Advances in Social Science, Education and Humanities Research, volume 220

3rd International Conference on Education, E-learning and Management Technology (EEMT 2018)

Study on the Continuous Berth Allocation Problem

Xinxin Yan[1*], Hanping Hou [1], Jianliang Yang [2], Chenyang Zhao[1], Xuehui Wang[1], Xue Li[3]

[1]School of Economics and Management, Beijing Jiaotong University, Beijing, 100044, China;

[2] School of economics and management, Beijing University of Chemical Technology, Beijing, 100029, China;

[3] Assistant Engineer Space star technology co., LTD Beijing, Beijing, China;

Keywords: Continuous berth allocation; total time in port; prediction; Genetic Algorithm

Abstract. Rationally making berthing plan and reducing waiting time of ship in port have great practical significance to improve wharf service quality and competitive strength. On the basis of studying and summarizing the research theories and model algorithms of domestic and foreign scholars in recent years, this paper studies the continuous berth allocation problem. Suppose that ship types, ETA time, loading time are known, the pier depth is enough to satisfy all types of ships berthing and the ship has no preference position. The integer programming model is established with the shortest total time as the objective function and the genetic algorithm is designed to solve the model. Finally, an example is given to verify the validity of the proposed model. Compared with the first come first served principle, it can optimize the allocation of berth.

1. Introduction

Due to the limited berth resources and increasing scale of ship amounts, the situation that ships stay too long in ports occurs frequently [1]. Berth Allocation Planning (BAP) is a basic tache to improve the production organization capacity of terminals, which affects the quality of service of ports [2]. When making berth allocation plan, we should determine the berthing time and berthing location of all ships arriving at the port within the planning period.

However, in actual production, most ports still make ship scheduling plans on the basis of "first come, first served". Undoubtedly, berth resource allocation cannot achieve efficient optimization. According to these problems, some domestic and foreign scholars have some research results. Akio Imai (2001) [3] established the nonlinear integer programming model and solved it by using Lagrange relaxation algorithm. Kap Hwan Ki (2003) [4] considered the lag time of ships and the optimal position of berthing, set the penalty coefficient, and established the mathematical model with the goal of minimum total cost.

2. Description and Hypothesis of Continuous Berth Allocation

2.1 Problem description

In the problem of continuous dynamic berth allocation, both berthing time and shoreline position are continuous. The problem of berth allocation can be converted into a two-dimensional packing problem. The principle of berth allocation is that time ordinate of the last arriving ship should be as small as possible when restrictions that ship rectangles don't overlap are met. As Fig. 1 shows:

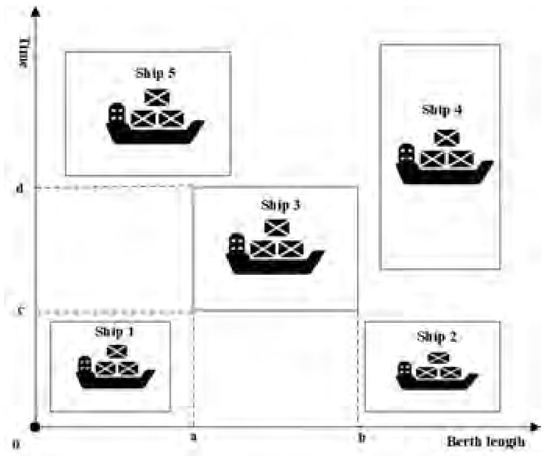

Fig.1 Time-Space diagram of ships

2.2 Model hypothesis

1) Each ship is serviced and serviced only once.
2) The shoreline depth meets the berthing requirements of all ships, and ships can berthing at any berth.
3) Ship length includes the safe distance between ships.
4) The ship's bow at the left end is where the ship begins to berth.

3. Construction of Continuous Berth Allocation

3.1 Known conditions

1) Total berth length.
2) Length of the planned period in hour units.
3) Length of each ship.
4) Arrival time of each ship.
5) Laytime of each ship.

