining an efficient arrangement of different objects in a region without any overlap and with minimal wasted gap between shapes. This paper presents a novel population based approach for optimizing arrangement of irregular shapes. In this approach, each shape is coded as an agent and the agents' reproductions and grouping policies results in arrangements of the objects in positions with least wasted area between them. The approach is implemented in an application for cutting sheets and test results on several problems from literature are presented.

Keywords**—**Optimization, Bin Packing, Agent Based Systems.

I. Introduction

PACKING problems arise from a variety of situations including pallet loading, textile cutting, container stuffing and placement problems. Such problems are optimization problems that are concerned with finding a good arrangement of multiple objects (2-D or 3-D) in a larger containing region without overlap. The usual objective of the allocation process is to maximize the material utilization and hence to minimize the wasted area. The packing problem becomes much simpler when both objects and the containing region are rectangular in shape. Many research works have been done on two and three dimensional rectangular packing problems. However, in many practical applications, objects and containing regions may have irregular shapes. Due to the geometrical complexity introduced by irregular shapes, such problems are not as well studied as rectangular packing.

There are relatively few works on two dimensional packing with arbitrary shapes, compared to 2D rectangle packing. They can be classified into two types, namely nesting and packing. Nesting is an approach in which irregular objects are nested in simpler regular shapes, and these simpler shapes are then packed into an available area ([1], [2], and [3]). On the other hand, straightforward single pass packing strategies involve taking the pieces in order and placing them on the stock sheet according to a given placement policy. This may be repeated several times for different orderings or different placements and the best solution chosen, or a more intelligent method may be used in a single pass ([4], [5], and [6]). There is another approach which has become increasingly popular in recent years. It is to produce an initial layout and then to use small changes in order to improve it. Such an approach may either continuously seek for improvement, or may incorporate meta-heuristic techniques such as simulated annealing or tabu search in order to allow up-hill, or non-improving moves ([7], [8], [9], [10], and [11]).

Ramin Halavati, Saeed B. Shouraki, and Saman H. Zadeh are with Artificial Creatures Lab, Computer Engineering Department, Sharif University of Technology, Tehran, Iran (e-mail: {halavati, sbagheri, harati}@ce.sharif.edu).

Mahdieh Noroozian is with the Computer Engineering Department, Shahid Beheshti University, Tehran, Iran (e-mail: m_noroozian@hotmail.com).

This paper presents a novel approach based on group making policies of agents to solve this problem which resides in the last category. The main idea is to represent each shape with an agent. Agents try to make friendship relations with each other while the relation describes their relative positions. Once a group of friend agents is formed and the group has one agent from each shape, the friendships patterns describe the arrangement of their shapes. Based on the quality of the final arrangement, the friendship patterns are duplicated and some of the relations get permanent. Using this iterative approach, the quantity of the good groups increases gradually and more and more acceptable solutions appear. The model is implemented in Zamin agent-based artificial ecosystem [12] and used in practical purposes for optimization of cutting lines.

The rest of the paper is organized as follows: At the next section, problem representation approach, agents' model and their relations are presented. Section three represents the optimization process and section four presents the experimental results. And the last section presents the conclusion and future works.

II. Problem Definition

This section presents the problem specification approach, the agents' structure and their friendships and groups. The main idea is to represent each shape as an agent. The agents' relations will specify their relative positions and these relations are restricted so that no overlapping friend agents (shapes) would be possible. Shapes are stored and coded as polygons and non-polygonal shapes are coded using their covering polygon.

A friendship between two agents is a relation which states the relative position and orientation of their shapes. As in almost every other approach for arrangement optimization, we have made a simplification assumptions to have a smaller search space: We have assumed that the relation between two shapes can only be made so that two of their vertices (one from each) lay on each other and two edges (that are connected to those two vertices) lay on each other. Figure 1 shows the possible relations for two arbitrary shapes. Using this assumption, the relation between two shapes can be specified by their common vertex and common edges.

Once two agents are friend, they stay together so that their common edges lie on each other, their common vertices are on each other, and they do not have any overlapped parts. If this situation would not be possible, they can not get friends with such relationship. A collection of two or more friend agents is called an agent group.

