The AFSA-GA Algorithm for the Quay Crane Scheduling Problem of the Loading and Unloading Operations

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ABSTRACT

In order to improve the efficiency of container terminals, eliminate the empty quay cranes movements, the simultaneous loading and unloading operations in same ship-bay is advanced. The AFSA-GA algorithm is proposed to solve the mixed integer programming model of the dual-cycle operation, which take advantage of the strong local search ability of GA and the global optimum search ability of AFSA. The experiment shows that AFSA-GA algorithm can improve the operation efficiency of quay crane significantly.

KEYWORDS
Artificial Fish Swarm Algorithm, Computational Intelligence, Dual-Cycle Operations, Genetic Algorithm, Quay Crane Scheduling

INTRODUCTION

As the production operation of the container terminal, the efficiency of the container loading and unloading operation by the QC (Quay Cranes) is the key point to influence the waiting-time of the ship’s stay in port and the transportation efficiency of the terminal. The container terminal operation includes the series of interrelated operations, such as, the quay cranes(QCs) begin to load and unload containers, the internal container trucks transport containers between ship and yard, when the container ship arrives at the pier. The import and export containers are stored in the yard temporary, the quay cranes(QCs) complete the containers’ loading an unloading in the yard, the external container trucks complete the transport between the yard and ship. Quay cranes are the most important equipment of container terminal, and they are the bottleneck of container terminal system. The operation efficiency of quay cranes directly determines the whole container terminal’s production efficiency.

Based on synchronized loading and unloading technology, and combined with actual scheduling method in terminals, quay crane collaborative scheduling among vessels is proposed. Mathematical models are established to minimize the maximum delay time of all ships. Then quay crane scheduling method based on synchronized loading and unloading for single ship is proposed.

At present, the container quay crane scheduling problem of container terminal can separate to the scheduling problem of multi-container cranes of single container ship and the base bay of the container crane allocation problem. Daganzo (1990) studied more than one ships’ static and dynamic container quay crane scheduling problem for the first time, and divided the container ships into multiple areas, requiring that at most one quay crane work for one area at any time, the objective function is

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to minimize the cumulative delay cost of all container ships. Kim and Park (2004) used the branch and bound algorithm and the greedy random heuristic algorithm to solve the quay crane scheduling problem of the single container ship by considered the constrains such as the non-cross-crossing of container quay crane, which take the minimum time-span of container ship and the total completion time of container quay cranes as objective function. Chen, Nishimura et al. (2008) proposed the multi-user container terminal berth and container quay cranes’ allocation model, used the heuristic-genetic algorithm to get the optimal solution of the problem. Lee, Wang and Miao (2008) established the non-interference constraint model of the container quay crane scheduling problem, and used the GA to obtain the approximate optimal solution of the problem. Canonaco, Legato, Mazza et al. (2008) used queuing theory to study the quay crane scheduling problem of container terminal, but ignored the influence of the non-interference of the container quay cranes and the operation’s sequence on the dock front loading and unloading operation. Tavakkoli-Moghaddam, Makui, Salahi et al. (2009) used the rolling decision method to study container quay crane scheduling problem, but simplified the ship berth distribution and ignored the influence of ship superstructure to the quay crane operation.

The integrated loading and unloading quay crane collaborative scheduling problem is the NP-Hard problem and difficult solved by the exact algorithm. Nishimura, Imai, and Papadimitriou (2001), Goodchild, Daganzo (2007) and Lee and Chen (2009) used heuristic algorithm, genetic algorithm and global search evolution algorithm to solve the problem. The former mostly relies on the heuristic developed by practical experience and its calculation speed is fast, but it easily falls into the local optimal result and difficultly get the global optimal result. The latter is mainly genetic algorithm, the advantage is to be able to search for the theoretical optimal result, the disadvantage is that the huge calculation of the model will be occurred with the increase in the number of ships and berths, which the search space will rapidly expand and the combined explosion problem will happen.

Li (2003) proposed the artificial fish swarm algorithm (AFSA) which is the new swarm intelligent optimization algorithm with a multi-point parallel random search manner. The artificial fish swarm algorithm simulates the fish swarm’s behaviors of prey, cluster, chase and random. Prey behavior is the basic operation. When discover food nearby, the fish will swim toward that direction. Clustering behavior often forms a large group. Chasing behavior indicates that when one fish finds rich food and then others will get there following the fish. Random behavior allows fish swim freely. AFSA is not sensitive to the initial value and parameter selection and has good global optimization ability, at the same time, it has adaptive ability to search space, and it has stronger robustness and better global optimization ability. This paper uses the AFSA-GA algorithm to solve the integrated loading and unloading crane operation scheduling problem of single quay.

INTRODUCTION OF THE DUAL-CYCLE QUAY CRANE OPERATION

The Quay Crane use the single cycle method for the container operation, which the QC usually handles loading tasks after all unloading tasks have been finished at most. The QC’s activities of single method will make more empty movements. Liang, Huang and Yang (2009) proposed the synchronized loading and unloading method of QCs has been used for reducing the operation number of QCs in some modern container terminals. This method of the dual cycle loading and unloading operation can improve the productivity of QCs, as shown in Figure 1. The dual cycling allows QC to discharge a container in the same cycle as a loading operation, thus doubling the number of QC tasks in one cycle, and decreasing the empty movements. This kind of efficiency improvement can observably reduce the ship turn-around time in order to increase the berth efficiency.

THE MATHEMATICAL FORMULATION OF PROBLEM

The Integrated loading and unloading quay crane scheduling optimization model is the following: Equation (1) represents the objective function which is the linear combination with the minimization
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