3.2 Variable description

N: total amount of ships
L: total length of the berth
H: length of planned period in hour unit
l_i: length of ship i
A_i: arrival time of ship i
P_i: laytime of ship i
x_i: the beginning berthing location of ship i
t_i: the beginning berthing time of ship i
$\alpha_{ij} \epsilon \{0,1\}$ indicates that on the time axis ,if ship i is located on the left side of the ship j, $\alpha_{ij} = 1$, otherwise $\alpha_{ij} = 0$
$\beta_{ij} \epsilon \{0,1\}$, indicates that on the space axis, if ship i is located below the ship j, $\beta_{ij} = 1$, otherwise $\beta_{ij} = 0$

3.3 Model construction

$$minf = \sum (t_i - A_i + P_i)$$

$$x_i + l_i \le L \qquad \forall\ 1 \le i \le N \qquad (1)$$

$$A_i \le t_i \le H \qquad \forall\ 1 \le i \le N \qquad (2)$$

$$x_i + l_i \le x_j + M(1 - \alpha_{ij}) \qquad \forall\ 1 \le i,j \le N\ ,i \ne j \qquad (3)$$

$$t_i + P_i \le t_j + M(1 - \beta_{ij}) \qquad \forall\ 1 \le i,j \le N\ ,i \ne j \qquad (4)$$

$$\alpha_{ij} + \alpha_{ji} + \beta_{ij} + \beta_{ji} \ge 1 \qquad \forall\ 1 \le i,j \le N\ ,i \ne j \qquad (5)$$

$$\alpha_{ij} + \alpha_{ji} \le 1 \qquad \forall\ 1 \le i,j \le N\ ,i \ne j \qquad (6)$$

$$\beta_{ij} + \beta_{ji} \leq 1 \qquad \forall\ 1 \leq i,j \leq N\ , i \neq j \qquad (7)$$
$$\alpha_{ij}, \alpha_{ji}, \beta_{ij}, \beta_{ji} \in \{0,1\} \qquad \forall\ 1 \leq i,j \leq N\ , i \neq j \qquad (8)$$
$$t_i, x_i \geq 0 \qquad \forall 1 \leq i \leq N \qquad (9)$$

4. Genetic Algorithm for Solving Model

4.1 Chromosome coding rules

Chromosome coding rule as follows: this is an N*2 dimensional chromosome code. The first line of the chromosome represents the starting berthing point of each ship and the second row represents the berthing time of each ship.

4.2 Algorithm flow

The following genetic algorithm is used to solve the problem. The arrival time, ship length and laytime of all ships that planned to be allocated are input into the information set, and then generate the initial population.

4.2.1 Steps for generating initial solutions

Step1: First assumes that the berthing time of ship i is equal to its arrival time.

Step2: Judging that whether there is still ship that doesn't accomplish mission.

Step3: If there is no ship on the shoreline, arrange the ship to berth at random, otherwise calculate the distance of the free area on the berth including the distance between the two ships on berth. Then turn to step 4.

Step4: If the free area can satisfy the berthing condition of the ship i then we berth ship i at the start point of a free area randomly. If the free area can not meet the berthing requirements of the ship, the berthing time t_i of the ship i will be increased by 5 units, t_i=t_i+5, then transfer to Step 2.

4.2.2 Crossover and mutation operations

a) Crossover operation

In view of the difference of x gene (berthing position) and t gene (berthing time) , different crossover rules are designed for the two chromosomes. Crossover rate is 0.5. With regard to x, arithmetic crossover method is adopted. The offspring gene was formed by linear combination of two parent genes.

$$x_{offspring} = \mu x_{parent1} + (1-\mu)\, x_{parent2}$$

For the berthing time t, this paper adopt a single point crossover method.

b) Mutation operation

Genetic variation makes different individuals more discrepant and can enrich populations and speed up convergence. In this paper, we exert mutation operation on the x gene. The rules of mutation are as follows:

$$\begin{cases} ral > 0.5, x_{offspring} = x_{parent} + floor(\frac{l_i}{5}) \\ ral \leq 0.5, x_{offspring} = x_{parent} - floor(\frac{l_i}{5}) \end{cases}$$

4.2.3 Modification of infeasible solution

After cross mutation, chromosomes produce infeasible solutions which do not satisfy the constraints. If these infeasible solutions are discarded directly, the convergence rate will slow down, so we choose to modify the infeasible solution to meet the constraints.

