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A Genetic Algorithm to Solve the Container's Location Allocation Problem in Rear Storage Yard

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Abstract—**In this paper, a genetic algorithm is designed to solve the container's location allocation problem (CLAP) in rear storage yard. The CLAP considers the number of reshuffles and the range of all bays, which is a two-objective optimization problem. In the model, we only take 20ft normal containers into account and ignore the weight of containers. The GA designed for CLAP can get the global optimum solution and the population is going to converge, which can provide the solution of the minimum number of reshuffles and the balance between bays.**

Keywords—genetic alogrithm; container terminal; location allocation; reshuffle; rear storage yard

I. INTRODUCTION

After China's accession to the WTO in 2001, international trading volume, especially China-Europe trade and China-US trade, continued to grow. With this trade, marine transportation became more and more important because of its low-cost and big-capacity. Also, the pressure on cargo-handling capacity of seaports went increasing, which attract a great number of researchers to develop the container stacking theories.

Generally, there are two ways to improve handling capacity for terminals (Dekker et al. 2006). The one is getting more land to build more berths, which costs lots of money and takes too much time. So most of terminal managers will not chose this method as a short time strategy, while it will be a long time strategy. The other is improving working efficiency to lift the capacity with present ports, by changing the operation strategies or employing some automation equipment. In this paper, we apply Genetic algorithm in solving stacking problem, which is a way of improving terminal efficiency.

Compared to other subjects, the research about container stacking strategy is at an early stage, of which there is not a systematic efficient theory existed. With the development of global economy, especially China-US and China-EU trade, present terminal situation cannot reach customers' need and it is necessary to improve handling capacity by improving decision-making method and achieving high working performance, which promote stacking strategy research.

At a comprehensive survey of published scientific literatures, although stacking problem is too complex to easily allow for analytical results, there are also two prime ways used in research, which are simplified analytical calculations and detailed situation studies (Dekker et al. 2006).

Kim et al. (2000) provided a methodology to determine the storage location of an arriving export container considering its weigh, which is going to minimize the number of relocation movements expected for crane.

Dekker et al. (2006) made a simulation study about stacking policies at an automated container terminal. In the experiment, they considered several variants of category stacking and the categories facilitate both stacking and online optimization of stowage.

Zhang et al. (2007) presented a simulation optimization method to realize the optimal planning on resource allocate of stack yard. Their optimal objection was to minimize the cost of resource allocation and ensure to maximize the utilization of resource.

Wang (2008) use the some advanced algorithm in stacking problem to minimize use of space. He provided a yard approach to the yard space allocation, called "DROP", based on recursive algorithm. Also, he offered a critical request local neighborhood search method to find the optimal sequence.

Wang and Niu (2010) established an object-oriented petri nets (OOPN) model of the working process of stockpiling. And they used simulation software ExtendSim to digitally simulate the whole operation processes of container ports.

Park et al. (2011) provided an online search algorithm to adjust and optimize a stacking policy by continuously generating variants of stacking policies and evaluating them when applied.

Feng et al. (2011) applied a mixed integer model to allocate depot space for export and import containers, and utilized the optimization software lingo to accelerate the loading/unloading operation of the yard.

Li et al. (2012) developed an efficient continuous time MILP model for yard crane scheduling to reduce the PM waiting time, which is one of main factors of inefficiency.

Genetic algorithm (GA) is a combine of life science and computer science, which was firstly raised by professor Holland in 1975. Genetic algorithm is a highly concurrent global search algorithm, following Darwin's biological

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evolutionism and Mendelism. GA can acquire and accumulate knowledge automatically in searching progress, and adaptively control the progress to get the global optimal solution. After the development lasting almost 30 years, genetic algorithm achieved a great progress not only in application and algorithm design, but also in basic theory. Currently, genetic algorithm is a hot topic in the research field about information science, computer science, operational research and logistics (Wu and Lu, 2008).

