Study on Improved Ant Colony Optimization for Bin-Packing Problem

Suxin Wang
Northeastern University at Qinhuangdao
Qinhuangdao Hebei, China
wsx96@mail.neuq.edu.cn

Leizhen Wang
Northeastern University at Qinhuangdao
Qinhuangdao Hebei, China
wlz@mail.neuq.edu.cn

Ruiping Shi
Shijiazhuang information engineering vocational college,
Shijiazhuang Hebei, China

Meng Ge
Northeastern University at Qinhuangdao
Qinhuangdao Hebei, China
gemeng1973@163.com

***Abstract*—Improved ant colony optimization (ACO) was applied to solve bin-packing problem. A tabu matrix bases on goods is established for ant colony optimization (ACO). Tabu matrix's every column corresponds to goods. Matrix has two rows, first row corresponds to goods load visit state, and second row corresponds to vehicle that ferries the goods. Ant state transfer probability is improved to solve bin-packing problem. According to ants tabu table, all the goods are searched by ants and satisfy the vehicle constrain.Illustrated with a practical case, ACO is feasible for bin-packing problem.**

Keywords- Bin-Packing Problem; Ant Colony Optimization; Assignment

I. INTRODUCTION

The bin packing problem (BPP) is a NP-hard combinatorial optimization problem where the primary aim is to pack a finite number of items using the least bins possible. It involves a number of practical constraints and requirements to be satisfied, such as weight, centre of gravity, irregularly shaped bins and priority items. BPP has many important applications such as multiprocessor scheduling, resource allocation, transportation planning, real-world planning, and packing and scheduling optimization problems. Many algorithms are using to deal with BPP, such as improved approximation algorithms [1], particle swarm optimization [2], and ant colony optimization [3], genetic approach [4, 5].

In the actual application, bin-packing problem is complex, to get the global solution, BPP model and its detailed design procedures are proposed in this paper. Choose suitable bin-packing solution by making good use of vehicle capacity and use minimum vehicle number are BPP targets.

II. BPP PARAMETER DEMARCATE AND MODEL

A. BPP Model Parameter Demarcate

BPP general description as follow: there are N goods u_1, u_2,…, u_n, …, u_N, which will load on K vehicle B_1, B_2, …, B_k…, B_K (K≤N),goods volume are $v_1(u_1)$, $v_2(u_2)$, …, $v_n(u_n)$, …, $v_N(u_N)$, vehicle B_k capacity is V_k. If vehicle B_k is loaded, y_k =1, other wise y_k =0. If goods u_n are in vehicle B_k, x_{kn} =1, other wise x_{kn}=0. In vehicle capacity, a vehicle can load one or more than one goods.

B. BPP Model

Objective function:

$$min\ f = \sum_{1}^{K} y_k \tag{1}$$

Subject to:

$$\sum_{n=1}^{N} x_{kn} v_n \le V_k \tag{2}$$

$$\sum_{k=1}^{K} x_{kn} = 1 \tag{3}$$

In the above proposed model, the objective function (1) is to minimize vehicle number. The constraints for vehicle load are showed in (2). The same goods is ferried by one vehicle is showed in (3).

III. BPP MODEL STRATEGY BASED ON ANT COLONY OPTIMIZATION

The ant colony optimization (ACO) [6] is a kind of simulant evolution algorithm based on real ant colony which is proposed by Italy experts M.Dorigo, V.Maniezzo and A.Colorni.

An important and interesting behavior of ants in colonies is their foraging behavior and in particular how they can find the shortest paths between food sources and their nest. While walking from food sources to the nest and vice versa, ants deposit on the ground a substance called a pheromone, forming in this way a pheromone trail. Ants can smell a pheromone, and when choosing their way they tend to choose paths marked by strong pheromone concentrations. When several paths are available from the nest to a food source, a colony of ants may be able to exploit the pheromone trails left by the individual ants to discover the shortest path from the nest to the food source and back. ACO is a multiagent heuristic search approach to difficult combinatorial optimization problems.

*A. **Parameter Representation***

In ACO, one dimensional table tabuk denotes depots state which will be visited by ant k, depots state is 0 when the depot was visited, otherwise is 1. Tabu table needs to be modified to solve BPMDVSP.