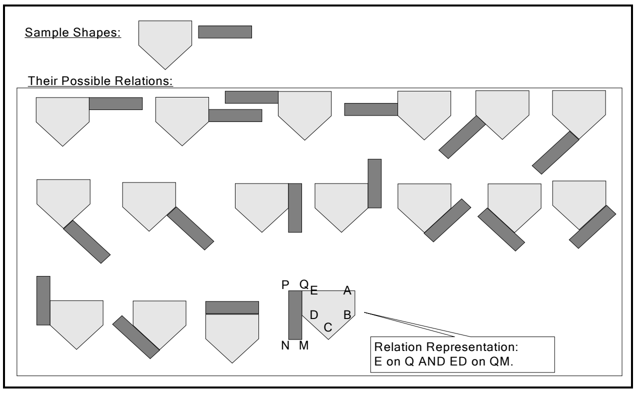

Fig. 1 Possible relations for two arbitrary shapes and the representation of one sample relation

III. The Optimization Process

To initialize the optimization process, a random population of agents with several copies of each agent is created. In every iteration of the process, some of agents try to get friend with other agents or groups of agents. Once an agent, namely agent A, wants to get friend with another agent (agent B), they consider the following restrictions to avoid construction of a group with duplicate or overlapping members:

(1) Agent A and B must not have a friend of the same shape.
(2) After A and B form their relation, none of them or their friends may overlap.

Once a group of friend agents is created and it has exactly one copy of each shape (*a complete group*), the area of the covering rectangle around them and the number of holes in this area is computed and they gain a reward negatively relative to this area and the number of holes inside it (Equation 1). Based on this reward, the group is duplicated and the number of duplications is relative to the ratio of reward to the average of last 10 best given rewards. Therefore, the criteria for rewarding gradually gets harder while better results are found.

Let G be a complete Group :

$$Reward(G) = C_1 \times \left[Area_G \times (1 + Holes_G)\right]^{-1} \qquad (1)$$

$$Copies(G) = \frac{C_2 \times Reward_G}{\sum\limits_{G_i \in Last\ 10\ best\ results.} Reward_{G_i}}$$

One a group is duplicated, the original one and all its copies explode. During an explosion, a few friendship relations inside the group tear apart and agents separate. The probability of breakage of a relation is inversely relative to its age. Thus, relations that have lasted longer will be more probable to be kept for later groups and therefore, relations that have proved to be useful in composing good designs are more probable to stay and groups of fitting shapes are gradually composed. Figure 2 shows a sample of such process.

Agents or agent groups which can not compose complete groups for some time or their quality is too poor in compare with the average result are frequently killed and removed from the population and some random friend agents are created instead to increase the variety. Figure 3 shows a diagram of the entire process.

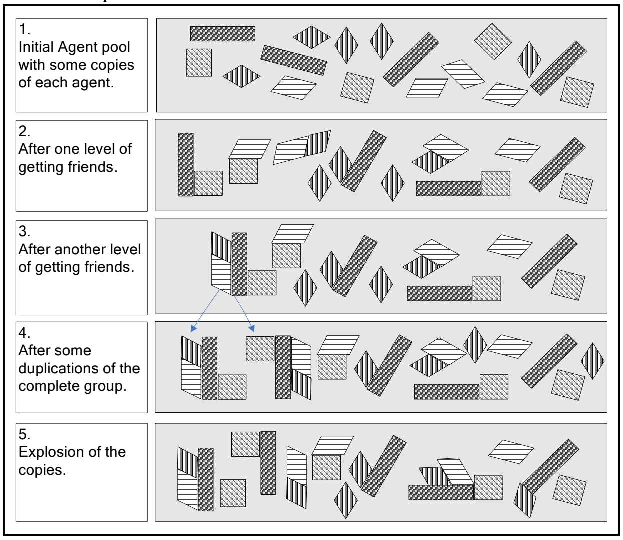

Fig. 2 A sample of the process: Stage 1 shows the initial agents' pool with some copies of each of the four shapes that must be put together. Stages 2 & 3 show the agents' pool after one and two levels of getting friends. In stage 4, a complete group which is formed in stage 3 is duplicated. And in stage 5, the complete groups are exploded and created some smaller groups of agents. The process continues with these agents and groups until when an acceptable complete group is found

IV. Experimental Results

The algorithm is coded using VC++ 6.0 language and run results on a Pentium IV 1800 MHz are presented. The algorithm is tested by a set of benchmarks from literature and results are presented in Table I.