Compared to traditional algorithms, there is no need to understand the essence of problem when using genetic algorithm and what we need to do is grasping the coding rules and the calculation of fitness. Besides, stacking problem is quite complex and not easy to be solved by traditional algorithm because of its complexity. Just in match, genetic algorithm can solve problems ignoring its detail and operating mechanism. So in recent years, more and more scholars started to use genetic algorithm (GA) in solving container stacking problems.

Bazzazi et al. (2009) presented an efficient genetic algorithm (GA) to solve storage space allocation problem (SSAP), with aim of balancing the workload between blocks in order to minimize the storage/retrieval times of containers.

Sun et al. (2011) discussed the decision-making problem of stockpiling position of containers in a yard-bay, and they develop a GA to minimize the re-handling movements. They only considered the location in a bay, with overlooking the allocation of bays.

Chen and Lu (2012) discussed a storage location assignment problem for outbound containers in two stages: the amount of locations in each yard bay and the exact storage location for each container. Their research dealed with the same problem with this paper, but our GA for CLAP can combine their two stages into one process.

Based on the reported works, we propose a novel genetic algorithm to solve the container's location allocation problem of rear yard area. The reported study of container's location allocation problem is concentrated in yard bay, while this paper set the point at yard area. Compared to CLAP in bay, CLAP of yard area is more complex and effective, which has more actual utility for terminal managers. Beside considering the minimum of the number of reshuffles, this paper take the balance of workload of bays into account as well, which made up a two-objective optimization problem.

The rest of the paper is structured as follows. Section 2 introduces briefly the background of container terminal, while a description to CLAP of yard area and the mathematical model of CLAP are presented in Section 3. Section 4 proposes a genetic algorithm to solve the problem. An example is exploited to evaluate the AG for CLAP in Section 5. The conclusion remarks are finally given in Section 6.

Fig. 1 Overview of a container terminal

II. BACKGROUND

A. The composition and layout of container terminal

Generally speaking, container terminal is consisting of berth, quay cranes, apron, stack yard, stacking cranes and gate, as is shown in Fig.1.

- Berth is the place to berth ships, locating at coastline of the port. The handle capability of a container terminal is related to the number of its berths, which is also affected by the length of coastline.
- Quay cranes are machines lifting containers from ships to trucks and they are the tool connecting container terminal and ships. The number of quay cranes allocated for a ship is related to the workload.
- Apron is the area between stack and berth. The width of apron is determined by the size of transport tools used in port as well as the layout.
- Stack yard is the place to store containers. Stack yard can be divided into two parts: front yard and rear yard. Front yard is going to store out-bound containers, while rear yard is going to store in-bound containers. Besides, there is mixed yard in some ports, which stores both in-bound and out-bound containers in one stack yard.
- Stack crane is the machine to move containers into/out of the stack yards, and its model is shown in Fig.2. In reality, stack crane need to move a container form present location to other location, as is known as reshuffles.
- Gate is key point between the port and the outside world, which is used to security check or prevention of thievery.

B. Operation machines

Beside quay crane and stack crane, operation machines in container terminal include container truck, forklift and other semi-automated equipment such as automatic guided vehicles (AGV) and automatic stacking crane (ASC).

- Container trucks are used to transport containers, which include inner container trucks and outer container trucks. Inner container truck is in charge of take containers from the quay crane to the stack and

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vice versa. Outer container truck is going to transport containers into the port or leaving the port.

- Forklift is another kind of equipment in charge of transport containers, as is shown in Fig.3.
- AGV and ASC are widely used in western port, like ECT in Rotterdam, CTA in Hamburg, and Thamesport in London (Dekker et al. 2006). They can reduce the error in placing containers and cut down the cost of human resource.

C. The workflow in container terminal

In common, according to different purposes and destinations, there are three kinds of operation in container terminal: in-bound container operation, out-bound container operation, and indirect container operation. The in-bound and out-bound container operations are shown in Fig.4.

III. PROBLEM DESCRIPTION

Container storage yard can be divided into front yard and rear yard. Front yard is planned to store out-bound containers, while rear yard is set for in-bound containers. As is shown in Fig.5, in container storage yard, there are several areas that contain several bays. And every bay also includes several rows and tiers. In our research, we only concentrate on rear yard, which is the room for storing in-bound containers.

