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Solving 2D strip packing problem using fruit fly optimization algorithm

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Abstract

Two dimensional strip-packing problem (2DSPP) consists of packing a set of rectangular items on one strip with a restriction of a maximal width and height. Because the conventional algorithms are still sub-optimal, the researchers tend towards searching for more successful alternative algorithms to solve 2DSPP. The fruit fly optimization algorithm (FOA), which is one of the recently proposed meta-heuristic algorithms, has been successfully applied on many engineering and mathematical problems. This study presents an implementation of FOA for solving non-oriented 2DSPP. The aim of the study is to find the optimal sequence of the rectangles in a strip, and then to place the rectangles by bottom left fill approach to have the optimal height within a fixed width box. The experiments are concluded on online available set of 2DSPP test problems. The preliminary results of the study are compared with the results of some conventional or heuristic approaches which use the same problem set. The experimental results show the promising results are obtained by FOA on solving 2DSPPs.

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Keywords: Fruit fly optimization algorithm; two dimensional strip packing problem; swarm intelligence; heuristic.

1. Introduction

Researchers are investigating the effects of meta-heuristic algorithms on many real world problems including mathematical, biological and mechanical problems. Conventional approaches are widely used and achieve a degree

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of solution quality. But, when the complexity of the problem increased, the conventional approaches lack in some problems. Thus, meta-heuristic approaches become a powerful alternative for overcoming this lack.

There are many meta-heuristic optimization algorithms which are employed in various non-linear optimization problems. Particle swarm optimization (PSO)[1] algorithm simulates the social behaviors of fishes or birds, artificial bee colony (ABC)[2] algorithm simulates the behaviors of the honey bees, ant colony optimization (ACO)[3] algorithm simulates the behaviors of the ants between the nest and the food source, bat algorithm (BA)[4] simulates the echolocation behaviors of the bats, cuckoo search (CS)[5] algorithm simulates obligate brood parasitism of some species of the cuckoos and firefly algorithm (FA)[6] simulates the flashing behavior of the fireflies. All of these algorithms are developed by inspiring the powerful problem solving capability of natural creatures, and these algorithms are still developing by the researchers for utilization or achievement of better success on of many different problems.

Fruit fly optimization algorithm (FOA), one of the novel developed meta-heuristic optimization algorithm on the field, has been utilized in many optimization problems[7]. Shen et al. implemented FOA for parameter optimization of support vector machines for classification of medical data[8]. Niu et al. presented a modified FOA based on differential evolution by modifying the expression of the smell concentration value and its application on gasification process operation optimization[9]. Dai et al. utilized FOA on determining the layout of inertial measurement units in large ships[10]. Yuan et al. suggested a chaotic-enhanced FOA based approach for parameter identification of BIPT system[11]. In another study, Yuan et al. suggested multi-swarm based FOA approach, and presented the suggested systems application on some numerical benchmark problems[12].

Among the various optimization problems, 2 dimensional strip-packing problem (2DSPP) is a real world problem which consists of packing a set of rectangular items on one strip with a restriction of a maximal width and height[13]. There are many studies found in literature in which researchers employ some meta-heuristic approaches for solving 2DSPP[14,15,16,17,18]. This study presents an implementation of FOA for solving non-oriented 2DSPP. The proposed approach is evaluated on 21 well-known online available test dataset, and obtained results are compared with results of the conventional algorithms and results of some studies which uses meta-heuristic algorithms in literature.

The rest of the paper is organized as follows; strip packing problem, FOA and utilization of FOA on 2DSPP is given in section 2 and the experiments and comparisons are presented in section 3. Results and discussion of the study is given in section 4, and the study is concluded in section 5.