5. Example Analysis

L = 600m, H = 168 hours. The total number of ships arriving in the planned period is 84, of which 50% are feeding vessels, 30% are medium-sized vessels and 20% are large vessels. The ship's arrival interval is 2 hours. The length of feeding vessel obeys the uniform distribution of 15-30 and the service time obeys the uniform distribution of 10-25, the length of medium vessel obeys the uniform distribution of 30-45 and the service time of medium vessel obeys the uniform distribution of 25-40. The length of large ships obeys the uniform distribution of 45-60 and the service time of large ships obeys the uniform distribution of 40-55. The berthing situation of 40 vessels of No.1-35 is analyzed. The berthing information is shown in Table 1:

Table 1 Berth allocation results of ships 1-35

NO.	Type	Arrival Time	Berth Time	Laytime	Leave Time	Berth Location
1	1	0	0	13	13	470
2	1	2	2	23	25	347
3	1	4	4	12	16	207
4	3	6	6	43	49	49
5	1	8	8	13	21	9
6	1	10	10	16	26	158
7	1	12	12	14	26	104
8	2	14	14	38	52	287
9	3	16	16	53	69	207
10	2	18	18	27	45	480
…	…	…	…	…	…	…
35	3	68	68	43	111	92

After the genetic algorithm iteration, to the 500th generation of the optimal solution remains unchanged to 2278. The evolutionary process of the optimal solution is shown in Fig. 2. It is obviously acknowledged that the genetic algorithm designed for the problem has good convergence.

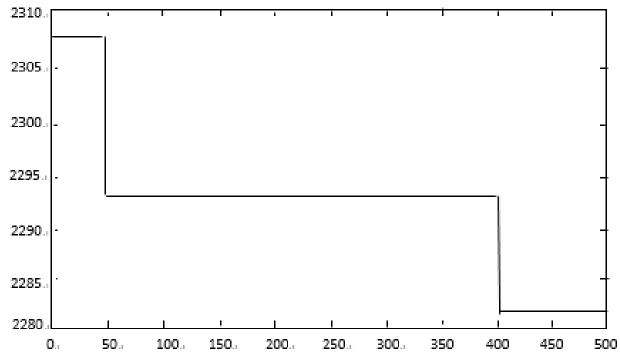

Fig.2 Evolutionary convergence diagram of genetic algorithm

6. Conclusion

The following conclusions are drawn: the established continuous dynamic berth allocation model in this paper can solve the allocation problem. The numerical results show that the model is feasible and can shorten the ship's harbor time to optimize berth allocation, which reflects the characteristics of the continuous dynamic berth allocation problem. However, the preference position of ships, influence of tides etc. are not considered in in this paper. Model in this paper is to solve the universal problem of continuous berth allocation.

7. Acknowledgment

This research was financially supported by the National Key R&D Plan Project "Research on Terminal Rapid and Accurate Delivery Dispatching System and Key Technologies" (No. 2016YFC0803207)

8. References

[1]. Zhang c, Zheng L, Zhang Z H, et al. “The allocation of berths and quay cranes by using sub-gradient optimization technique”. Computers & Industrial Engineering, 58(1):40-50, 2010.

[2]. Liu Jie, “Study on dynamic allocation optimization of container terminal berth, Master, South China University of Technology”, March 2012.

[3]. Akio Imai, Etsuko Nishimura, Stratos Papadimitriou, “Berth allocation in a container port: using a continuous location space approach” .Transportation Research Part B: Methodological, Volume 39, Issue 3, March 2005, Pages 197

[4]. Kap Hwan Kim, Kyung Chan Moon. “Berth scheduling by simulated annealing”, Transportation Research Part B 37:541–560, 2013