A Scheduling Framework for Railway Container Terminals Based on Internet of Vehicles

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Abstract. In this paper, we establish a dynamic optimization model based on the information of container trucks collected by internet of vehicles (IOV). This research aims to realize the direct loading and unloading operation between the container trucks and the container trains to reduce waiting time of the container trucks. Finally, the frame we introduced can get an optimal job sequence and is helpful for the operation in railway container terminals.

1. Introduction

As an important part of logistics modernization, railway container transportation combines the advantages of railway transportation and container transportation. It not only facilitates multimodal transportation, but also has many advantages such as safe, high-speed, energy saving, environmentally friendly and highly efficient. It is an important direction for the development of railway freight transportation in the future. Under the circumstance of the Belt and Road Initiative, container transportation may gain a promising potential. Linking China with Europe, it can be easily anticipated that its development will cause considerable shifts in container transportation.

The railway container terminal is an important platform for railway container transportation. It plays an important role in the compilation of China-European trains. It promotes the further development of railway international logistics and trade, and is the key to the rationalization and scientification of international and domestic trade transportation. In recent years, the freight volume of railway container shipments has grown rapidly, and more demands have been placed on the loading and unloading operations of railway container terminals. Therefore, improving the efficiency of production operations at the container terminals, reducing operation costs, and optimizing container operation scheduling are critical to the operational practice of the container terminals.

However, currently operation in container terminals generally have the problems of hard to increase service scale and utilization efficiency of facilities and equipment, as well as decrease the operating costs, which hinders the long-term operation of the container terminals. This paper focuses on this aspect, which has some reference significances for the efficient use of equipment and the reduction of container terminals operation cost.

The structure of this paper is as follows. A brief review of existing work is given in Section 2. Container terminal’s status is introduced in Section 3. A scheduling framework based on the Internet of Vehicles is developed in Section 4. Section 5 gives key points. And Section 6 gives the conclusion of the paper.
2. Literature Review
In recent years, the optimization of the containers’ assignment has attracted much attention. Ambrosino and Siri use a mathematical model to compare different solutions for the problem of train load planning in a seaport container terminal [1]. Zeng and Yang simulate and optimize container loading problems [2]. There are some scholars who have studied the problem of the distribution of workload between gantry cranes as well [3,4]. And some other scholars have established and analyzed mathematical models for container transportation problems [5,6].

The researches on the operation scheduling of gantry cranes in container terminals mostly consider the scheduling optimization problem under static conditions, and fail to combine the modern Internet of Vehicles (IOV) technology to achieve dynamic optimization scheduling.

3. Layout and Operation Mode of Railway Container Terminals
Container terminals, performing as a key connection point in multimodal transportation and an important technical facility in the railway transportation system, have been playing a significant part in global and domestic trade. Typically, in container terminals, loading process and unloading process are two main operation processes. Therefore, it is becoming more and more important for the operation of the container terminals to improve the efficiency.

Figure 1 gives the layout of the facilities in the railway container terminals. The railway container terminals can be divided into three parts: the main operation area, the auxiliary storage area and the service area. The main yard is mainly used for the storage of heavy containers for import and export as the auxiliary yard is mainly used for the storage of special containers such as empty containers, refrigerated containers, and maintenance containers. The containers are mainly stored in the main yard.

The handling equipment corresponding to different operations mainly includes gantry cranes, reach stackers and container trucks. As the core loading and unloading resource of the container terminals, the gantry crane is also used for stacking and carrying operations of the heavy containers in the main yard.

In the process of loading and unloading, taking the unloading process as an example, after the container trains arrive at the container terminals, the containers are hoisted from the container trains to the container trucks by the gantry cranes, and then transported to the main yard by the container trucks, and finally placed to the appropriate location by the gantry cranes.
The loading and unloading operation modes of the sending and arrival containers of the container terminals can be divided into two categories: the "Container truck-Storage yard-Container train" mode and the "Container truck-Container train" mode.

i) "Container truck-Storage yard-Container train" mode: The arrival containers are first unloaded from the container trains to the main yard, and then transported away by the container trucks; the sending containers are first unloaded to the main storage yard by the container trucks and then transported to the container trains, as shown by the yellow lines in Figure 2.

ii) "Container truck-Container train" mode: The arrival containers are transported directly to the container trucks after being unloaded from the container trains. The sending containers are directly discharged from the container trucks to the container trains and then transported away, as shown by the blue lines in Figure 2.

Through the comparison of the two types of modes, the "Container truck-Container train" mode can reduce the operation of container landing, which greatly reduces the working time. Thus applying this mode more into practice will play a vital role in improving the efficiency of the container terminals.

Figure 2. The operation modes of the sending and arrival containers.

4. Scheduling Framework Based on IOV

Due to the limited access to information, most of the container terminals adopt the "Container truck-Storage yard-Container train" mode in the operation practice rather than the time-saving and efficient "Container truck-Container train mode" at present. In the process of multimodal transportation, the container trucks’ arrival time is uncertain, and it is likely to have some random problems. Therefore, the "Container truck-Storage yard-Container train" mode is adopted in the operation of the containers, which increases the operation part of landing the containers. Also there is very little direct loading and unloading operation between the container trucks and the container trains, which can easily make the container trucks line up and crowd in the container terminals. The phenomenon of queuing and crowding is not propitious to the release of the full capacity of the equipment and the efficient operation in the container terminals.