As stated in results table, the average wasted area is less than 2.5% and all results have been achieved in less than 15 minutes of process. Figures 4, 5 and 6 also present some of these results. Figure 7 presents the average waste area for different number of shapes, for Table I samples. As stated there, there is no correlation between number of shapes to optimize and the wasted area, therefore it can be concluded that algorithm's performance does not degrade while shapes number is increased.

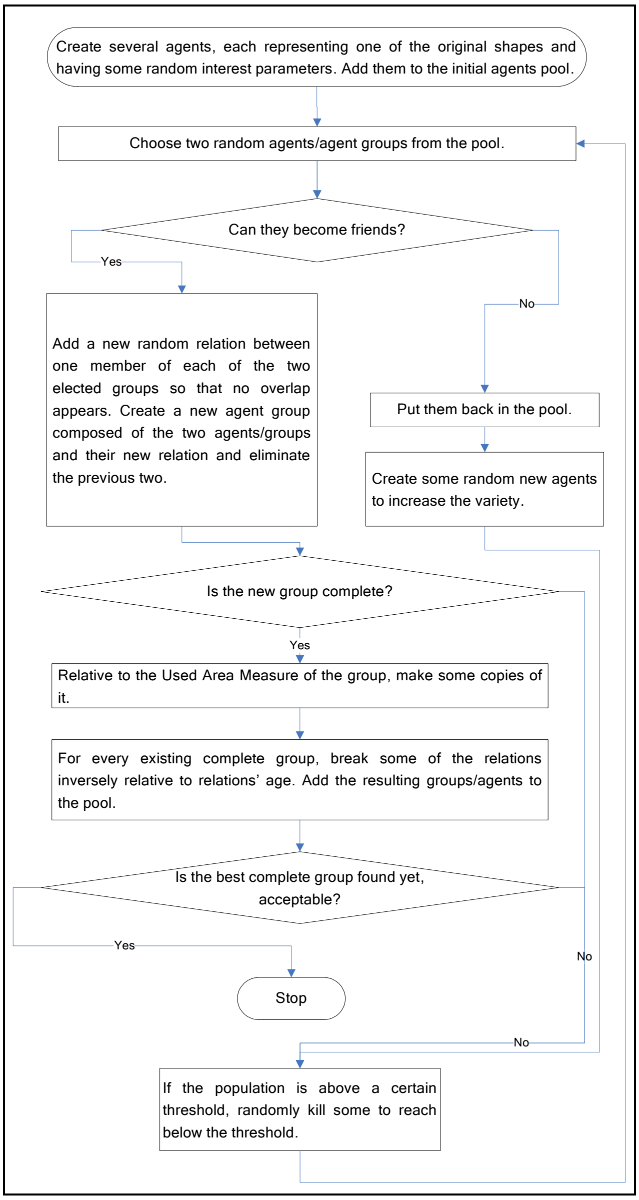

Fig. 3 Diagram of the optimization process

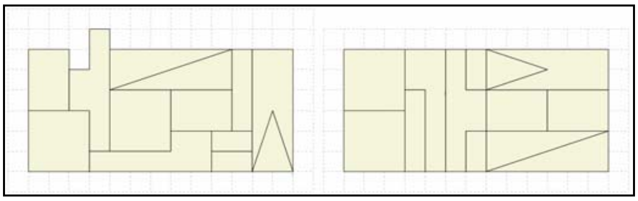

Fig 4 Left side, output from [19], Right side, our programs' result after 5 minutes of process

