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Intelligent Stowage Expert Decision-Making System for Ro-Ro Passenger Ships

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Abstract. The safe operation of ro-ro passenger transport has become the focus of attention in recent years, and reasonable ship stowage is the basic guarantee for the safe navigation of ro-ro passenger ships. In view of the vehicle stowage problem, the Intelligent Stowage Expert Decision-Making System for Ro-Ro Passenger Ships is proposed. Based on the real-time loading situation of the ship and combined with the ship attitude monitoring information, the expert decision-making system analyzes the balance status of the hull and guides the dynamic stowage of vehicles. It aims to achieve scientific stowage of ro-ro passenger ships through the decision-making system and obtain a reasonable stowage plan, thereby improving ship stowage efficiency and transportation safety.

Keywords. Ro-ro passenger transportation, vehicle stowage, expert decision-making system, algorithm

1. Introduction

In recent years, in order to better meet the people's growing material and cultural needs, develop the island economy, and improve the land-island transportation system, a large number of passenger and cargo ro-ro terminals have been built. As a convenient transportation method that conforms to economic development, the safe operation of ro-ro passenger transportation has become the focus of attention.

Stowage is one of the important steps in the transport process of ro-ro ships, which directly affects the loading and unloading efficiency of the terminal, the transportation efficiency and safety of the ship [1]. A reasonable stowage plan can not only meet the performance requirements during ship operation, but also ensure the effective operation of the port, make full use of the ship's transportation capacity, and ensure the economic benefits of shipping. It is also fundamental to the safe navigation of ro-ro passenger ships. The traditional stowage method relies on manual experience and the sequential stowage of vehicles [2]. During the process of vehicles getting on and off the ship, if the ship is improperly stowed or commanded incorrectly, it will cause the vehicle to shift or even overturn, causing the ship to roll, capsize and casualties and other accidents [3]. With the trend of up-sizing of ro-ro passenger ships, the stowage operation of ro-ro passenger ships has become more and more complex, and the pursuit of efficiency has become higher and higher. The traditional stowage method can no longer meet the development of ro-ro transportation.

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In order to better study the stowage scheme of ro-ro passenger ships, this paper proposes an intelligent stowage expert decision-making system that integrates real-time analysis, parameter judgment, warning value decision-making, and algorithm optimization processing. Based on the real-time loading situation of the ship, combined with the ship attitude monitoring information, this system can analyze the balance status of the hull and guide the dynamic loading of the vehicle.

2. Overview

The Intelligent Stowage Expert Decision-Making System for Ro-Ro Passenger Ships uses information technology to collect and monitor the basic information of ship status and stowage vehicles, uses scientific algorithms to analyze parameters, determines risk levels, and ensures ship stowage balance and operational safety. The system adopts unified interface standard to aggregate and manage data resources in each step, and provide security protection capabilities such as intelligent collection, intelligent perception, intelligent analysis, and intelligent alarm. This system also equips multi-faceted auxiliary decision-making capabilities, such as data analysis, situation monitoring, information release, and portal services. In addition, it has the command and control capabilities to provide command, prevention, control, and disposal.

2.1. System Composition and Architecture

The Intelligent Stowage Expert Decision-Making System for Ro-Ro Passenger Ships consists of software, hardware and algorithms. The software mainly includes data center subsystem, user management module, ship management module, shift management module, alarm management module, stowage algorithm module, data dashboard module, statistical analysis module, and operational data simulation tools.

(1) Data Center Subsystem. This system establishes a basic data storage platform, establish a unified interface specification for the database, and establish an IoT data collection center. The subsystem includes database design, data management, and database maintenance, and realizes the overall core support center for system operation.

(2) User Management Module. The user management module is divided into basic user information management and rights management.

(3) Ship Management Module. As one core module of the system, it realizes the addition, modification, query and deletion of ship information.

(4) Shift Management Module. As one module of the system, it can realize the addition, modification, query, deletion and archiving of ship schedules.

(5) Alarm Management Module. As one core module of the system, it can realize the collection, analysis, display, processing and archiving of alarm information during the operation of software.

(6) Stowage Algorithm Module. As one core module of the system, it realizes the core part of the stowage work by selecting dynamic and static methods through configuration to provide the optimal solution for ship stowage.

(7) Data Dashboard Module. This module displays the billboard on a large screen to display the system operation process, ship loading process, alarm information prompts, etc.

