

Ships Inbound&Outbound Model Analysis

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Abstract

Aiming at the issue of ship entry and exit scheduling, this paper analyzes the various types of ships under different channel water conditions, combined with the application of information technology such as AIS, and introduces the model of ship entry and exit scheduling, and the algorithm and optimization of ship scheduling. The method is explained. The goal of dispatching is put forward: to minimize time cost and maximize economic benefits as much as possible under the premise of ensuring safety and following the rules of navigation.

Keywords

Ship scheduling; Inbound&outbound ports; Algorithm introduction; Channel waters; Scheduling model.

1. Introduction

Ship scheduling is an important part of water traffic organization. Scientific and effective scheduling according to the situation of the port can not only reduce the waiting time of ships entering and leaving the port, but also reduce the risk of ship collision and achieve both safety and economic benefits. With the continuous development of navigation technology and intelligent technology, ship scheduling on water has gradually developed and matured after integrating various technologies such as path optimization, multi-objective model and ship collision avoidance. The research on ship scheduling, combined with the currently used AIS technology and VTS technology, has certain significance for ship navigation in port, ship entry and exit and port management and scheduling.

we analyze the information of different water types, and introduce the model and characteristics of the algorithm of ship scheduling in combination with the ship communication technology VTS and AIS, propose the problems to be researched in the scheduling, and look forward to the future development direction.

2. Water Type

Port waterways can be divided into single channel water, double channel water and complex channel water according to the type of water. Different types of waterways have different specific requirements for ship scheduling. The ultimate goal of channel scheduling is to minimize scheduling time and waiting time to maximize efficiency. The time efficiency is improved while ensuring navigation rules and safety.

In the case of vessel scheduling in single channel waters, only one vessel can pass in the channel at the same time, regardless of vessel size and type. The most basic purpose is to save scheduling time while ensuring safety as much as possible, and also to take pollution, fuel consumption and other factors into consideration. Considering the possibility of berth conflicts [1], the berth conflict dissipation model can be transformed into coding rules, and the flow conversion model and time slot allocation model into decoding rules [2].

Two-way channel waters can better improve vessel navigation efficiency compared with single channel waters, i.e., save vessel scheduling time, reduce vessel waiting time, and ease port

scheduling pressure. However, at the same time, the two-way channel waters also require higher requirements from the relevant information processing department, the regulation and control department and the ships themselves compared with the single channel waters. The requirements for safety are also higher. The purpose of dual channel waters is to minimize dispatching time and vessel waiting time and maximize safety. Under certain circumstances, dual channel waters or complex channel waters need to be converted to single channel waters for consideration, such as when visibility is too low, or when there are large vessels entering and leaving the port [3]. Complex channel waters can be narrowly understood as a combination of single channel and multi-channel, and the difficulty lies in the problem of multi-ship encounter [4]. The study of complex channel waters focuses on the problems of traffic flow congestion and traffic flow conflicts [5].

3. Related Technologies and Scheduling Process

The most common ship information technology to realize the ship scheduling process is AIS (Automatic Identification System), and the common information service system for AIS technology is VTS (Vessel Traffic Service System), in addition to MSP (Marine Service Portfolios) technology. Real-time data of VTS can be used to implement information exchange with the information dispatch center of the port during the voyage of the ship, mainly in the process of entering and leaving the port, using communication equipment. Through the AIS technology statistics can get the ship operation law, because the ship speed is not unified and unchanging when entering and leaving the port, AIS can draw the ship operation law into a chart image, which is convenient to do further research. Similarly, AIS data can also be used for ship trajectory clustering [6], using ship behavior characteristics for similarity modeling, and then clustering the trajectories through the similarity model determined in the previous step on the basis of AIS technical support.

For the ship scheduling problem, the algorithm is used to optimize the path planning in the process of ship scheduling so that the ship can better achieve collision avoidance. During the channel operation, when the ship departs from the port of origin, the navigation plan is sent to the port of destination and the corresponding scheduling plan is made by the port, and the VTS information is sent to the VTS control center in the port of entry and the corresponding arrangement is accepted when the ship departs from the port. In the process of channel scheduling, it is necessary to classify the vessels first, including the classification of vessel size and the classification of vessel type. Generally speaking, bulk carriers and container vessels are considered, while the scheduling process for special types of vessels is different and needs to be carried out separately, and some articles are devoted to LNG vessels [7] [8].

