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Research on Automatic Berth Scheduling for Yangshan Phase IV based on Genetic Algorithm

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Abstract

With the huge increase in the throughput of container terminals, the problem of berth scheduling is a problem that restricts the development of container terminals. To address the problem of container terminal ship berth scheduling and improve the operational efficiency of the terminal is a necessary way to reduce the operating cost of the terminal and reduce the total time of ships in port. This paper establishes a discrete berth scheduling mathematical model for improving the operational efficiency of Yangshan Phase IV automated terminal on the basis of the ship scheduling system of Yangshan Phase IV automated terminal, aiming at the shortest total time in port for all ships. The optimal solution to the mathematical model is sought using a genetic algorithm based on integer coding.

Keywords

Yangshan IV automated terminal; Berth scheduling optimization; Genetic algorithm; Total ship time in port; Discrete berths.

1. Introduction

Sea transport is currently China's international cargo transport in the main way, in the process of international cargo transport, container transport occupies a large proportion, and the proportion is increasing year by year. Container transport service level and quality of service to a large extent by the port terminals on the import and export ship service efficiency of the impact. The service efficiency of port terminals is mainly influenced by the operational efficiency of port machinery and the berth scheduling allocation scheme. However, the operational efficiency of port machinery is usually certain, and the service efficiency of port operations will only be improved if the number of port machinery is increased. Therefore, without increasing the cost of the port terminal, the service efficiency of the whole port can only be improved by increasing the efficiency of berth scheduling as much as possible and reducing the total time of the vessel in the port. Therefore, in this paper, the problem of optimizing berth scheduling schemes will be studied. Berth scheduling schemes can be divided into discrete berth scheduling, continuous berth scheduling and mixed berth scheduling. Discrete berth scheduling divides the shoreline into a number of fixed berths, and there is a one-to-one correspondence between vessels and berths; continuous berth scheduling makes the shoreline continuous, and vessels can berth at any location as long as the length of the shoreline does not exceed the length of the shoreline. Although mixed berth scheduling divides the shoreline into several fixed berths, it also allows one berth to serve multiple small vessels or multiple berths to serve one large vessel. There are a total of seven independent berths for vessels to berth and operate at the Yangshan IV automated terminal in Shanghai, and each berth has a fixed length, therefore, berth scheduling at the Yangshan IV automated terminal is a discrete berth scheduling problem.

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In the study of discrete berth scheduling schemes, Imai et al [1-4] proposed a dynamic berth allocation problem for multi-user container terminals based on the static berth allocation problem, developed a mixed-integer planning model, and designed a Lagrangian relaxation-based subgradient optimization algorithm.Golias et al [6] also considered the dynamic berth allocation problem with priority, where each vessel has an arrival and The time window of departure minimizes the total delayed time of ship departure and maximizes the total time of ship early departure.Kap Hwan Kim et al [5] proposed a berth allocation model based on simulated annealing algorithm. Wang Jun and Zhuorong Li [13] studied the discrete berth allocation problem, established a mathematical model aiming at minimizing the ship's time in port, and designed a genetic algorithm to solve the problem. Qin Jin et al. [14] considered the discrete berth allocation problem under the time window constraint, with the goal of minimizing the ship's in-port time, added the time constraint condition between the ship and the berth, established a mixed-integer planning model, and designed a simulated annealing algorithm to solve the NP-hard problem. Sun Bin et al [15] considered the robustness of the allocation scheme, and due to the uncertainty of the ship arrival time, they adopted a design method based on redundancy strategy, integrated service indexes and robustness indexes, and finally designed an ant colony algorithm to solve the optimization model. Ping Li [11] applied the genetic algorithm and hybrid optimization strategy to solve the berth scheduling problem of container port. Zi-ai Lu [7-8] treats port production as a stochastic service system and establishes a computer simulation system to simulate port operating conditions. Xu Xiaoyi [12] applied the theory and methods of queuing theory to establish a computational method for determining the optimal number of berths in a port and the evaluation of terminal berth construction, among others.

Due to the special geographic location and port characteristics of the Yangshan IV automated pier, especially the tidal influence on it, the number of berths for ships is different in the two cases of high and low tide. The above method obviously cannot be applied to the Yangshan IV automated pier, and it is necessary to re-establish the model and constraints, and this paper focuses on the low tide situation. In the low tide condition, the seven berths of the automated pier can all berth.

2. Description of the problem

Since the Yangshan IV automated terminal is fully automated and mechanically operated, it is more urgent to improve the service efficiency of the terminal, and there is less interference from human factors, so there is still much room for improving the service efficiency. The purpose of ship dispatching is to ensure the safety of ship navigation and reduce the delay time and total time in port by making the ship berth quickly and in compliance with the channel management and operation rules. The core problem of dispatching is to optimize the allocation of berth and channel resources. In this paper, the study is based on the discrete berth scheduling environment.

