Genetic Algorithm to Optimize the Repositioning of Empty Containers

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Abstract: According to the procedure of empty container repositioning in the ocean shipping system and the land-carriage system, we construct the optimization model based on the target of minimizing the integral cost in this paper, and then optimize a model example by using genetic algorithm to achieve the empty containers repositioning strategies.

Keyword: empty container repositioning; optimization of integral cost; genetic algorithm

1. Introduction

Along with the rapid development of technology, the marine transportation of container has been the dominant service mode in an international market for a few decades. Because of the imbalance among the regional economy development and the difference among the container management mode of shipping company, the contradiction between supply and demand is increasingly prominent. Previous research on empty container repositioning divides into two parts, the ocean shipping and the land-carriage. And most researches are done with qualitative analysis and practical experience. So it not only makes the volume of empty container repositioning increase, but also cannot get the overall cost of optimal strategies[1-4].

Because the cost of empty container repositioning has a great influence on the shipping company, the shipping company takes this problem very seriously. The main research of container repositioning is that when and from where to transport how many empty containers to the designated place who is in need. The transportation of empty container has many properties, includes the dynamic of the supply and demand place, the complexity of container types and node, the diversity of mode of transportation, the randomness of supply and demand for empty containers, and the restrictive of transport capacity and supply. Many procedure parameters and uncertain factors make this problem more complex[5].

In this paper, I consider both the styles of the containers and the combination of the land-carriage and the ocean shipping. That is to say, this paper not only considers inland transportation between adjacent freight stations, but also considers the transportation between the ocean areas. And then establish a reasonable dynamic optimization model of empty containers repositioning. And then achieve the optimal solution of an example by using genetic algorithm.

2. The Model of Empty Container Repositioning

2.1. Assumptions of the Model

To simplify the factors affecting the model, make the assumptions as follows:

- To simplify the factors affecting the model, make the assumptions as follows:
- Assume that the demand for goods is not change in a sure period.
- Consider the port and the station as a node.
- The number and the demand of empty containers in every node are known to all.
- Be considering of one type of container: 20 feet.
- Don't consider repositioning empty containers to and fro. And do not allow mutual replacement between different empty containers.
- In any port, the number of leasing containers is not restricted at any time.
- The storage ability of any station is unlimited.
- The container is intact and it has no problem of maintenance and scrap.

2.2. The Model

It is aimed at repositioning/ renting how many empty containers at the port of departure in order to finish the assignment at the least cost.

1) The setup of parameters

Total A is used to describe the overall number of missions in a period of time.

a) Free variable:

c_{Lij}^{k} Stuffing charges of a container at port i.

c_{Titj}^{k} Transportation expenses of an empty container from port i to port t.

c_{Uij}^{k} Stevedorages of an empty container at port i.

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c_{Rij}^{k} The unit inland renting fees and stuffing charges of a container at port i.

c_{Sij}^{k} The unit transportation expenses from the inland leasing company to port i.

D_{ij}^{k} The empty containers demand of port i in assignment j (Port i is not only the first port of departure in assignment j, but also a port is in need of empty container).

S_{Ni}^{k} The total number of empty containers that the port i can provide.

x_{ij}^{k} The number of empty containers that port i can provide for assignment j, so $(S_{Ni}^{k} - \sum_{j} x_{ij}^{k})$ is used to describe the number of empty containers that the port i can provide in assignment (j+1).

b) *Decision variable*

x_{ij}^{kE} The number of empty containers that port i need to reposition for assignment j

x_{ij}^{kR} The number of empty containers that port i need to rent from inland for assignment j

X_{Tj}^{k} All of the selected route for assignment j

x_{ijk}^{L} A route in X_{Tj}

2) *Objective function*

$$\min z = \sum_{j=1}^{totalA}\Big(\big(\sum_{x_{ij}\in X_{Tj}} c_{Titj}^{k} + c_{Lij}^{k} + c_{Uij}^{k}\big)\times x_{ij}^{kE} + (c_{Sij}^{k} + c_{Rij}^{k})\times x_{ij}^{kR}\Big)$$

The objective function is used to describe to finish all missions of empty containers repositioning at the least cost.

A detailed explanation of it is just as follows:

$(\sum_{x_{ij}\in X_{Tj}} c_{Titj}^{k} + c_{Lij}^{k} + c_{Uij}^{k})\times x_{ij}^{KE}$ It means that all cost of repositioning x_{ij}^{kE} empty containers from port t to port i by one known route x_{ijk}^{L} in X_{Tj}^{k}. It includes stuffing charges and stevedorages at port i and transportation expenses between port t and port i.