For most ports, VTS technology as well as port dispatch centers are still using manual dispatching as the main method, and they mostly use the scheme of giving priority to large vessels, with a policy of first-in, first-out or first-in, first-out. Due to the increasing number of ships entering and leaving the port, the use of manual operation alone will definitely lead to a decrease in port operation efficiency and the risk of misoperation. Therefore, the port command center needs to use more intelligent scheduling solutions.

4. Scheduling Models

4.1. Multi-objective Model And Non-linear Programming Model

There are various models and algorithms used by ports in the process of developing scheduling solutions. Scheduling models commonly used are multi-objective models or nonlinear programming models with total scheduling time and total waiting time as the objective [9]. In the multi-objective model used for scheduling, a nonlinear binary autoregressive analysis

method can be used to achieve the construction of the control objective function for transport vessel scheduling, and then a multi-objective equilibrium optimization strategy is used to solve the global optimal solution of the control objective function [10] [11]. In the nonlinear programming model used for scheduling, the constraints of the model are generally set to include the time window to be solved, and the total scheduling and waiting time is minimized as much as possible by considering the time window [12]. The constraints of the model vary for different water types, and continuity constraints and safety constraints can be added to the model for dual-channel waters compared to single-channel waters [13]. Subjective influence constraints can also be added to the scheduling model, i.e., considering the human factors in the collision avoidance process [14]. In addition, the effects of track deviation as well as time deviation can also be considered in the establishment of the scheduling model [15].

4.2. Collision Avoidance Model

To avoid collision as much as possible in the process of ship scheduling, collision avoidance is mainly carried out by carrying out the calculation of ship's speed and heading in the process of ship navigation. The collision circle of the ship is the collection of all possible collision positions determined by the speed of two ships together. In the process of establishing the actual ship collision avoidance circle model, the principle of eccentric expansion can be used [16]. The process of collision avoidance in multi-ship encounter is generally established based on the ship collision avoidance objective function model of the nearest encounter distance and range loss, and the ship is often regarded as a physical individual with mass, velocity and position attributes in multi-ship encounter due to too many considerations, and the collision avoidance process is regarded as the attraction or repulsion between physical individuals. The process of collision avoidance is regarded as the attraction or repulsion between physical individuals [17] [18], and it is often necessary to judge collision avoidance by calculating the meeting distance and meeting time between ships [19].

4.3. Sequential Scheduling and Time Scheduling Models

Sequential scheduling model refers to the scheduling algorithm under the premise of following a certain navigational order (large ships first or a certain direction first). The use of sequential scheduling model can effectively reduce the waiting time of ships. However, this algorithm is used to solve the problem of ship scheduling optimization, and the ship navigation order of each round will have an impact on its own round or even the next round. The upper limit of ship waiting time should be proposed when the model is established, although a shorter total sailing time can be achieved when some ship passages are abandoned, although of course the limitation of ship waiting time needs to be considered in the practical application process is not considered in general. The prediction model for the combination of ship passage time and time, RECIP-MILP model is proposed by Paola Pellegrini. This model illustrates how to convert the distance safety constraint into a time constraint when the canal layout has a well-defined structure [20].

5. Scheduling-related Algorithms

5.1. Genetic Algorithms

There are many kinds of scheduling-related algorithms, among which the most widely used is the genetic algorithm. The traditional genetic algorithm has certain limitations, with problems such as large search space, excessive search redundancy and low convergence efficiency. There are numerous optimization methods for genetic algorithms. The most common optimization methods are multiple population genetic algorithms and simulated annealing genetic algorithms. Traditional genetic algorithms need to test the optimal combination of genetic(crossover, variation)operator parameters in advance to ensure an effective collision

avoidance path when making collision avoidance decisions for a particular ship encounter situation, and standard genetic algorithms are prone to premature convergence. The multiple swarm genetic algorithm solves the problem of setting genetic operator parameters and premature convergence of the standard genetic algorithm in ship path planning. Essentially, it improves the process of random generation for ships from different directions with different situations while ensuring that it is a genetic method, and the obtained results converge faster by simulation [21] [22].

The simulated annealing algorithm, referred to as annealing algorithm, belongs to the monolithic search algorithm, first proposed by N. Metropolis et al. The main idea arises from the solid annealing process, which itself has a strong local search capability. The advantage of genetic algorithms is that they have strong parallelism and global search capability, while simulated annealing algorithms have strong local search capability. Incorporating multiple population genetic algorithms into the annealing mechanism (SAMPGA) can improve the situation that genetic algorithms tend to lead to local optima and slow convergence in the later stages. Specifically, this means designing sequential coding operators and chromosome repair operators. Due to the large search space, high annealing temperature, and large range of adaptation value change in the early stage can make the local optimum situation less likely to occur. In addition the rapid reduction of the search range after the cooling can make the convergence speed increase [23]-[26].

