Research on Intelligent Loading System for Container Ships

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Abstract. Container transportation is an important part of the global transportation industry, and its transport capacity affects the development of the global economy to a certain extent. Ship stowage is an important part of container transportation. Its intellectualization level determines the time of container ships in port and the frequency of overturning containers, thus affecting the efficiency and economic benefits of ship transportation. Based on the container ship stowage process, this paper analyzed the factors affecting the stowage, focused on the study of the composition of intelligent stowage system, and provided a safe and reliable idea for the construction of container ship stowage system.

Keywords: Container ship, Intelligent Loading, System design.

1. Introduction
In the past 20 years, with the development of container transportation industry, the scale of container ships has been expanding, the number of containers that can be accommodated has been increasing, and the stowage problem of container ships has become more and more complex [1]. The traditional artificial stowage method has not been able to meet the increasing demand of ship stowage. In this context, it is necessary to explore effective theoretical methods and carry out corresponding research on intelligent stowage system.

2. Research on stowage of container ships

2.1. Container ship stowage definition
Container ship stowage refers to the process of making specific and detailed shipping position and sequence before the ship approaches the port according to the shipping requirements of the ship and the operation requirements of the terminal. Intelligent stowage is based on the experience of artificial stowage. The experience of artificial stowage is regularized by computer software, and the rational stowage plan is generated quickly by the rule base.

2.2. Container ship stowage process
(1) The shipping company carries out a pre stowage process based on the remaining space on the ship and according to the booking situation of the customers. The stowage usually only considers the size, type, empty and load box of the box, the destination port to be transported, etc., and arranges in advance according to the attributes to form a pre stowage chart.
(2) After receiving the pre allocation drawing, the wharf stowage man will arrange the CWP of ship unloading and loading, and simulate the completion time of each road of the bridge operation through the arrangement, so as to ensure the balance of ship loading and unloading operation. Stowage is usually carried out after CWP arrangement.

(3) According to the pre allocation requirements of the shipping company and the actual conditions of the container yard, the terminal stowage personnel determine the specific loading position and loading sequence of the container in the ship. That is to say, after the stowage personnel have known the list of boxes and the distribution of boxes in the yard, and combined with the pre stowage drawing of the ship company and the distribution of the shore bridge, the stowage personnel comprehensively consider the efficiency, low cost, safe operation and other factors of loading in the yard to carry out the stowage plan between the boxes and the spaces.
According to the berth plan and scheduling plan, the stowage man shall ensure that the loading and unloading work volume can be relatively balanced in each road and bridge, and shorten the completion time of the whole ship's work.

2.3. Factors affecting stowage

Stowage, as the core business process of container ship transportation, is closely related to berth planning, yard planning, yard and bridge equipment utilization. Stowage scheme is a multi-objective combination optimization problem with complex constraints. In the face of different working conditions, its constraints and objectives are different. In addition, in the process of system design, economic, safety, efficiency and other issues need to be considered comprehensively. Therefore, the influencing factors of container ship stowage can be roughly divided into the following two aspects.

(1) Transportation economy. That is to say, considering how to make full use of loading and unloading equipment resources and improve loading and unloading efficiency in the face of different port configuration conditions. At the same time, control the production cost and energy consumption, and focus on how to maximize the ship's loading capacity under full load.

(2) Ship safety factors. That is to say, make full use of the carrying capacity of the container ship to ensure that the ship has appropriate strength, stability and draft difference, so that the immersion depth, longitudinal inclination, lateral stability and weight distribution of the ship are within the corresponding limits; at the same time, consider the size of the container, the type of goods, the structure of the container ship, so that it must comply with the limits of stacking, weight and capacity.
3. Design of intelligent stowage system for container ships

3.1. Architecture strategy of intelligent stowage system
Considering the influence factors, the following strategies can be adopted in the overall design of intelligent stowage system for container ships:

1) Horizontal hierarchical planning. In the face of various business processes and many levels of container ship stowage, the hierarchical planning method is adopted to make the business rules clear and the problem boundary clear, which is conducive to the interactive fusion of stowage data and the control of constraint problem solving range.

2) Vertical sub problem extraction. The problems such as berth and yard planning that affect stowage are refined and decomposed into several small problems, and the constraint scale of each problem is controlled within a certain range of effective solutions in the form of modules. Finally, the solutions of the subproblems are aggregated through algorithms and other ways.