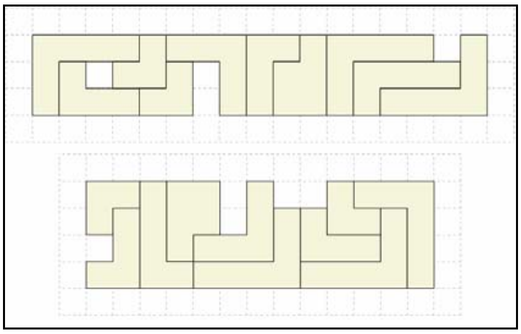

Fig. 5 Top side, output from [20], Bottom side, our algorithm's result after 3 minutes of process

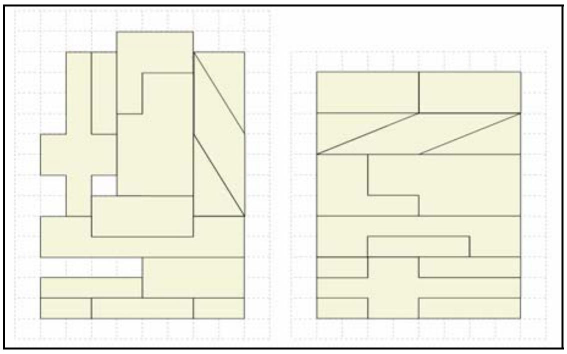

Fig. 6 Left side, output from [19], Right side, our algorithm's result after 10 minutes of process

TABLE I
ALGORITHM RESULTS ON BENCH MARK CASES

Sample Name	No of Shapes	Waist	Source
J1	25	3.8%	[13]
J2	50	6.2%	[13]
Dagli	21	7.5%	[14]
Kendall	13	14%	[17]
D1	31	2.5%	[14]
D2	21	3.0%	[15]
D3	37	2%	[15]
D4	37	1.7%	[15]
Dighe1	16	0%	[16]
Dighe2	10	1.5%	[16]
T1a	17	2.1%	[18]
T1b	17	1.1%	[18]
T1c	17	2.8	[18]
T2a	25	0%	[18]
T2b	25	2.3%	[18]
T2c	25	0.5%	[18]
N1a	17	1.5%	[18]
N1b	17	0	[18]
N1c	17	1.3%	[18]
N2a	25	1.8%	[18]
N2b	25	1%	[18]
N2c	25	0%	[18]
M1	16	0.5	[18]
M2	18	0.9%	[18]
M3	20	0.8	[18]

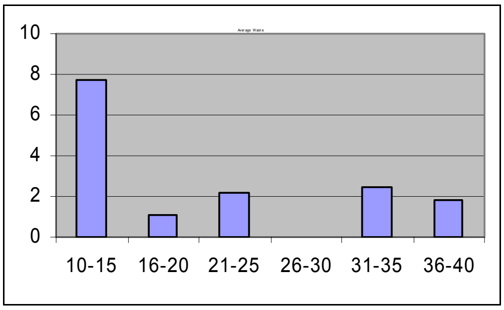

Fig. 7 Average waste area with different shapes number for Table I samples. Vertical Axis: average wasted area, Horizontal axis: Shapes Number

V. Conclusions AND Future Works

Packing problems arise from a variety of situations including pallet loading, textile cutting, container stuffing and placement problems. Such problems are optimization problems that are concerned with finding a good arrangement of multiple objects (2-D or 3-D) in a larger containing region without overlap. This paper presents a novel population based approach to this problem. In this approach, shapes are represented with agents and agents make relations with specify their relative positions. Once a complete group of related agents are composed, their fitness is computed and their relationships are duplicated and sub groups of fitting shapes are composed. The process goes on as long as the fitness is below the required criteria. The approach is implemented in application for cutting sheets and some comparisons with other contributions and some subjective tests are presented which shows that it can successfully arrange the requested shapes and its performance does not degrade with increment of shapes count.

As a next step to this contribution, the following tasks can be done: First, one can alter the restrictions on shapes relations to allow a more variety of arrangement. Second, different process control methods may affect the search speed. Third, adding mutation operator of genetic algorithms to the duplication section may result in a better search of the area and it can be tested in a next contribution.