2. Materials and methods

2.1. Two dimensional strip packing problem

2DSPPs are combinatorial problems in which the solution space could be very large. 2DSPP consists of packing a set of rectangular items on one strip with a restriction of a maximal width and height[13,19]. There are many heuristic algorithms for solving 2DSPPs. Baker presented bottom-left (BL) heuristics in which the objects are ordered according to their area, and then pushed down to the bottom left as much as possible[20]. Chazelle present an improved version of BL namely bottom left fill (BLF) in which the objects are placed to the bottom left as much as possible considering the spaces[21]. Hooper present an improved version of BL also in which the objects are ordered by using their height, width or area and then then pushed down to the bottom left as much as possible[15]. The improved versions are called according to their order as bottom left decreasing height (BLDH) and bottom left decreasing width (BLDW). Also, the researchers implement meta-heuristic algorithms for solving 2DSPPs. Burke and Kendall implemented genetic algorithm (GA), simulated annealing (SA) and tabu search (TS) algorithms for clustering rectangles[22]. Hopper and Turton also investigated GA, SA, naïve evolution (NA), hill climbing (HC) and random search (RS) approaches for 2D packing problem[23].

Researchers implement their experiments on various test datasets. For the test purpose, the dataset which is presented by Hopper and Turton is used in this study[23]. This dataset has 21 instances in 7 classes and each problem class has 3 instances. Demonstration of the problem dataset is given in Table 1. The suggested approach depends on the BLF heuristic, and the obtained results are compared with the results of both the heuristic approaches including BL and BLF, and the meta-heuristic approaches which were presented in references[15,21,23]. The detailed information about these methods can be reached from the concerned papers[15,21,23].

Table 1. Dataset description

Class	Number of Rectangles	Sheet Width	Optimal Height
C1	16 or 17	20	20
C2	25	40	15
C3	28 or 29	60	30
C4	49	60	60
C5	72 or 73	60	90
C6	97	80	120
C7	196 or 197	160	240

2.2. Fruit fly optimization algorithm

The FOA algorithm is developed by Pan[7]. FOA simulates the osphresis and vision behaviors of a fruit fly on foraging. Fruit flies can match even the food source is 40 km away. During their way to food source, firstly the flies find the orientation of the food source by using osphresis, and fly towards there. Then, they use their vision behavior to get closer to the food source by their partners locations. According to the Pan, the steps of FOA can be summarized as follows[7];

Step-1 : The initial swarm location is set up by using (1) as follows;

$$\begin{aligned} x - axis &= a \cdot (2 \cdot rand - 1) \\ y - axis &= a \cdot (2 \cdot rand - 1) \end{aligned} \tag{1}$$

where a is a problem dependent adjustable parameter which is commonly taken as 1,2 or 10 and $rand$ is randomly generated value within the range $[0\ 1]$.

Step-2 : Calculate each fly's positions which are randomly distributed around the initial swarm location by using (2) given as follows;

$$\begin{aligned} x_i &= x - axis + (2 \cdot rand - 1) \\ y_i &= y - axis + (2 \cdot rand - 1) \end{aligned} \tag{2}$$

where x_i and y_i are position parameters of i^{th} fly, $i = 1,2,..n$ and n is the population size.

Step-3 : Calculate each fly's distance to the origin by using (3) and the smell density values by using (4) given as follows;

$$D_i = \sqrt{x_i^2 + y_i^2} \tag{3}$$

$$S_i = \frac{1}{D_i} \tag{4}$$

where D_i and S_i are the distance and smell density values of the i^{th} fly respectively.

Step-4 : Calculate each fly's judge value which is evaluated by the fitness function related to the problem. The calculation of judge value is given in (5) as;

$$Smell_i = fitness(S_i) \tag{5}$$

where $Smell_i$ is the smell concentration value of the i^{th} fly.

Step-5 : Keep the position of the best fly, update the swarm positions and let the flies fly around to that location. The swarm positions are updated using (6) and the flies positions are updated using (7) given as follows;

$$x - axis = x_b$$
$$y - axis = y_b \quad (6)$$

$$SmellBest = Smell_b \quad (7)$$

where x_b, y_b and $Smell_b$ are the positions and smell concentration value of the best fly respectively, and $SmellBest$ is the best smell concentration value achieved during the iteration processes.

