Application of Selective Breeding Algorithm for One-Dimensional Bin Packing Problem with Precedence Constraints

P.Sriramya[1], B.Parvathavarthini[2]

[1]Department of Computer Science and Engineering, Sathyabama University, Chennai 600119, Tamilnadu, India
[2]Department of Computer Application, St. Joseph's College of Engineering, Chennai 600119, Tamilnadu, India
Email: sriramya82@yahoo.com

Abstract: The bin packing optimization problem packs a set of objects into a set of bins so that the amount of wasted space is minimized. The bin packing problem has many important applications. These include multiprocessor scheduling, resource allocation and real world planning, packing, routing and scheduling optimization problems. The bin packing problem is NP-hard. Since there is little hope in finding an efficient deterministic solution to the bin packing problem approximation methods have been developed. The advantage of these methods is that they have guaranteed packing performance bounds. In many practical applications of bin packing a small improvement in packing efficiency can result in great cost savings. In this paper, a new selective breeding algorithm (SBA) is proposed for solving the one dimensional bin packing problem with precedence constraints. The proposed algorithm made use of the trail information which is deposited between the item and the item selected position, and pheromone summation rules was adopted. The effectiveness of SBA algorithm is investigated through computational results for test instances. The performance of SBA algorithm is competent and efficient to that of other approaches reported in literature.
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I. INTRODUCTION

Bin packing problem is concerned with minimizing the number of bins into which small items need to be packed in. There are several different versions of this problem appearing in single dimension or multiple dimensional items and bins. The solution to this problem has several industrial applications. Example applications are wood and glass industries, vehicle loading, vehicle routing. This is an NP-hard problem [1] and many authors have developed algorithms to solve the classical single-dimensional items and with no additional constraints problem. Eilon and Christofides had developed a heuristic procedure to solve the problem with different objective viz. minimize the number of bins; minimize the un-accommodated number / value of items; and a combination of both [2]. Later Johnson et al had developed first fit decreasing (FFD) and best fit decreasing (BFD) algorithms to solve the one-dimensional bin-packing problem [3]. Gupta et al. (1999) had developed minimum bin slackness algorithm to solve the bin-packing problem [4]. In the actual application, bin packing problem with precedence constraints is more complex. Considering the One-Dimensional Bin Packing Problem with Precedence Constraints character, such as precedence relations between items, variability of operation times, none of the single heuristic rule methods guarantees an optimal solution. Meta heuristics, such as Simulated Annealing [5], Tabu Search [6], Genetic Algorithm [7, 8] and Ant Colony Optimization (ACO) algorithms [9] to provide an alternative to traditional optimization techniques.

Given a set of identical capacitated bins, a set of weighted items and a set of precedence among such items in determining the minimum number of bins that can accommodate all items and can be ordered in such a way that all precedences are satisfied. The problem, denoted as the Bin Packing Problem with Precedence Constraints (BPP-P), has a very intriguing combinatorial structure and models many assembly and scheduling issues [10].

This paper aims to present an effective and efficient selective breeding algorithm for bin packing problem with precedence constraints. Artificial selection practiced by breeders of agricultural plants and domesticated animals. Breeders of animals and plants in today's world are looking to produce organisms that will possess desirable characteristics, such as high crop yields, resistance to disease, high growth rate and many other phenotypical characteristics that will benefit the organism and species in the long term. This process of selecting parents is called artificial selection or selective breeding and poses no threat to nature from man manipulating the course of nature. It has allowed our species to increase the efficiency of the animals and plants we breed, such as increasing milk yield from cows by continuously breeding selected cows with one another to produce a hybrid [11].

This paper is organized as follows: Chapter 2 discusses the problem conceptualization and formulation. Chapter 3 discusses Selective Breeding Algorithm to solve the problem. Chapter 4 and 5 contains computational results and conclusions.

II. Problem Formulations

The bin packing problem is defined as follows: given a number of items i=1,…, n of integer sizes t_i, what is the minimum number of bins, each having the same integer capacity c, necessary to pack all items. In bin packing problem, the precedence constraints between items should be considered [12].

The notation for the bin packing problem with precedence constraints as follows:

I be item set (I = {1,2,…, i,…, m}).
J be bin set (J = {1,2,…, j,…, n}).
c be bin capacity.
n be number of items.
t_i be size of item i=1, …, n.
m be number of bins.
S_k be set of items which are currently assigned to bin
k=1, …, m.
$t(S_k)$ be load of bin k,
i.e. sum of the sizes of items assigned to bin k, given a set of items S_k, $t(S_k)= \Sigma_{j\in S_k} t_j$
UB be the upper bound of the number of bins.
R={all (h, i)|h is an immediate predecessor of i) (i.e., the arc set of the precedence network), $P(i)=\{h\in I|(h, i)\in R\}$ (i.e., the immediate predecessors of item i).