3) Flexible algorithm design. Aiming at some subproblems in the hierarchy, this paper deeply excavates the characteristics and influencing factors of the problem itself, focuses on the core problems of "time space" mutual transformation and data interaction, takes satisfying the engineering application as the standard, and combines various effective calculation and flexible design of constraint solution, so as to meet the requirements of practicability and effectiveness.

3.2. Key modules of intelligent stowage system

3.2.1. Database module. The database module contains the original data needed for stowage, such as container information, field information, etc., including some intermediate information obtained in the process of automatic stowage, such as berth plan, field bridge plan and other intermediate data [2], including the final constraint optimization result data and other auxiliary information data. Among them, the original data entered initially can be designed into four types of databases:

1) Container database. Be responsible for storing all information related to container, including container number, size, type, weight, unloading port, relevant remarks, etc;

2) Ship database. It includes basic information database, performance parameter database and safety verification parameter database;

3) Yard database. It is mainly used to store the actual location information of containers in the field area for voyage booking, including the area code, column number, floor number, etc. of each container;

4) Helper library. Including port sequence information, reasoning rule code, etc.

![Data flow chart of ship intelligent stowage.](image)

Figure 5. Data flow chart of ship intelligent stowage.
3.2.2. **Knowledge base module.** According to the problem of stowage under complex constraints, it is necessary to build a knowledge base module based on the experience of industry experts and the basic requirements of container ship stowage. The basic requirements for ship stowage include the requirements for recording special and common containers, smooth unloading of Midway port containers, storage yard stacking, etc.; the experience in selecting and distributing expert container areas mainly comes from the long-term practical experience of port operators. The above rules and experience results are stored in the database in the form of knowledge expression. The basic expression of knowledge is as follows:

\[ \text{rule (Rno, \{Condition1, Condition2,..., Condition n\}, Result, Remark)} \]

Where: RNO is the sequence number of the rule; condition1 to n are the precondition of the rule; result is the conclusion of the rule; mark is the interpretation of the rule.

In the process of knowledge base design, in addition to the reasonable loading rules, the relevant rules stored in the knowledge base also form a number of indicators and hierarchical structure according to the actual experience under different working conditions. According to the hierarchical relationship, it can be designed as a network structure mode, as shown in the figure below. It can simplify the search mode and path of knowledge base, get the best effect in a short time, and improve the efficiency of module.

After the original data is input into the system, multiple dynamic databases can be generated for data reasoning and algorithm optimization of loading. The data flow formed by the connection and transformation between databases is shown in the figure.

![Knowledge base hierarchy](image)

**Figure 6. Knowledge base hierarchy.**

Most of the related randomness problems beyond the reasonable rules involved in the stowage process are completed with the help of the actual experience and knowledge reasoning technology of the industry stowage personnel. When designing the knowledge management module of the stowage system, the industry stowage technical experts such as many years of practical experience of the terminal, the first mate, the terminal management personnel, etc. provide the corresponding dynamic stowage rules and empirical knowledge to the learning module of the system, quantify and learn to extract relevant information through the system learning module, so as to continuously optimize and
improve the knowledge base and enhance the system knowledge reasoning module. The ability of parallel learning and automatic stowage can improve the rationality and efficiency of the system.

3.2.3. Inference engine module. Based on the knowledge base, combined with the matching principle and system relearning technology, the inference engine module based on the stowage process is to find new practical knowledge by integrating the expert opinions of the industry. After the reasoning process similar to the human brain, it can improve the uncertainty of ship stowage and give the best suggestions. The inference engine module takes forward inference as the core and combines depth first search technology to complete the inference and optimization functions. The execution flow chart is shown in Figure 7. Each matching rule number RNO is recorded in the table list. When the terminal manager needs to understand the reason of the stowage conclusion, the inference engine of the system will be in the corresponding remark mode (REMARK) of each rule in the list table for the decision-making reference of the manager.

![Figure 7. Schematic diagram of inference engine.](image)

4. Conclusions
With the rapid development of the global transportation industry, container ships are developing towards the direction of intelligent and large-scale. The traditional stowage process can not meet the needs of the development of modern ships. Based on the traditional stowage process, this paper analyzes the influencing factors of stowage, aiming at the intelligent stowage system, the system architecture and key modules are designed to provide reference for the development of ship intelligent. At the same time, container ship stowage is a complex constraint problem. In the follow-up study, it is necessary to further analyze and explore various factors of the terminal.

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