Considering BPP, a tabu matrix bases on goods is established for ant colony optimization (ACO). Tabu matrix's every column corresponds to goods. Matrix has two rows, first row corresponds to goods load visit state, and second row corresponds to vehicle that ferries the goods.

Vehicle serial number that ferry goods initialize as -1, when goods is load, goods visit state is 0, vehicle serial number is the vehicle that ferry goods, and otherwise goods visit state is 1. Tabu matrix expression is presented in Fig 1.

$$\begin{array}{ll} & \text{goods} \quad \begin{array}{cccccc} u_1 & u_2 & \cdots & u_n & \cdots & u_N \end{array} \\ \text{tabu=} & \begin{array}{c} \text{goods visit state} \\ \text{vehicle serial number that ferry goods} \end{array} \left[\begin{array}{cccccc} 0 & 1 & & 0 & & 0 \\ B_k & -1 & \cdots & B_{k+2} & \cdots & B_k \end{array} \right] \end{array}$$

Figure 1. Tabu matrix expression

B. State Transfer Rule

In the construction of a solution, ants select the following depot to be visited through a stochastic mechanism. p^k_{ij} is ant k state transfer probability from good u_i to u_j. When ant k load good u_i, the probability of load good u_j is given by:

$$p^k_{ij} = \begin{cases} \dfrac{(\tau_{ij})^\alpha (\eta_{ij})^\beta}{\sum\limits_{h \in \text{tabu}} (\tau_{ih})^\alpha (\eta_{ih})^\beta} & j \in \text{matrix and } i \neq j \\ 0 & \text{otherwise} \end{cases} \quad (4)$$

u_j is a goods and isn't yet visited by the ant k. τ_{ij} is the quantity of pheromone laid on edge (u_i, u_j) by ant k . The parameters α and β control are the relative importance of the pheromone versus the heuristic information η_{ij}, which is given by:

$$\eta_{ij} = 1/(B_{ki} - v_j(u_j)) \quad (5)$$

B_{ki} is vehicle B_k load volume when it loads good u_i.

According to the normal state transferring rule calculate p^k_{ij}, if vehicle B_k has more than one goods with biggest p^k_{ij}, select one random good u_j to improve the possibility of getting the global solution. The vehicle with biggest p^k_{ij} can walk to u_j. If there is more than one vehicle with biggest p^k_{ij}, one random vehicle with biggest p_{ij} can walk to u_j to improve the possibility of getting the global solution.

C. Pheromone Update Rule

In iteration, the pheromone values are updated by all the ants that have built a solution in the iteration itself. τ_{ij} is updated as follows:

$$\tau_{ij} = (1-\rho)\tau_{ij} + \sum_{k \in m} \Delta\tau^k_{ij} \quad (6)$$

$$\Delta\tau^k_{ij} = \begin{cases} Q/L_k & \text{if ant } k \text{ used edge } (i, j) \text{ in its tour} \\ 0 & \text{otherwise} \end{cases} \quad (7)$$

Where ρ is the evaporation rate, Q is a constant, L_k is the load volume constructed by vehicle B_k. No modifications are needed for update rules.

D. Step of the Algorithm

When initialize ant colony, set ants randomly on goods, and the correlative tabu matrix elements need to be modified. A generic ACO procedure is given as follows:

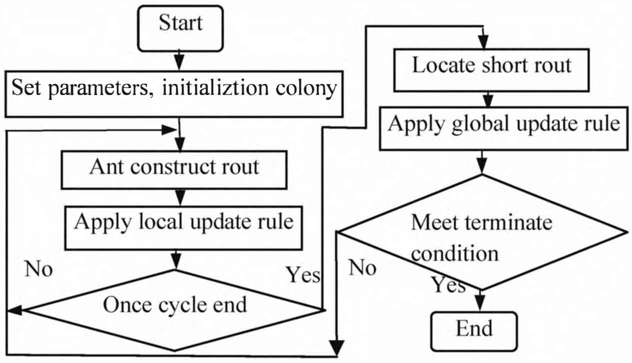

Figure 2. ACO Procedure for BPP

IV. COMPUTATIONAL RESULTS

A. Example

Goods information is showed in TABLE1, set Q_v =10m^3. It is required to finish goods consignment with optimized vehicle load and without overload, if overload happened, objective function should be punished.