Mathematical expression of bin packing with precedence constraints are as follows:

$$\text{Min } f(x) = \sum_{J=1}^{UB} \max \{x_{ij}\} \qquad 1\le i\le n \qquad (1)$$

Subject to:

$$\sum_{j=1}^{n} x_{ij} = 1 \qquad \forall i \in I, \qquad (2)$$

$$\sum_{j=1}^{m} t_i x_{ij} \le c \qquad \forall i \in J, \qquad (3)$$

$$x_{ik} \le \sum_{j=1}^{k} x_{hj} \qquad \forall i \in J, \forall i \in I \text{ and } \forall h \in P(i) \qquad (4)$$

$$x_{ij} = 0, 1, \forall i \in I \text{ and } \forall i \in J \qquad (5)$$

x_{ij} is equal to 1 if item i is assigned to bin k, otherwise x_{ij} is equal to zero.

The objective function (1) minimizes the number of bins. Condition (2) ensures that every item is assigned to a bin. As a result of condition (3), the bin capacity is not exceeded by the sum of the sizes of items assigned to the bin. Constraint (4) represents the precedence constraints ensuring that no item is assigned to an earlier bin than a predecessor. (5) guarantees that each variable assume only values of 0 or 1, that is, a item cannot be split among two or more bins.

The items can be summarized and visualized by a precedence graph. An example of bin packing problem with precedence constraints, refer to Figure 1. Each of the 7 nodes represents an item to be assigned, and an edge connecting two nodes indicates that one item must be completed before the other. The number in the circle of each node indicates the serial number of item, and node weights above the circle indicate the size of item.

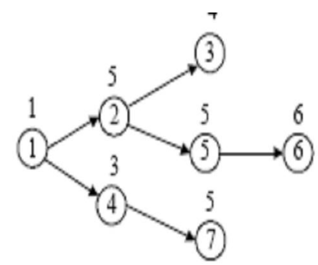

Figure 1. Precedence graph of the bin packing problem with precedence constraints

I. Results and Discussion

ROSZIEG benchmark problem [12] is solved by the proposed Selective Breeding Algorithm and the problem refers to Figure 2. Given bin capacity c=21, the proposed SBA finds the optimal number of bins of Roszieg problem within 1 second, and get the best solution 6 in 2nd iteration. In the first iteration, the proposed SBA gets the solution of 7. The proposed SBA Algorithm has the advantages of quick search by using breeding process. Assignment schedules of the problem generated by SBA refer to Table I.