Step-6 : Repeat steps 2 to 4 until the stopping criteria, commonly maximum iteration limit is reached; check if the best smell concentration value is better than old one, if so process step 5.

2.3. Utilization of FOA on 2DSPP

2DSPP consist of a set of rectangular items on one strip with a restriction of a maximal width and height. Dealing with this problem concept, the prime aim of this study is to find the optimal sequence of the rectangular items by using FOA and packing the items by using BLF approach. According to this aim, the sequence is obtained by assuming the ascending order of the smell density values of a fly in FOA. An assumption of this obtainment process can be exemplify as given in Fig. 1 for a problem with 16 items.

S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}	S_{16}
0.35	1.25	0.12	12.10	3.65	4.01	3.60	0.78	0.14	3.15	2.00	2.89	1.74	1.45	9.60	7.85

3	5	1	16	12	13	11	4	2	10	8	9	7	6	15	14

Fig. 1. Illustration of conversion process.

Each fly in FOA algorithm represent the sequence of the rectangles in the problem set. The maximal height is obtained by using the fitness function which calculates the height of the packed items after packing the rectangles utilizing the obtained order in BLF approach. Thus, the aim of FOA is to minimize the maximal height of the packed rectangles. So, the best solution (best smell density value) shows the optimum sequence of the rectangles.

3. Results and discussion

FOA is utilized for solving 2DSPP in this study. The order of the smell density values is used to obtain the sequence of the rectangles in the problem. Then, the sequence is employed in packing the rectangles by using BLF approach. The suggested approach is evaluated on the dataset including 21 well-known test problems which was presented by Hopper and Turton[23].

There are three sub-problem for each class in the dataset. The experimental results of each class is given being as the average of the sub-problems of the corresponding class. In order to achieve more reliable and stable results, the suggested approach is run 50 times with different randomized seeds of the datasets for each sub-problem, and the average value of the 50 run is used in the comparisons.

The population size and the maximum iteration number parameters of the suggested approach are used as 50 and 1000 respectively. The dimension of the flies are utilized as being equal to the number of the rectangles corresponding to each problem class as expected. In order to compare the obtained results of the suggested approach with the results of the Hopper and Turton, the fitness functions are proposed to calculate the relative distance of the best solution to the optimum height.

The relative distances of the best solutions to optimum heights are given in Table 2 and Table 3 for comparing with the heuristic approaches and meta-heuristic approaches respectively. The results except the suggested approach (FOA+BLF) are directly taken from[23]. The results of the suggested approach are compared with the results of heuristic methods BL, BLF and variations of BL and BLF in Table 2. Besides, the results of the suggested approach are compared with the results of the meta-heuristic methods including BLF and some hybrid methods are given in Table 3. Also, the rank analysis is evaluated for the results given in both Table 2 and Table 3.

According to the test results given in Table 2, the suggested approach achieves better results than BL, the variants of BL and BLF for each problem class, better results than the variants of BLF for C1, C2 and C3 class problems. The results of the suggested approach are slightly worse than the results of the two BLF variants which are BLF-DH and BLF-DW for relatively bigger problems C4, C5, C6 and C7. This situation is expected because the BLF-DH and BLF-DW methods arrange (sort) the problem set according to the rectangles height and width properties.

According to the test results given in Table 3, the suggested approach achieves better results than the other hybrid meta-heuristic algorithms for C1 class problem. The results of the suggested approach are relatively worse but competitive than the results of the hybrid approaches for more complex problem classes. Also, the suggested approach is proposed utilizing the original version of FOA in this study. According to the literature, the original version of FOA has some disadvantages based on its formulation[9,24]. Thus, the suggested system might achieve better results by using the improved or hybrid versions of FOA for the same way.