$(c_{St}^{k} + c_{Rij}^{k})\times x_{ij}^{kR}$ It means that all expenses of renting empty containers at port i. It includes the unit inland renting fees and stuffing charges and transportation expenses from leasing company in the inland to port i.

3) *Constraint conditions*

$$\text{st:}\quad x_{ij}^{kE} + x_{ij}^{kR} + x_{ij}^{k} \geqslant D_{ij}^{k}$$

$$x_{ij}^{kE},\ x_{ij}^{kR},\ x_{ij}^{k} \geqslant 0$$

The constraint conditions describe that port i must meet the needs of empty containers.

3. The Design of Genetic Algorithm

In practice, genetic algorithm has been widely used. Based on the characteristics of genetic algorithm and the characteristics of empty container repositioning problem, I choose to use genetic algorithm to optimize the case in this paper.

3.1. Chromosome coding

In order to understand it easily, I use an integer coding. We set the gene digits to the half of the all ports number. For example, 6 610 120 213, 6 is used to show port 6, a port of departure. Meantime, it is also a port providing empty containers for port 1. And 610 are used to show a feasible route from port 6 to port 1. And 120 are use to show the number of empty containers that port 6 needs to reposition. And 213 show the number of empty containers that port 6 needs to rent from inland leasing company.

3.2. Selection

Use the roulette wheel selection. In this way, although it increases the randomness of the genetic algorithm, it ensures the population diversity and makes the algorithm not to premature convergence.

3.3. Crossover

Crossover operation is an important feature in genetic algorithm which is distinguished from other evolutionary algorithm. In my study, I choose the single-point crossover.

3.4. Mutation

It is a kind of global random search, in company with selection operator, they assure the validity of genetic algorithm. Meantime, make genetic algorithms maintain the diversity of population in order to prevent the premature convergence.

The structure of genetic algorithms is shown in figure 1.

In 1991, Michalewicz researched for this kind of constraint optimization problem. In order to make linear constrained optimization problem be suitable for genetic algorithm, they eliminated possible variables to reduce the number of variables and they eliminated equality constraints and designed methods of special genetic operations. This genetic optimization algorithm is called GENOCOP (genetic algorithm for numercal optimization for constrained problem), a constraints optimization of genetic algorithm[6].

4. Use of Genetic Algorithm in Empty Container Repositioning

4.1. Briefly description of the example

In this example, there are 6 ports. It is assumed that transport capacity and stockpiling ability are unlimited, and we don't consider that the port itself can provide empty containers. We know the empty containers repositioning assignments that the liner companies formulate base on its operating routes. We also know the supply and demand of the six ports and the route information between ports.

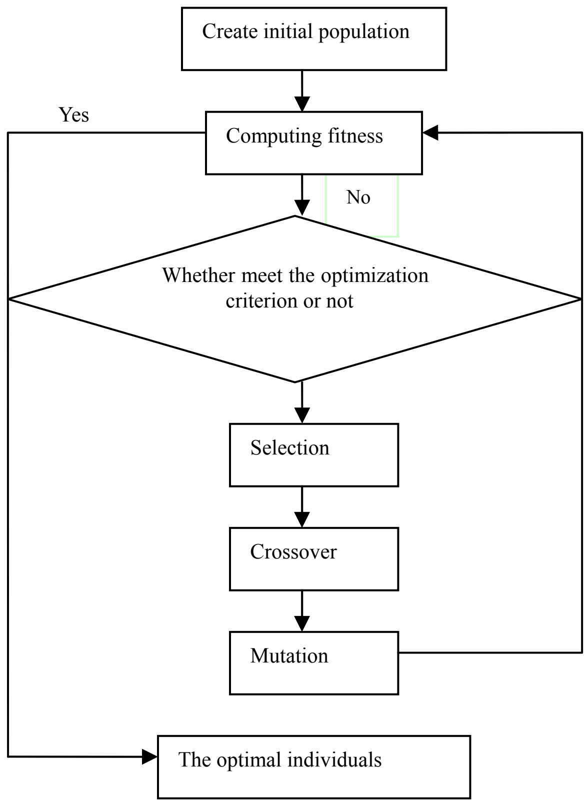

Figure 1.The classic GA structure

The transportation network of the six ports is shown in figure 2. It is reflected empty containers status of every port and the route information between linked ports in a given period of time. For example, the number 452 means that Port A has 452 empty containers.