Discrete berth scheduling refers to assigning a suitable berthing position and docking time to each arriving ship on a shoreline that is divided into i berths.

3. Model building

3.1 Model assumptions

(1) Each ship must be serviced only once.

(2) The vessel cannot be served until it arrives.

(3) The length of the vessel cannot exceed the length of one berth.

(4) Only one vessel per berth at a time.

(5) The depth of water at the berth is not less than the depth of the draft of the ship.

3.2 Establishment of objective functions

$$\text{Min F} = \sum_{i\in B}\sum_{j\in V}\sum_{k\in U}(m_j - A_j + C_{ij})x_{ijk}$$

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3.3 Constraints

(1) The total number of vessels serving each berth shall be equal to the total number of vessels in port.

$$\sum_{i\in V} S_i\text{=S}$$

(2) Each vessel must be served only once at each berth.

$$\sum_{i\in B}\sum_{j\in V} x_{ijk}=1 \quad , \quad \forall j \in V$$

(3) Each vessel must be served upon arrival.

$$m_j\text{-}A_j\geq 0, \qquad \forall j \in V$$

(4) The depth of the berth is not less than the draft of the vessel.

$$(W_i - D_j)x_{ijk}\geq 0$$

(5) The length of the vessel does not exceed the length of the berth.

$$(P_i - L_j)x_{ijk}\geq 0$$

3.4 Model parameters

i=(1,2, ...,I) ∈ B, denoting the set of berths.

j = (1,2, ...,S) ∈ V, denoting the set of ships.

k = (1,2, ...,S) ∈ U, denoting the set of service sequence numbers of the ship.

Aj ---- indicates the time of arrival of ship j at the port.

Cij ---- indicates the service time used by ship j at berth i.

mj ---- indicates the time when boat j started being served (i.e., the time when boat j entered the berth).

Wi indicates the water depth at berth i.

Dj indicates the draft of the ship j.

Pi indicates the length of berth i.

Lj denotes the length of the vessel j.

x_{ijk}=1 means if ship j is the kth served at berth i; otherwise, x_ijk=0.

y_{ijk} ---- indicates the idle time between the departure of the (k-1) vessel serving berth i and the docking of the kth vessel.

4. Problem solving

4.1 Algorithm Operation and Parameter Design

(1) Initialization of the population: in order to ensure the quality of the initial population and not to lose the diversity of the population, the initial population is generated randomly and the size of the initial population is taken as P = 20 in the example.

(2) Crossing operation: randomly selected individuals in the population are crossed with the best individuals in the entire population according to a certain probability, and the partial mapping hybridization operation is adopted in this paper.

The following describes the partial mapping hybridization operation, this paper adopts integer coding for ship berths, and the certificate coding is very intuitive compared to binary coding, which reduces the work and tediousness of converting from decimal to binary (encoding) and then from binary to decimal (decoding).

Parent 1: 2 5 3 6 1 4 7

Parent 2: 3 4 7 2 5 1 6

In order to achieve partial mapping hybridization, two hybrids are first randomly selected, e.g., after picking the 3rd and 6th berth, where the cleft is marked as x, which becomes the following form.

Parent 1: 2 5 3 x 6 1 4 x 7

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Parent 2: 3 4 7 x 2 5 1 x 6

Observe the middle section of the two parent generations and note the correspondence between them. Here are.

$6 \rightarrow 2$

$1 \rightarrow 5$

$4 \rightarrow 1$

Now check each of the two incidental genomes one by one, and each time you find a match to one of the genes listed above, swap them. Proceed step by step, as in.

Step 1

Offspring 1: 2 5 3 6 1 4 7

Offspring 2: 3 4 7 2 5 1 6

(This step is just a direct copy of the parent to the child)

Step 2-1

Offspring 1: 6 5 3 2 1 4 7

Offspring 2: 3 4 7 6 5 1 2

Steps 2-2

Offspring 1: 6 1 3 2 5 4 7

Offspring 2: 3 4 7 6 1 5 2

Steps 2-3

Offspring 1: 6 4 3 2 5 1 7

Offspring 2: 3 1 7 6 4 5 2

To this gene to complete the hybridization, to obtain a valid substitution without duplicate berths.

(3) Mutation operation: mutations are produced in the population with a certain probability, and this paper adopts the transformation mutation operation.

The mutation operation should be able to provide a sequence that will only generate a valid berth alignment, the transform mutation operation fulfills this requirement by selecting two genes on a chromosome and swapping them. The following explains the process of the mutation operation.

5, **3**, 2, 1, 7, **4**,6.

Swapping two genes, here assuming mutation of the second locus and the sixth locus, after mutation of.