TABLE I. GOODS INFORMATION

Goods number	v_n/ m^3	Goods number	v_n/ m^3	Goods number	v_n/ m^3	Goods number	v_n/ m^3
0	1.05	11	4.02	22	1.8	33	1.2
1	1.98	12	2.78	23	3.8	34	1.2
2	2	13	3.22	24	4	35	3.89
3	3.14	14	2.6	25	5.46	36	1.01
4	2.86	15	1.23	26	3.54	37	1.23
5	2.17	16	0.65	27	1.6	38	1
6	4.8	17	2.4	28	2.46	39	3.2
7	5.2	18	0.87	29	2.2	40	0.8
8	2.3	19	1.54	30	2.8	41	1.1
9	3.8	20	5.6	31	3.2		
10	2	21	4.4	32	3		

B. Optimized Solution

ACO parameters set as follows: α=1, β=5, ρ=0.7, Q=100, iterate 20 times.

Run 40 times, optimized solution can be seen in Tab 2. In Tab 2 we can see, 12 vehicles take part in goods convey and there aren't vehicle overload. Goods sum volume is 109.1 m3, and 11 vehicles are needed to convey goods. Vehicles number difference is due to ACO is not Exact Algorithm.

TABLE II. OPTIMIZED SOLUTION

vehicle number	solution 1		solution 2	
	Goods number	*Volume / m^3*	*Goods number*	*Volume / m^3*
1	12,35,39	9.87	16,22,29,35,40	9.34
2	0,6,31	9.05	0,12,13,27,41	9.75
3	5,28,30,34,38	9.63	23,2	5.8
4	8,26,32	8.84	6,7	10.0
5	3,9,16,19	9.13	4,9,28	9.12
6	2,7,15,18	9.30	5,24,26	9.71
7	17,21,27	8.40	25,30	8.26
8	4,25	8.32	20,21	10.0
9	11,13,33,40	9.24	1,3,14,38	8.72
10	20,23	9.4	11,31,34,36	9.43
11	1,24,29,36	9.19	15,19,32,39	8.97
12	10,14,22,37,41	8.73	8,10,17,18,33,37	10.0

V. CONCLUSIONS

Improved ant colony optimization (ACO) was applied to solve bin-packing problem. A tabu matrix bases on goods is established for ant colony optimization (ACO). Tabu matrix's every column corresponds to goods. Matrix has two rows, first row corresponds to goods load visit state, and second row corresponds to vehicle that ferries the goods. Ant state transfer probability is improved to solve bin-packing problem. According to ants tabu table and vehicle subject function all the goods are searched by ants and satisfy the vehicle constrain.Illustrated result show ACO is feasible for bin-packing problem.

ACKNOWLEDGMENT

This work is partially supported by National Natural Science Foundation Key Items of P.R.China (70931001), Group Innovative Research Team of National Natural Science Foundation of China（60821063), National Natural Science Foundation (70771021).

REFERENCES

[1] N. Bansal, A. Caprara, M. Sviridenko, Improved approximation algorithms for multidimensional bin packing problems, 47th Annual IEEE Symposium on Foundations of Computer Science, 697-708,2006

[2] D.S.Liu, K.C.Tan, C.K.Goh, W.K Ho, On solving multi objective bin packing problems using particle swarm optimization, IEEE Congress on Evolutionary Computation, 2095-2102, 2006

[3] Z.Q. Zhang, W.M. Cheng, L.S. Tang, Y. Cheng, Improved ant colony optimization for one-dimensional bin packing problem with precedence constraints, Third International Conference on Natural Computation, Vol.4, 539 -543,2007

[4] Leo Ho Wai Yeung, Tang W K S. A hybrid genetic approach for container loading in logistics industry [J]. Industrial Electronics, IEEE Transactions on, 2005, 52(2):617-627.

[5] Ponce-Perez A, Perez-Garcia A, Ayala-Ramirez V. Bin-Packing Using Genetic Algorithms [J]. Electronics, Communications and Computers, 2005. CONIELECOMP 2005. Proceedings. 15th International Conference on,2005:311-314.

[6] M.Dorigo, M.Birattari, T.Stutzle, Ant colony optimization, IEEE Computational Intelligence Magazine, Vol.1, No.4, 28 -39, 2006.