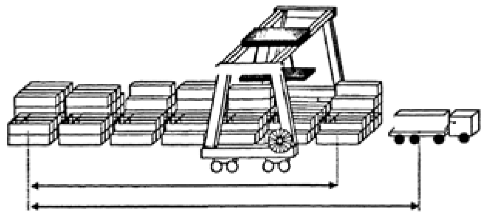

Fig. 2 The model of stack crane

Fig. 3 The model of Forklift

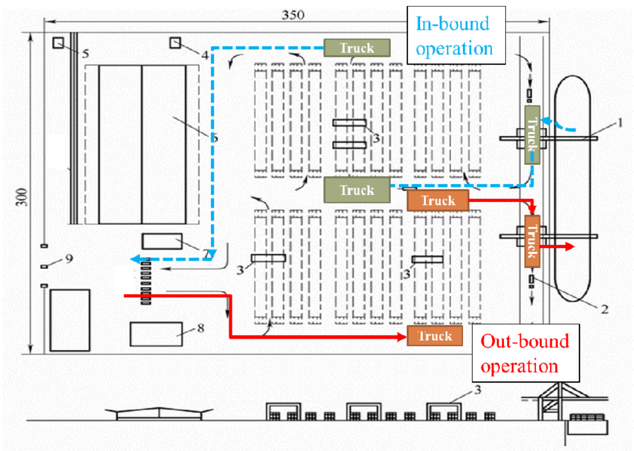

Fig. 4 Work flow of in-bound container operation and out-bound container operation

In real operation, if we want to get a low tier container, we have to move away upper containers, which is called reshuffle, and the number of upper containers is the number of reshuffles for the low-tier container. Actually, we cannot avoid reshuffle at all. But we can reduce the reshuffle number as possible as we can, which is one of the targets of our research. On the other hand, we have to keep the balance of workload among bays.

A. Assumptions

- The size of the area is x bays* (y+2) rows* z tiers. In each bay, we set 2 rows in reserved for reshuffle, so the real size available is x*y*z, which is considered in the algorithm.
- Although there are several sizes of container in reality, such as 20-ft, 40-ft, and 45-ft. But we only consider one size among them to simplify our model. And we do not take special containers into account, like reefer containers or empty containers. Besides, we do not concern the weight of containers, and every container can be stacked over another one.
- Reshuffle can be only operated in the same bay, which is to say that when we have to move away upper containers, we can only move them to other rows in the same bay.
- Every container has its own priority class. Customers need book a take-away time for their containers, and the time cannot exceed 15 days. We set priority classes

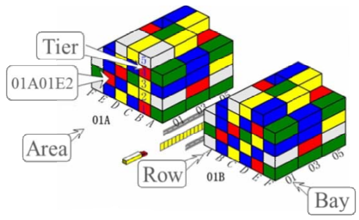

Fig. 5 Location describtion of a container.

TABLE I. Priority Class Explain

Take-away time (h)	Priority class
0~12	1
13~24	2
25~36	3
37~48	4
(12n-11)~12n	n (n≤30)

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based on the take-away time for each container, and its priority class is the take-away time divides 12 hours, as is shown in TABLE I. For example, if the take-away time of a container is 35 hours, its priority class is 3.

- Containers arriving yard are batched, and containers in a batch comes sequentially. When new containers arrive, we cannot change the present statue of the area, which is to say, we cannot move original containers at all.