5, **4**, 2, 1, 7, **3**, 6.

This generates an efficient arrangement.

(4) Selection operation: individuals are selected using the roulette method, the probability of the i-th individual being selected is $P_i = \frac{f_i}{\sum_1^M f_i}$, f_i is its degree of adaptation and $\sum_1^M f_i$ is the sum of the degrees of adaptation of all individuals.

(5) Population termination: when the maximum number of times the population can evolve or produce the optimal individual is reached.

4.2 Algorithmic Steps and Processes

The following gives the algorithm steps and algorithm flow diagram for solving the berth scheduling model with a genetic algorithm (Figure 1).

Step 1: Determine the parameters of the algorithm to randomly generate an initial population of some individuals.

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Step 2: Calculate the adaptation value for each individual in the population, determine if the optimization criterion is met, if so, come up with the best individual and the optimal solution it represents and conclude the calculation, otherwise, move on to step 3.

Step 3: Select regenerating individuals based on their fitness level, with those with a high fitness level having a high probability of being selected and those with a low fitness level possibly being eliminated.

Step 4: Generate new individuals according to certain crossover probabilities and crossover methods.

Step 5: Generate new individuals according to a certain mutation probability and mutation method.

Step 6: There is crossover and mutation to produce a new generation of populations and return to step 2.

Step 7: Terminate the operation and designate the best individual that appears in any generation as the result of the execution of the genetic algorithm.