Nowadays, with the continuous maturity of the Internet and the Internet of Things technologies, we can introduce IOV technology into the operation of the container terminals and this paper proposes a new operation scheduling method.

As shown in Figure 3, the wireless communication equipment is used to collect the in-transit information such as the location, speed and route of the container trucks through IOV technology. And then we can use the feedback information to simulate the dynamic information of the container trucks such as the arrival time and loading status. Combined with the simulation prediction results, we can establish a dynamic optimization model of the gantry cranes scheduling operation on the basis of the
original operation sequence, aiming at maximizing the number of direct loading and unloading operation between the container trucks and the container trains and minimizing the working distance of the gantry cranes. Based on the model constraints, a rescheduling algorithm is proposed for the arrival of the container tracks, and the original operation plan and resource allocation are adjusted accordingly to determine the optimal container operation sequence.

Figure 3. Container loading and unloading operation dynamic optimization process.

Through dynamic adjustment, the containers can be directly loaded into the empty container trucks after being unloaded from the container trains as soon as the empty trucks arrive. After the container trucks arrive, the containers can also be directly loaded into the delivery container trains. Thus the amount of direct loading and unloading operation between the container trucks and the container trains is added, and the number of landing the containers is reduced, which has a great theoretical significance and practical application value for eliminating the queuing and crowding phenomenon at the gate.

To get the approximate optimal sequence of the container loading and unloading, we choose to develop a genetic algorithm in the optimization process as shown in Figure 4. Genetic algorithm is a heuristic global optimization algorithm that searches for optimal solutions by simulating natural evolutionary processes. The key to the calculation of genetic algorithms is the calculation of the group fitness function. According to the degree of fitness, from the offspring and the previous generation, a certain number of individuals are chosen, and continue to evolve as the next generation group. The algorithm converges on the best chromosome finally after several generations. In the process of implementing genetic algorithm, the representation of chromosome and genetic operator design are two key steps to quickly enter the feasible domain and quickly approach the optimal solution neighborhood. Main implementation steps are elaborated as follows.
4.1. The Representation of Chromosome

Chromosomes are represented by a series of encoding. Every gene represents an operation’s sequence from the initial position to the corresponding end, and the value of the gene represents the number of loading operations. An example of chromosome representation is shown in Figure 5.

\begin{figure}
\centering
\includegraphics[width=0.5\textwidth]{chromosome_representation.png}
\caption{An example of chromosome representation.}
\end{figure}

\begin{table}
\centering
\begin{tabular}{|c|c|}
\hline
Chromosome & 4 1 3 2 5 \\
\hline
Handling Sequence & 4 \rightarrow 1 \rightarrow 3 \rightarrow 2 \rightarrow 5 \\
\hline
\end{tabular}
\caption{An example of chromosome representation.}
\end{table}

4.2. Evaluation of fitness value

The fitness function can be designed by the following formula to evaluate chromosome.

\begin{equation}
Fitness = \frac{1}{T(task)}
\end{equation}

\(T(task)\) is the whole operation’s completing time.

4.3. Genetic operators design

The roulette wheel selection is adopted for the selection operator. For each chromosome, it is possible to select potentially valid chromosomes for recombination based on the likelihood of the selection.

4.3.1. Crossover operator

Genes represent loading operations in the tasks. In offspring, no loss or duplication of gene values can occur. So the order crossover operator is needed.

4.3.2. Mutation operator

To improve the accuracy and completeness of the operation sequence, it is necessary to avoid the phenomenon so that the offspring gene values avoid losing or duplicating. Therefore, we use an inversion mutation. Two mutation points in chromosomes are randomly selected and the gene value of these points are inverted.
4.4. Stopping criterion

Continue the whole iteration process until the time reaches the specified value. Take the population’s best individual as the final optimal solution.

5. Key Points

The research aims to maximize the skipping of the stacking operation steps in the main operation area, and realize the direct operation of loading and unloading between the container trucks and the container trains. In daily work, the container terminals first sort the loading and unloading operations of a series of containers to generate an initial sequence of operations. This initial sequence of operations can only ensure that all the loading and unloading tasks of the gantry cranes can be completed. However, the efficient use of the equipment cannot be ensured at the same time and the queuing and crowding phenomenon in the container terminals often occurs.

i) This paper builds a model which uses genetic algorithm to find the initial optimal operation sequence.

ii) We use IOV technology to obtain the real-time position and speed information of the trucks in order to make some adjustment dynamically and generate a new operation sequence on the basis of the initial optimal operation sequence.

iii) The frame gets a new optimal job sequence by using the genetic algorithm again.

Thus this frame can help the arrival container trucks achieve direct loading and unloading operations and reduce the waiting time.

6. Conclusion

In this paper a scheduling framework for railway container terminals is introduced. And a dynamic optimization model of gantry cranes scheduling operation is established based on the real-time dynamic information of the container trucks collected by IOV to optimize the operation sequence of gantry cranes.

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