The cost of each port is shown in table 1. The last row of it is the number of empty containers. The number zero means there is no empty container at the port. And the port needs to reposition empty containers. As it is shown in the model above, c^k_{Lij} is the stuffing charges of a container at port i.. c^k_{Uij} is the sevedorages of an empty container at port i. c^k_{Rij} is the unit inland renting fees and stuffing charges of an container at port i. c^k_{Sij} is the unit transportation expenses from the inland leasing company to port i.

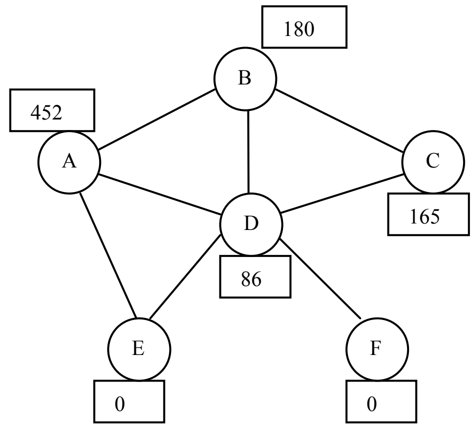

Figure 2.The transportation network

Table 1. The Cost of Each Port (UNIT: USD)

Port Index	c^k_{Lij}	c^k_{Uij}	c^k_{Rij}	c^k_{Sij}	Status of Empty Containers
A	223	121	268	120	452
B	134	377	207	195	180
C	262	260	443	200	165
D	354	125	756	266	86
E	238	178	645	120	0
F	367	388	452	267	0

The cost of freight between two directly linked ports is shown in table 2. For example, "A-B "shows that port A and port B id two directly linked ports. And the number under it is the unit cost of transportation freight. And in this way, we can compute the unit cost of transportation freight through multiple ports. That is to say, a fixed route is A→D→F, the cost between A and F is 148+34=182 USD

Table 2.The Cost of Fright Between Two Directly Linked Porte (UNIT: USD)

Two Directly Linked Ports	A-B	A-D	A-E	B-C	B-D	C-D	D-E	D-F
c^k_{Titj}	192	148	112	48	132	152	191	34

The assignments of empty containers repositioning are shown in table 3. And the assignments formulated by liner companies are based on the routes of their own and the owners' operational requirements. In a period of time, as is shown in table 4.3, there are seven assignments. For example, the first assignment A→F, it describes that port A needs to reposition 200 empty containers to port F by the fixed route on time. And the operating routes have

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been formulated by liner companies. We really need to optimize is that how to reposition empty containers to port of departure in the assignment to make sure the integral cost is the least. Because if there are enough empty containers in the port of departure, the port can reposition empty containers to the port of destination by fixed course and scheduled flight. There is one point to say, the port of destination is just the a port is in need of empty container.

Table 3. The Assignments of Empty Container Repositioning (UNIT: TEU)

Assignment	A→F	A→E	E→D	D→C	D→F	D→B	B→C
D_{ij}^{k}	200	371	412	194	300	115	300

Table 4. The Optimized Empty Container Repositioning Strategies Based On GA

Assignment	A→D→F	A→E	E→D	D→C	D→F	D→B	B→C
x_{ij}^{kE}	0	0	412	194	300	115	0
x_{ij}^{kR}	200	371	0	0	0	0	300

4.2. Experimental Results and Analysis

This algorithm is solved by Matlab2008a. In GA tool, the maximum number of iterations is 500, that is G=500. And population size N=50, crossover probability p_c =0.8, mutation probability p_m =0.01. Then we get the optimized empty container repositioning strategy which is shown in table 4. In this algorithm, the fitness function is the objective function in the model we build above. In this way, we get the least cost 993,550 USD. As it is shown in table IV, for assignment 1, port A needs to rent 200 empty containers and then repositions them to port F through port D according to the fixed course. Through our calculation, in order to finish the seven fixed assignments, port A needs to rent 571 TEU, port E needs to reposition 412 TEU, port D needs to reposition 494 TEU, port B needs to rent 300 TEU. In this way, there are enough empty containers at port of departure, which assure that the seven assignments can be finished.

5. Conclusion

In this paper, we build a model of empty containers repositioning based on the integral cost of ocean shipping and land-carriage. And it is also under the condition of knowing the empty containers demand and the designed route by liner companies. This model aims to increase the shipping company's management level and efficiency of empty containers repositioning. And save unnecessary costs of transportation. However, empty container repositioning is affected by many uncertain factors. Such as the uncertainty of transportation time, the conversion between empty container and the loaded. How to introduce random factors into the model, it will be the direction for further improve.

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