References

[1] Freeman H. and Shapira R. *Determining the minimum area encasing rectangle for an arbitrary closed curve*. Communications of the ACM, pp 409–413, 1975.

[2] Adamowica M. and Albano A. *Nesting two dimensional shapes in rectangular modules*. Computer Aided Design, pp 27–33, 1976.

[3] Dori D. and Ben-Bassat M.. *Efficient nesting of congruent convex figures*. Communications of the ACM, pp 228– 235, 1984.

[4] Qu W. and Sandersc J. *A nesting algorithm for irregular parts and factors affecting trim losses*. International Journal of Production Research, pp 381–397, 1987.

[5] Dowsland K. and Dowsland W. *Heuristic approaches to irregular cutting probelms*. Working Paper EBMS, 1993.

[6] Albano A. and Sapuppo G. *Optimal allocation of two dimensional irregular shapes using heuristic search method*. IEEE Transactions on Systems, Man, and Cybernetics, pp 242–248, 1980.

[7] Blazewicz H. P., Walkowiak J. *Using a tabu search approach for solving the two-dimensional irregular cutting problem*. Annals of Operations Research, pp 313–327, 1993.

[8] Sakait J. and Hae C. *Two-dimensional packing problems using genetic algorithms*. Engineering with Computers, pp 206–213, 1998.

[9] Keishi S. N., Yoji S. and K. *The multi-bsg: stochastic approach to an optimal packing of convex-rectilinear blocks.* ICCAD98, pp 267–274, January 1998.

[10] Maggie Z. and Wayne W. *Arbitrary rectilinear packing based on sequence pair*. ICCAD98, pp 257–266, 1998.

[11] Chen P., Fu Z., Lim A., and Rodrigues B., *Two dimensional Packing for Irregular Shaped Objects*, In proceedings of the thirty-sixth Hawaii International Conference on System Sciences (HICSS-36) 2003, Big Island, Hawaii, USA.

[12] Halavati R., Shouraki S.B., Zedeh S.H., Lucas C., Zamin, *an Agent Based Artificial Ecosystem*, Proceedings of Forth Hybrid Intelligent Systems Conference (HIS'04) 2004, Kitakyushu, Japan.

[13] Jakobs S., *On genetic algorithms for the packing of Polygons*, European Journal of Operations Research 88, 165-181, 1996.

[14] Ratanapan K. and Dagli C. H., *An object-based evolutionary algorithm for solving irregular nesting problems*. In: Proceedings for Artificial Neural Networks in Engineering Conference (ANNIE '97), vol. 7, ASME Press, New York, pp. 383-388, 1997.

[15] Ratanapan K. and Dagli C. H., *An object-based evolutionary algorithm: the nesting solution*. In: IEEE (eds.) Proceedings of the International Conference on Evolutionary Computation 1998, ICEC '98, IEEE, Piscataway, NJ, USA, pp. 581-586, 1998.

[16] 7. Dighe R. and Jakiela M. J., *Solving Pattern Nesting Problems with Genetic Algo-rithms Employing Task Decomposition and Contact Detection.* Evolutionary Com-putation 3, 239-266, 1996.

[17] Burke E. and Kendall G., *Applying Simulated Annealing and the No Fit Polygon to the Nesting Problem*. Proceedings of the World Manufacturing Congress, Durham, UK, pp. 27-30, 1999.

[18] Hopper E, *Two-dimensional Packing utilizing Evolutionary Algorithms and other Meta-Heuristic Methods*, PHD Thesis, University of Wales, Cardiff, 2000.

[19] Pasha A., *Geometric bin packing algorithm for arbitrary shapes*, MS-Thesis, Center for Intelligent Machines and Robotics, Department of Mechanical and Aerospace Engineering,University of Florida, 2003.

[20] Fujiyoshi K, Murata H, *Arbitrary convex and concave rectilinear block packing using sequence-pair*, Proceedings of the 1999 international symposium on Physical design.