(8) Statistical Analysis Module. This module provides a combination of filtering conditions, and configures work operation conditions based on combined statistics and analysis.

(9) Operational Data Simulation tool. This tool receives incoming external data, and provides simulate data.

The overall design architecture of the system is shown in Figure 1.

<table>
<tr><td colspan="6">Application Layer</td></tr>
<tr><td>User Management Module</td><td>Ship Management Module</td><td>Shit Management Module</td><td>Alarm Management Module</td><td>Data Dashboard Module</td><td>Statistical Analysis Module</td></tr>
<tr><td colspan="6">Logic Layer</td></tr>
<tr><td colspan="3">Stowage Algorithm Module</td><td colspan="3">Data Interface</td></tr>
<tr><td colspan="6">Data Layer</td></tr>
<tr><td colspan="3">Relation Database, Document Database</td><td colspan="3">Data Center Subsystem</td></tr>
</table>

Figure 1. Architecture diagram of intelligent stowage expert decision-making system.

2.2. Key Technologies of System

The overall technical route of this system adopts the guiding ideology of linear programming, and uses computers to run loading algorithms to achieve reasonable and efficient stowage of ro-ro passenger ships under established constraints.

(1) Smart IoT technology

Intelligent IoT technology is the basis for equipment intelligence. Through IoT technology, equipment can intelligently interact with the network to achieve big data collection and analysis, as well as remote monitoring and control. In addition, IoT technology can also realize the interconnection of equipment, making the production process more coordinated and efficient.

(2) Intelligent detection technology

Intelligent detection technology is a key technology to improve and ensure production safety. Through intelligent detecting equipment and systems, real-time monitoring and early warning of the production process can be carried out, as well as full-process quality testing of products. In addition, intelligent detection technology can also be combined with technologies such as big data and artificial intelligence to discover problems in production and provide solutions.

(3) Intelligent algorithm technology

Intelligent algorithms identify core constraints under the framework of finite element technology, run, simulate, and judge linear programming combinations through computer algorithms, and discover and determine the best soution by studying and judging strategies.

3. Stowage Algorithm

3.1. Basic Conditions of Stowage Algorithm

The stowage algorithm is the core work of vehicle loading on ro-ro passenger ships, and is also the core content of the intelligent stowage expert decision-making system. The quality of the stowage algorithm directly determines the efficiency and safety of the ship's loading work. Before proceeding with the loading algorithm, following basic assumptions shall be met:

- The ship has the ability to carry designated types of vehicles.
- The weight and dimensions in the loading algorithm model correspond to the weight and dimensions of the actual vehicle.
- The weight of the vehicle is evenly distributed.
- The shape of the load-carrying vehicle is regular, and there are no special-shaped vehicles.
- The vehicle moves in a translational manner on the computer side.

At the same time, the system set constraints:

- During the entire stowage process, the trim and heel of the ship shall not exceed the warning threshold.
- Overweight, over-length, and over-width vehicles are not allowed to board the ship.
- The total stowage weight shall not be greater than the ship’s carrying capacity.

3.2. Stowage Algorithm Classification

The vehicle stowage of ro-ro passenger ships can be categorized as static stowage and dynamic stowage according to the actual situation.

(1) Static Stowage Algorithm

Static stowage is suitable for "vehicles waiting for ships" scenario, that is, all vehicles have arrived at the port, and the collection of weight, size and other relevant information has been completed, and the information of the arriving ships has also been identified. The static stowage algorithm is based on known information, considers the deck parameters globally, uses computers to combine and adjust the algorithm for the vehicle, and obtains the most optimal stowage plan within the constraints.

When the static stowage algorithm is running, the program loads all basic vehicle information and performs parameterized simulation of the deck in the algorithm, including initialization of the deck center of mass, establishment of a potential-moment coordinate system, parking area division, channel area division, etc.

The algorithm loads all vehicle length information, and uses the algorithm to reasonably plan and park the vehicles on the deck. The algorithms used include complete enumeration method, greedy algorithm, dynamic programming method, etc. Vehicles whose length and weight exceed the threshold after initial judgment are added to the list of unloadable vehicles and finally output to the user.

After the deck vehicle arrangement plan is completed, the centroid position is calculated overall based on the vehicle-related position information in the data set, and compared with the threshold. If the threshold range is exceeded, the vehicle arrangement plan is adjusted.