5.2. Ant colony Algorithm

The main idea of the ant colony algorithm is to use pheromones to assign weights to obstacles. And it is often modeled together with the artificial potential field method and the raster network method, and it is often accompanied by the fuzzy comprehensive evaluation method to quantify the ship collision hazard [27]. The ant colony algorithm can also be optimized by dividing static weights and dynamic weights according to the different factors influencing the route, static weights are used to measure the route weights in terms of ship sailing distance and dynamic weights are used to measure the economic efficiency [28].

The improved ant colony algorithm is to prioritize the route whose walking real-time direction angle is consistent with the initial direction angle when the ants start searching until they walk to the next node and re-prioritize the route until the end point, reducing the number of iterations to iterate from zero. On the other hand, the artificial potential field method can also be optimized. There may be force equilibrium points in the artificial potential field method, points of equal gravitational repulsion, which may lead to stagnation of the operation. In this regard, an unstable potential field with a small localization is added to randomly generate unstable potential forces, so that the artificial potential field can ensure that no force equilibrium occurs. The method of randomly varying target points is used to avoid the situation where the potential field is zero somewhere, combining the chain network with the dynamic target point method [29] [30].

5.3. Other Algorithms

Scheduling-related algorithms also include particle swarm optimization algorithms, Dijkstra's algorithm, A* algorithm, *bacterial foraging algorithm, and neural network algorithms [31]. The practice of combining multiple algorithms also exists in scheduling optimization schemes, for example, combining particle swarm optimization algorithm and multispecies genetic algorithm, which is prone to prematureness when calculating the extreme value of a function using particle swarm optimization algorithm, while multispecies genetic algorithm uses selection, crossover and variation to run the function objective search in a probabilistic form, which can speed up the particle swarm optimization algorithm's computing Dijkstra algorithm can be modified on the basis of genetic algorithm and the initial planning path can be obtained using Dijkstra algorithm.

A* algorithm is an effective method for solving the shortest path in static networks by using cost function to calculate the cost of departure, and then based on the integrated evaluation function the results of the different functions are evaluate and select the optimal solution. By optimizing the A* function, adding the corresponding constraints and modifying the estimation function can make the A* function operation much faster. The bacterial foraging algorithm is similar to the ant colony algorithm in that the pheromones in the environment are given weights and the obstacles are given certain exclusion weights. The neural network algorithm is mainly used to construct environmental variables.

6. Summary

Ship port scheduling has always been an important part of water traffic organization. With the continuous development of navigation information technology and the increasing maturity of AIS and VTS technology, ship scheduling is gradually developing in the direction of intelligence and high speed. Algorithms are used to optimize and improve the multi-objective model or non-linear model of scheduling, from genetic algorithm to ant colony algorithm, as well as particle swarm optimization algorithm, Dijkstra algorithm, A* algorithm, bacterial foraging algorithm, neural network algorithm and so on. The fundamental purpose of each algorithm is to achieve the shortest possible scheduling time and ship waiting time under the premise of ensuring safety and complying with navigation rules.

However, most of the research on port ship scheduling at this stage is on single channel waters, and a few of them are on dual channel waters. There are only a few studies on complex waterways. It is difficult to have a unified research standard because of the complex topography, policies and currents in complex waterways, so if we want to study complex waterways, the most likely research direction is to analyze a specific waterway for a specific port.

In addition, in the research of ship scheduling, most of the studies regard the ship as a physical individual with constant speed and no external influence, and the influence of ship draft and tide height is not carefully considered in most of the models established, and the weather factor is not taken into account. There are also wind and wave influences, current flow speed influences, and the factors of uneven model and individual differences among ships to be further considered. With the development of information technology, such as 5G technology and digital twin of ships, the real-time dissemination of ship information will be presented in a more rapid and specific form, so the research on the influencing factors of ships will be more detailed and the fine degree of ship scheduling will be required more. Research on intelligent algorithms for ship scheduling will also be carried out continuously.

As the issue of green and low-carbon is getting hotter and hotter, the consideration of environmental pollution to the port in the scheduling process will also gradually attract attention. How to minimize carbon emission in the process of port scheduling, how to reduce the pollution of water bodies, and the scheduling of new energy vessels or new structure vessels are all trends of development.

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