II. Selective Breeding Algorithms

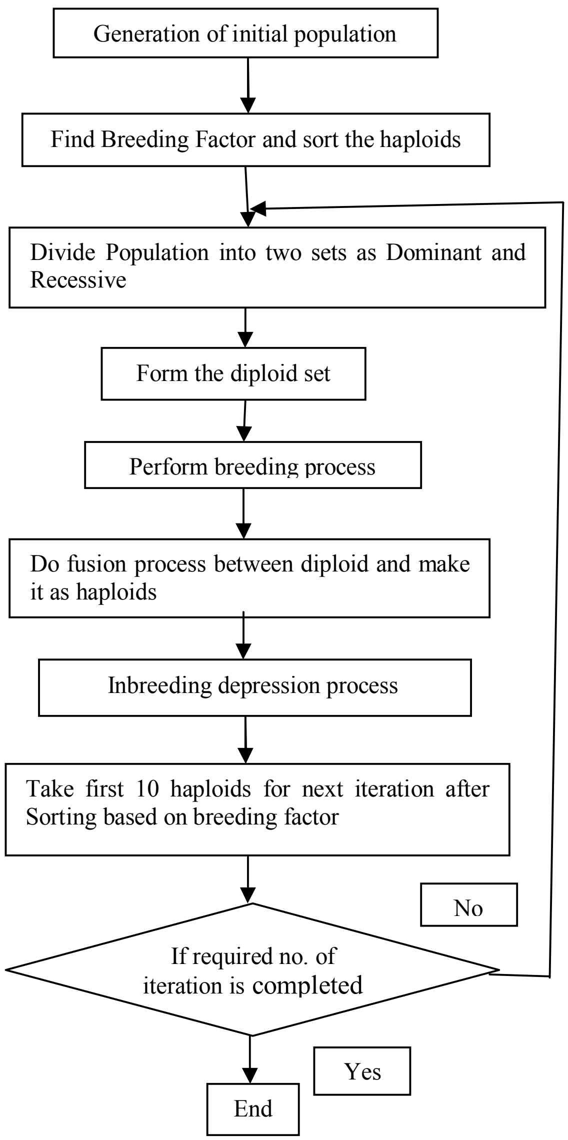

Figure 1. Flow chart for Selective Breeding Algorithm

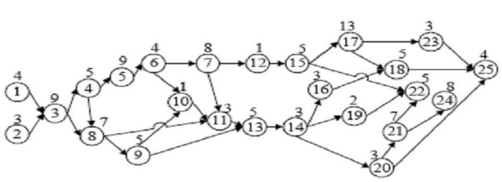

Figure 2. Network representation of the problem

TABLE I . ASSIGNMENT SCHEDULES OF THE PROBLEM GENERATED BY IMPROVED SBA

Bin	Assigned items	Bin load	idle
1	2, 1, 3, 4	21	0
2	8, 5, 9	21	0
3	6, 10, 7, 11, 13	21	0
4	12, 15, 14, 19, 20, 21	21	0
5	16, 17, 18	21	0
6	23, 22, 24, 25	20	1

The proposed SBA is applied to different bin capacity of the problem. Modification of the first fit descending (MFFD) heuristic and improved Ants Colony Optimization algorithm results are taken from literature and presented in a summarized form in Table II for comparison. The second column (headed by m_{min}) contains the best known solution, and the third, fourth and fifth column contain the values of the solutions found by MFFD, ACO and SBA respectively.

TABLE II EXPERIMENTAL RESULTS FOR DIFFERENT BIN CAPACITY

C	$m_{\min}$	MFFD	ACO	SBA
14	10	10	10	10
16	9	-	-	9
18	8	8	8	8
21	6	7	6	6
25	6	6	6	6
32	4	5	4	4

As can be observed in Table II, the proposed SBA algorithm could find the optimal solution in all of the instances. Whereas, there are two instances out of five instances that MFFD found such an allocation with one station more than the optimal. The result shows that the proposed SBA gives optimal solution for all tested instances.

III. Conclusion

In this paper, a newly developed Selective Breeding algorithm is applied on Bin packing with precedence constraints. The computational results show that this new SBA algorithm produced optimal solutions for all the different bin capacity tested. An experimental validation on ROSZIEG benchmark precedence problem shows the feasibility, the efficiency, and the flexibility of this Selective Breeding approach. Computational experience with the algorithm has shown that the algorithm performs remarkably well.

References

[1] E. G.Coffman, , M. R. Garey, and D. S. Johnson, An application of bin packing to multi-machine scheduling, *SIAM Journal of Computing,* 1978, Volume 7, Issue 1, pp. 1-17.

[2] S. Eilon, and N. Christofides, The loading problem, *Management Science,* 1971, Volume 17, Issue 5, pp. 259-268.

[3] D.S.Johnson, A. Demers, and J. D. Ullman, Worst case performance bounds for simple one-dimensional packing algorithms, *SIAM Journal of Computing,* 1974,Volume 3, Issue, 4, pp. 299-325.

[4] J. N. D.Gupta, and J. C. Ho, A new heuristic algorithm for the one dimensional bin-packing problem, *Production Planning and Control*, 1999, Volume 10, Issue 6, pp. 598-603.

[5] M. J. Brusco, G. M. Thompson, and L. W. Jacobs, "A morph-based Simulated annealing heuristic for a modified bin-packing problem," *Journal of the Operational Research Society*, 1997, vol. 48, pp. 433-439.

[6] A. Lodi, S. Martello, and D. Vigo, "TSpack: A unified Tabu Search code for multi-dimensional bin packing problems," *Annals of Operations Research*, 2004, Vol. 131, pp. 203-213.

[7] F. T. S. Chan, K. C. Au, L. Y. Chan, and T. L. Lau, "Using Genetic algorithms to solve quality-related bin packing problem," *Robotics and Computer-Integrated Manufacturing*, 2007, Vol. 23, pp. 71-81.

[8] G. Levitin, J. Rubinovitz, and B. Shnits, "A Genetic algorithm for robotic assembly line balancing," *European Journal of Operational Research*, vol. 168, pp. 811-825, 2006.

[9] M. Dorigo and C. Blum, "Ant colony optimization theory: A survey," *Theoretical Computer Science*, vol. 344, pp. 243-278, 2005.

[10] http:\\www.biology-online.org/2/12_ selective_breeding .html

[11] Zeqiang Zhang, Wenming, Liasheng Tang, Yue Cheng, "Improved Ant Colony Optimization for One Dimensional Bin Packing Problem with Precedence Constraints", Third International Conference on Natural Computation, IEEE Transactions, 2007.

[12] www.or.unimore.it/BPP_P/instances.html

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