To simulate the boarding process, the fixed element judgment method is used. The vehicle boarding process in the parking area is calculated firstly, and then the vehicle boarding process in the channel is calculated. During the simulated vehicle boarding process, the parking area is based on the position moment (the one with the larger position moment is prioritized), and the passage vehicle is based on the corresponding vertical axis coordinate (the one with the smaller coordinate is prioritized). During the calculation process, if a certain vehicle calculation result causes the ship center of mass offset to exceed the threshold, the vehicle arrangement plan will be readjusted. The adjustment method adds a constraint on the current calculation vehicle: as close as possible to the center of mass of the ship.

After the queue is processed, the stowage plan is output. The main algorithm flow chart is shown in Figure 2.

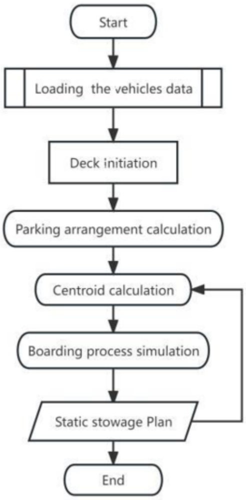

Figure 2. Flow chart of static stowage algorithm.

(2) Dynamic Stowage Algorithm

Dynamic stowage is suitable for the "ship waiting for vehicles" scenario, that is, the ship has arrived at the port and is waiting for vehicles to board the ship within a specified time. The weight and size of the vehicle need to be obtained in real time by on-site intelligent equipment, and linear programming algorithms and dynamic prediction methods are used to guide ship boarding.

When the dynamic stowage algorithm is running, the program loads the deck configuration information and performs parameterized simulation of the deck. These include initialization of the deck center of mass, establishment of the position-moment coordinate system, parking area division, passage area division, etc.

As vehicles arrive one after another, the algorithm uses the length and weight of the current vehicle as the judgment criteria. When the length and weight of the current vehicle are initially judged to exceed the threshold, the current vehicle will be added to the list of vehicles that cannot be loaded, and the user will finally be notified.

The ship deck has been divided into cells with a side length of 20cm (i.e., the smallest computing unit), which are mainly divided into parking areas and passage areas. Based on the length of the vehicle, the minimum combination of consecutive cells where the vehicle needs to be parked will be calculated. Taking the center of the deck cell position as the calculation point, loop to obtain the cell that can park the vehicle, and ensure that the cell is the cell with the largest potential moment. Based on this cell and combining the weight of the boarded vehicle, the weight of the ship and the weight of the vehicles, the overall center of mass of the ship is calculated, and the offset is calculated. If the threshold is exceeded, the vehicle will be parked in the waiting area and the number of times the vehicle has been processed will be marked.

Same steps will be done for next vehicle. When one vehicle is successfully parked at the designated location, the vehicles in the waiting area will be processed in turn, and the final number of processing times is marked. When the number of times the vehicles has been processed exceeds the threshold setting, the vehicle cannot be loaded this time.

When the number of vehicles loaded on the ship reaches the specified value or the total loading weight reaches the specified value, the loading of this ship will end. The specific algorithm flow is shown in Figure 3.

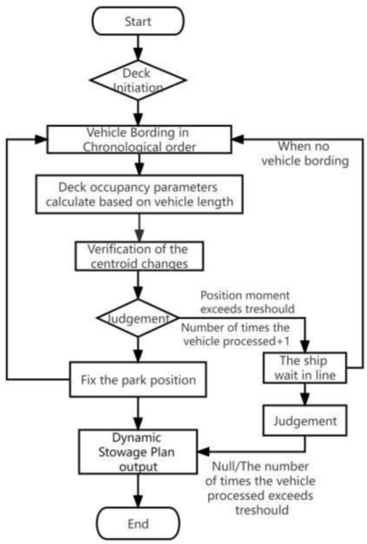

Figure 3. Flow chart of dynamic stowage algorithm.

4. Conclusion

In recent years, the passenger and roll-off transport industry, as an important branch of the water transport industry, has become one of the important forces in prospering the local economy and promoting the tourism industry. It is a sunrise industry that our country actively promotes and supports. The investigation of the stowage scheme of ro-ro passenger ships will help to reasonably arrange the stowage sequence of vehicles and ensure the safe operation of the ship. This article lays a theoretical foundation for the scientific stowage of ro-ro passenger ships.

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