B. Parameter definition

- x a constant, the number of bays in the area
- y a constant, the number of rows in each bay
- z a constant, the number of ties in the area
- C_i a known variable, the priority class of container i, $1 \le C_i \le 30$
- NC a known variable, the set of priority classes of new arrived containers
- nB_j the number of all the containers in bay j
- Range the range of the set of nB_j
- $S_{j,k}$ the row k stack of bay j
- $hS_{j,k}$ the height of $S_{j,k}$
- $pS_{j,k}$ the height of the container whose priority class is the minimum in $S_{j,k}$
- $rS_{j,k}$ the number of reshuffle operations of $S_{j,k}$
- rB_j the number of reshuffle operations of bay j
- rA the number of reshuffle operations of the area

C. Mathematical model

In this paper, there are two objective functions, that is, the minimum reshuffle operations and the minimum range of bays. To simplify the calculation of the number of reshuffle operations, we use the number of the total reshuffle containers instead (Wang et al. 2010). The objective functions of the model are written as follows:

$$\min nR = \sum_{j=1}^{x} rB_j = \sum_{j=i}^{x}\sum_{k=1}^{y} rS_{j,k} = \sum_{j=i}^{x}\sum_{k=1}^{y}(hS_{j,k} - pS_{j,k}) \quad (1)$$

$$\min Range = \max\{nB_1, nB_2, \ldots, nB_x\} - \min\{nB_1, nB_2, \ldots, nB_x\} \quad (2)$$

and subject to:

$$1 \le C_i \le 30, \forall i \quad (3)$$

$$1 \le j \le x \quad (4)$$

$$1 \le k \le y \quad (5)$$

$$1 \le hS_{j,k} \le z, \forall j,k \quad (6)$$

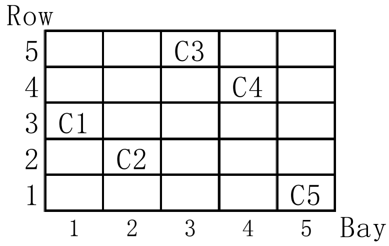

Fig. 6 The locations of the example

IV. Genetic Algorithm Designling

A. Solution Representation

In container's location allocation problem, the output is the location of the new batch of containers. So we use a 2n-long array to describe the locations for n new containers. The front n elements of the array stands for the bay number of the n new containers, while the latter n elements stands for the row number of them. If the priority classes set of new containers is $\{C_1, C_2 \ldots C_n\}$, and a feasible solution is $\{Bay_1, Bay_2 \ldots Bay_j, Row_1, Row_2 \ldots Row_k\}$. The location of container n is the top of $S_{j,k}$ (the stack in bay j and row k).

For example, there are 5 new containers arrive at a 5bays*5rows*5tiers yard and the feasible solution is {1,2,3,4,5,3,2,5,4,1}. The locations of these containers are shown in Fig. 6.

B. Initial population

We utilize the function crtbp() to create the initial population randomly, which is a function of genetic algorithm toolbox (gtabx) based on MATLAB.

C. Fitness function

To provide a reason for selection, we have to calculate fitness value for each solution in the population. The method of fitness value count as follow:

- Calculate the number of reshuffles and the range for each solution. If the solution is unfit for the present yard, change both of the number of reshuffles and the range to 1000.
- Use function ranking() with the number of reshuffles

TABLE II Examples of Function Ranking()

Example 1		Example 2	
input	*output*	*input*	*output*
1	2	3	1.75
2	1.5	3	1.75
3	1	4	1
4	0.5	9	0.5
5	0	11	0

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and the range respectively. Ranking() is a number-distribution function, which give a number in [0,2] at regular intervals according to its inputs, as is shown in TABLE II.

- The final fitness value is the mean of ranking(number of reshuffles) and ranking(range).

D. *Genetic Operators Design*

- Selection is the process that program choses some solutions from the last population to the new population. We apply the roulette wheel selection in our GA, which makes that the probability of a solution equals its fitness value divide the sum of fitness value of all solutions in the population. Besides, we set a strategy of retaining the best that we keep the best solution of the last population in the new population.

- Crossover is the process that program choses two solutions from the population with a larger probability, and exchange some part of them. We used one-point crossover in the GA, which is to say that we get a crossover point randomly and exchange the vis-à-vis part of each other. The probability is set at 70%.

- Mutation is the process that we change some data of solutions with a small probability. In the GA proposed in this paper, we set the probability at 30% and we change only one point of the solution with a random number.

E. *Stoppage rule*

When the population evolution to the 100^{th} generation, the program is stopped and then the best solution in final population is the final solution.