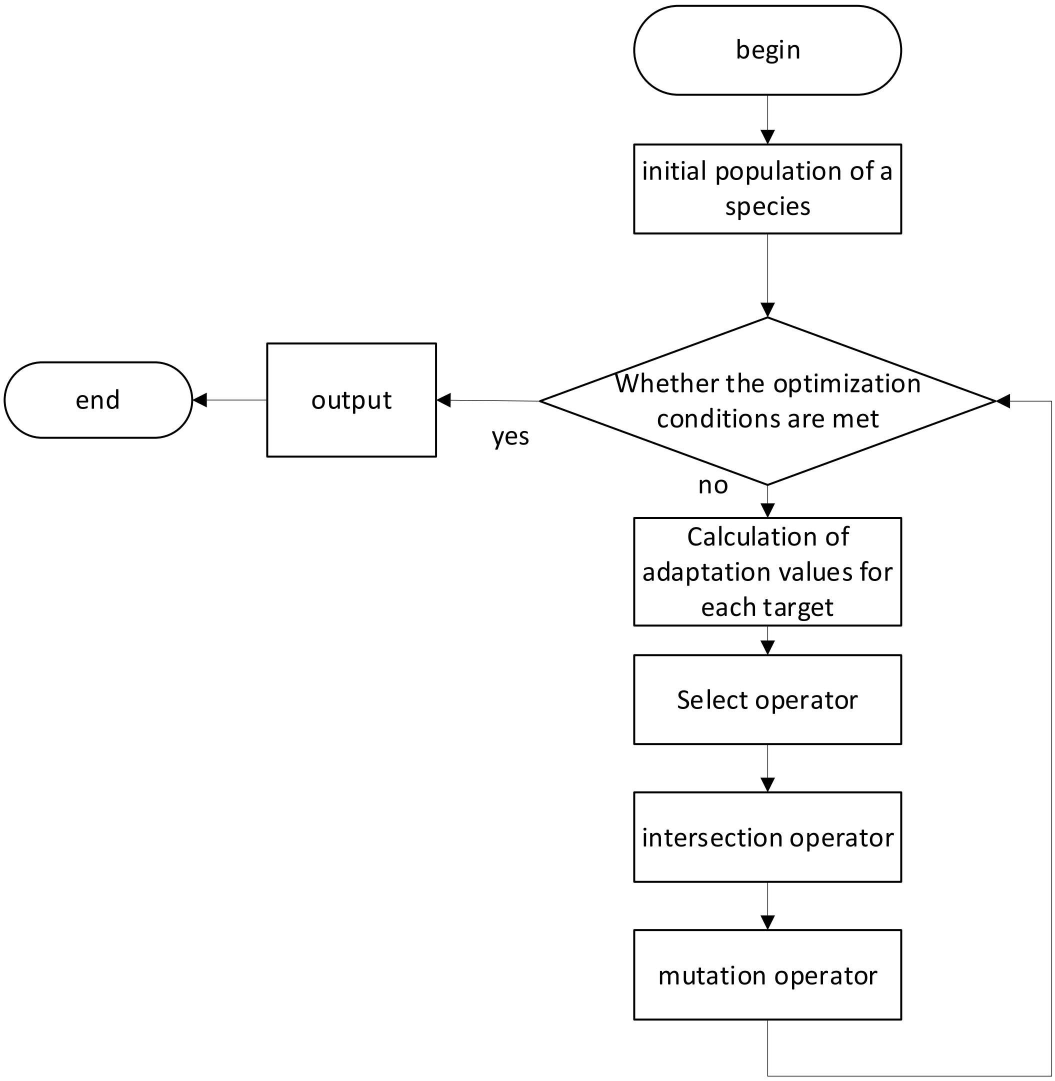

Figure 1 Flowchart of the genetic algorithm for the berth scheduling problem

4.3 Adaptation functions

Since the berth scheduling problem is a minimization constraint problem, the smaller the value of the objective function, the higher the degree of adaptation. In this paper, the objective function is used to take the reciprocal after an exponential transformation.

$$f(x)=1/(1+\exp(y(x)/10000))$$

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where y(x) is the objective function of the model.

4.4 Analysis of results

After the variation and selection process of the genetic algorithm, an optimal result is finally obtained, i.e., the optimal berthing method for the berth assignment scheme. It can be seen from the table below that when evolving different generations, different berth allocation schemes are obtained, and the total time in port of the vessel corresponding to each berth allocation scheme calculated according to the objective function is different. Each time the population evolves, the obtained berth allocation scheme tends to be optimal, and the corresponding total ship time in port decreases once. After evolution to a certain number of generations, the population reaches the optimum and the best berth allocation scheme is obtained.

Stock size P=20		
Evolutionary algebra	Berth scheduling optimization solutions	Total ship time in port(hours)
1	1 4 6 3 2 6 7	84
20	1 5 4 2 3 7 6	76
30	1 3 5 7 2 4 6	74
40	1 5 4 3 2 7 6	73
50	1 5 4 3 2 7 6	73

5. Conclusion

This paper analyzes and studies the berth scheduling problem of Yangshan Phase IV automated terminal, designs the solution algorithm for the actual problem, and verifies the effectiveness of the scheduling scheme and algorithm by combining with numerical experiments. Finally, it realizes the optimization of the sequence of ship entry and exit, improves the berth utilization rate, and has some reference value for the operation and scheduling practice of the terminal.

References

[1] Imai A,Nagaiwak,Chanw T.Efficient planning of berth allocation for container terminals in Asia[J]. Journal of Advanced Transportation 1997 31:75-94.

[2] Imai A,Nishimura E,Papadimitriou S The dynamic berth allocation for a container port.Transportation Research (Part B) (2001) 35:401-417.

[3] Imai A,Nishiura E, Berth allocation with service priority[J].Transportation Research 2003 Part B 37:437-457.

[4] Imai A,Nishimuar E, Berth allocation planning in the public berth system by genetic algorithms[J]. European Journal of Operational Research 2001(4):282-292.

[5] Kap Hwan Kim,Kyung Chan Moon Berth scheduling by simulated annealing,Transportation Research Part B 37(2003)541-560.

[6] Golias M,Bolie M,Theofanis S.The berth allocation problem:a formulation reflecting time window service deadlines [C] Proceedings of the 48th Transportion Research Forum Annual Meeting. Boston(MA): Transportion Research Forum.2006.

[7] Zhang Yantao. Optimization of berth scheduling problem based on genetic algorithm and simulation [D]. Wuhan: Wuhan University of Technology, 2005.

[8] Lu Zi-ai, Study on the optimization of port construction scale [J], Journal of Hohai University (Natural Science Edition), 2002.5.

[9] Lu Zi-ai, Application of queuing theory in port planning [J], Water Transport Engineering, 1997.8.

[10] Wang Xiaoping and Cao Liming, Genetic Algorithm - Theory, Application to Software Implementation, Xi'an: Xi'an Jiaotong University Press, 2002.1.

[11] Wang Ling, Intelligent Optimization Algorithms and Their Applications, Beijing: Tsinghua University Press, Springer Publishing House, 2001.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202012_6(12).0037

[12] Li Ping, Sun Junqing, Han Mei, GATS hybrid optimization strategy for berth scheduling problem [J]. 2016.8.

[13] Huang Xiaoming and Xu Xiaoyi, Application of queuing theory in port planning and design [J].1996.3

[14] Wang Jun, Li Zhuorong. Optimization study of dynamic berth allocation problem based on genetic algorithm [J]. Sino-56 Water Transport, 2011, 11(1) 63-65.

[15] Qin Jin, Miao Lixin, Chen Changbin, et al. A model for optimal allocation of port berths under time window constraints [J] Marine Engineering, 2010,39(2) 142-145.

[16] Sun Bin, Sun Junqing, Liu Fenglian, et al. Study of robust discrete berth allocation problem based on ant colony algorithm [C] Proceedings of the 29th China Control Conference, 2010.