According to the obtained results, it can be said that the proposed system can be used as an alternative approach for solving 2DSPP.

Table 2. Comparison of FOA+BLF with heuristics

Class	**FOA+BLF**	**BL**	**BL-DH**	**BL-DW**	**BLF**	**BLF-DH**	**BLF-DW**
C1	2	25	17	18	14	11	11
Rank	*1*	*6*	*4*	*5*	*3*	*2*	*2*
C2	7	39	68	31	20	42	12
Rank	*1*	*5*	*7*	*4*	*3*	*6*	*2*
C3	6	33	27	24	17	12	12
Rank	*1*	*6*	*5*	*4*	*3*	*2*	*2*
C4	7	33	21	18	15	6	5
Rank	*3*	*7*	*6*	*5*	*4*	*2*	*1*
C5	7	31	18	22	11	5	5
Rank	*2*	*6*	*4*	*5*	*3*	*1*	*1*
C6	7	34	19	21	12	5	5
Rank	*2*	*6*	*4*	*5*	*3*	*1*	*1*
C7	6	41	31	29	10	4	5
Rank	*3*	*7*	*6*	*5*	*4*	*1*	*2*
Mean Rank	*1.86*	*6.14*	*5.14*	*4.71*	*3.29*	*2.14*	*1.57*
Final Rank	*2*	*7*	*6*	*5*	*4*	*3*	*1*

Table 3. Comparison of FOA+BLF with meta-heuristics

Class	**FOA+BLF**	**GA+BLF**	**NE+BLF**	**SA+BLF**	**HC+BLF**	**RS+BLF**	**BLF**
C1	2	4	5	4	7	5	11
Rank	*1*	*2*	*3*	*2*	*4*	*3*	*5*
C2	7	7	7	6	10	8	16
Rank	*2*	*2*	*2*	*1*	*4*	*3*	*5*
C3	6	5	4	5	7	7	12
Rank	*3*	*2*	*1*	*2*	*4*	*4*	*5*
C4	7	3	4	3	7	7	5
Rank	*4*	*1*	*2*	*1*	*4*	*4*	*3*
C5	7	4	4	3	6	6	5
Rank	*5*	*2*	*2*	*1*	*4*	*4*	*3*
C6	7	4	4	3	7	7	5
Rank	*4*	*2*	*2*	*1*	*4*	*4*	*3*
C7	6	5	5	4	7	7	5
Rank	*3*	*2*	*2*	*1*	*4*	*4*	*2*
Mean Rank	*3.14*	*1.86*	*2.00*	*1.29*	*4.00*	*3.71*	*3.71*
Final Rank	*4*	*2*	*3*	*1*	*6*	*5*	*5*

4. Conclusion

This study presents an implementation of recent developed algorithm namely FOA on 2DSPP. FOA is used to obtain the sequence of the rectangles in the dataset. Then, the rectangles are packed employing BLF approach according to the sequence obtained by FOA. The suggested approach is evaluated on 21 test datasets. The preliminary results of the study are compared with the results of some conventional and heuristic approaches which use the same problem dataset. The experimental results show that the proposed approach could be an alternative method on solving 2DSPP. Future works include implementing improved/hybrid versions of FOA for solving 2DSPP.