F. *Algorithm flow chart*

The flow char of the proposed AG is shown in Fig.7.

V. Computational Results

In this section, we will provide an example, in which there are 50 new containers need to be stored, to show the performance of the proposed model and GA.

A. *Settings and inputs*

- The area considered in the example is 10 bays* 8

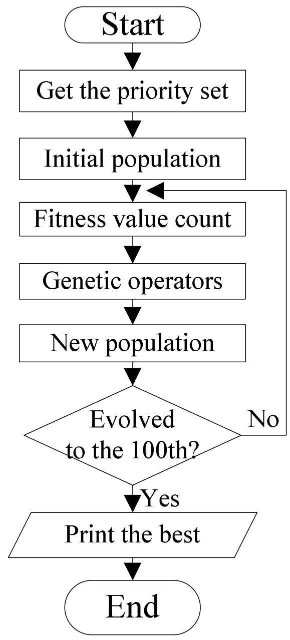

Fig. 7 Flow Chart of AG of CLAP

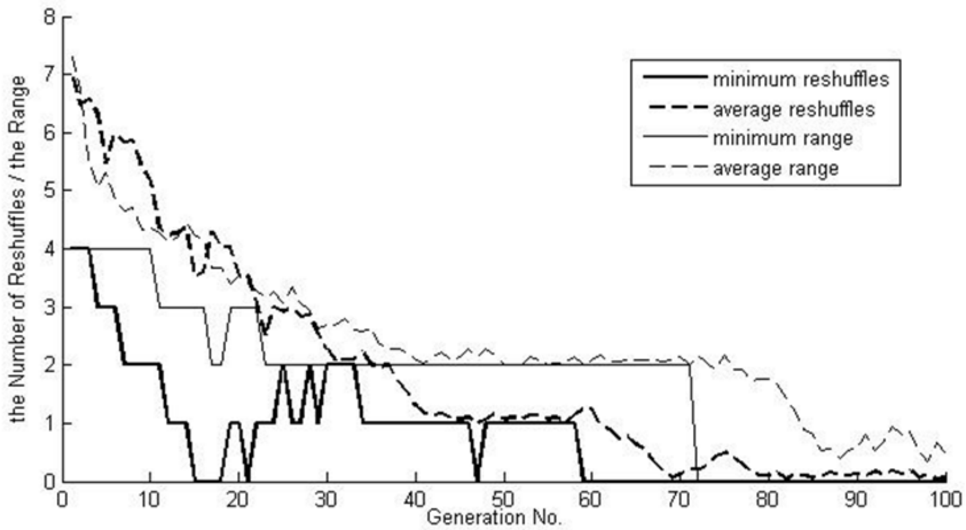

Fig. 8 Typical example's result of AG designed for CLAP

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rows* 5 tiers.

- The original statue of the area is empty.
- The set of priority of 50 new containers, in order, is {22 1 9 2 3 25 21 10 29 2 14 12 23 24 6 15 14 20 22 23 9 21 20 5 4 15 29 11 18 7 23 8 16 21 27 29 17 5 5 8 26 8 25 8 28 11 6 8 19 15}.

B. Result

When the initial population evolved to the 100th generation, the program is stopped and the result is shown in Fig.8. The average reshuffles/the average range in Fig.8 is the mean of all the solutions except illegal ones. As shown in Fig.8, the algorithm got the global optimum solution at about the 72th generation, in which both of the minimum reshuffles and the minimum range are zero. And the population is going to converge with the increase of generation number.

VI. CONCLUSION

Although container's location allocation problem in yard bay has already been studied in the reported literatures, there is almost no reported literature on CLAP. In this paper, we proposed a novel genetic algorithm to solve the container's location allocation problem (CLAP) in rear storage yard. As shown above, the GA designed for CLAP is able to get the global optimum solution and the population is going to converge, which can provide the minimum number of reshuffles and the balance between bays. However, due to the complexity, we only took 20ft normal containers into account and also ignored the weight of containers. In future, we will further discuss the problem.

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