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References

1. Kennedy J and Eberhart R. Particle swarm optimization. In: *IEEE International Conference on Neural Networks*; 1995. 1-6, p. 1942-1948.
2. Karaboğa D. An idea based on honey bee swarm for numerical optimization. In: *Technical Report-TR06*, 2005, Erciyes University, Engineering Faculty, Comput. Eng.Dep.
3. Dorigo M, Maniezzo V and Colorni A. Ant system: Optimization by a colony of cooperating agents. In: *IEEE Transactions on Systems Man and Cybernetics Part B-Cybernetics;* 1996. 26(1), p. 29-41.
4. Yang XS. A New Metaheuristic Bat-Inspired Algorithm. *Nicso 2010: Nature Inspired Cooperative Strategies for Optimization;* 2010. 284: p. 65-74.
5. Yang XS and Deb S. Cuckoo Search via Levey Flights. In: *2009 World Congress on Nature & Biologically Inspired Computing (Nabic 2009);* 2009: p. 210-214.
6. Yang XS, Hosseini SSS and Gandomi AH. Firefly Algorithm for solving non-convex economic dispatch problems with valve loading effect. *Applied Soft Computing,* 2012. 12(3): p. 1180-1186.
7. Pan WT. A new Fruit Fly Optimization Algorithm: Taking the financial distress model as an example. *Knowledge-Based Systems*; 2012. 26: p. 69-74.
8. Shen L et al. Evolving support vector machines using fruit fly optimization for medical data classification. *Knowledge-Based Systems*, 2016. 96: p. 61-75.
9. Niu JW et al. Fruit fly optimization algorithm based on differential evolution and its application on gasification process operation optimization. *Knowledge-Based Systems*, 2015. 88: p. 253-263.
10. Dai HD et al. Optimization about the layout of IMUs in large ship based on fruit fly optimization algorithm. *Optik,* 2015. 126(4): p.490-493.
11. Yuan XF et al. Parameter identification of BIPT system using chaotic-enhanced fruit fly optimization algorithm. *Applied Mathematics and Computation*, 2015. 268: p. 1267-1281.
12. Yuan XF et al. On a novel multi-swarm fruit fly optimization algorithm and its application. *Applied Mathematics and Computation*, 2014. 233: p. 260-271.
13. Hopper E. *Two-dimensional Packing utilising Evolutionary Algorithms and other Meta-Heuristic Methods.* 2000, University of Wales.
14. Cintra GF et al. Algorithms for two-dimensional cutting stock and strip packing problems using dynamic programming and column generation. *European Journal of Operational Research,* 2008. 191(1): p. 61-85.
15. Hopper E and Turton BCH. A review of the application of meta-heuristic algorithms to 2D strip packing problems. *Artificial Intelligence Review*, 2001. 16(4): p. 257-300.
16. Riff MC, Bonnaire X and Neveu B. A revision of recent approaches for two-dimensional strip-packing problems. *Engineering Applications of Artificial Intelligence*, 2009. 22(4-5): p. 823-827.
17. Thomas J and Chaudhari NS. Hybrid Approach for 2D Strip Packing Problem Using Genetic Algorithm. *Advances in Computational Intelligence,* Pt I, 2013. 7902: p. 566-574.
18. Zhang DF et al. A meta-heuristic algorithm for the strip rectangular packing problem. *Advances in Natural Computation,* Pt 3, Proceedings, 2005. 3612: p. 1235-1241.
19. Neveu B et al. A Strip Packing Solving Method Using an Incremental Move Based on Maximal Holes. *International Journal on Artificial Intelligence Tools,* 2008. 17(5): p. 881-901.
20. Baker BS, Coffman EG and Rivest RL. Orthogonal Packings in 2 Dimensions. *Siam Journal on Computing,* 1980. 9(4): p. 846-855.
21. Chazelle B. The Bottom-Left Bin-Packing Heuristic - an Efficient Implementation. *IEEE Transactions on Computers;* 1983. 32(8): p. 697-707.
22. Burke E and Kendall G. Comparison of meta-heuristic algorithms for clustering rectangles. *Computers & Industrial Engineering,* 1999. 37(1-2): p. 383-386.
23. Hopper E and Turton BCH. An empirical investigation of meta-heuristic and heuristic algorithms for a 2D packing problem. *European Journal of Operational Research,* 2001. 128(1): p. 34-57.
24. Dai HD et al. Comment and improvement on "A new Fruit Fly Optimization Algorithm: Taking the financial distress model as an example". *Knowledge-Based Systems,* 2014. 59: p. 159-160.