Research Status and Development Trend of Intelligent Ships

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Abstract
By exploring the current situation of research and development of intelligent ships at home and abroad in recent years, this paper analyses the development course and current trend of the intelligent ship industry, focuses on the practical situation of advanced technologies in the hot areas of intelligent ships, such as unmanned ships, expounds some problems existing in the current development of intelligent ships, and puts forward some suggestions. Consideration and constructive suggestions on ship development. This paper also studies and analyses the efficient development of ship intellectualization in the era of big data. Combining with the rapid follow-up of current information technology, it looks forward to the future development prospects of ship intellectualization.

Keywords
Research, Intelligent Ships.

1. Introduction
Driven by economic globalization, the volume of trade among countries in the world continues to rise, which also puts forward higher requirements for freight transportation. Waterway transportation plays a more and more important role in cargo transportation because of its advantages of large volume and low cost. At present, water transportation accounts for 95% of the total crude oil transportation and 99% of the total iron ore transportation, which is an irreplaceable mode of transportation. However, with the increasing number of ships and the increasing busyness of routes, more attention has been paid to the serious environmental pollution, high manpower cost and insufficient safety related to waterway transportation. In recent years, the development of information, computer, communication, network, new energy, artificial intelligence and the application of Internet of Things, big data, integrated bridge system and information physics system have greatly promoted the process of ship intelligence, and made it possible to realize a truly green, safe, efficient and unmanned intelligent ship.

In 2012, the Maritime Unmanned Navigation through Intelligence in Networks project, co-operated by eight research institutes, including Fraunhofer CML, MARINTEK and Chalmers University, launched the first large unmanned bulk carrier research. Figure 1 shows the effect of the MUNIN project implementation. The ship on the left is an autonomous navigation ship. The navigation path, meteorological navigation and trajectory parameters displayed in the ship computer system will be updated and stored in real time. The ship monitors the surrounding environment through radar, ship-borne automatic identification system (AIS) and infrared sensors. When encountering other ships or obstacles, the vessel will conduct collision avoidance operations in accordance with COLREGs (International Maritime Collision Avoidance Rules). At the same time, all the parameters monitored by the ship will be transmitted to the Shore Control Center (SCC) in real time. When the ship is close to the land, it can communicate through GSM, 3G or 4G network. When the ship is far away, satellite communication is needed. In 2013, Rolls Royce, one of the world's largest suppliers of ship
equipment, has carried out research on the unmanned cargo ship project. It is expected that the first unmanned cargo ship will be put into operation in 10 years. In September 2015, LR, Quinartique and Southampton University jointly launched the Global Marine Technology Trends 2030 (GMTT 2030), which lists smart ships as one of the 18 key marine technologies. In order to keep abreast of the development trend of intelligent ships and standardize and guide the development of intelligent ships, China Classification Society issued the "Code for Intelligent Ships" in 2015, which clarifies the specific requirements of intelligent ships in intelligent navigation, intelligent hull, intelligent engine room, intelligent energy efficiency management, intelligent cargo management and intelligent integrated platform.

Figure 1. Operation effect of MUNIN project

2. Development Background of Intelligent Ships

The world has entered the "industrial 4.0" period of development. In May 2015, China issued "Made in China 2025", and highlighted the high-tech ships, ship intelligent manufacturing and so on. The development of intelligent ships will effectively solve the main problems faced by ships in energy saving and emission reduction, manpower cost and ship safety. The existing countermeasures to these problems are as follows:

Energy saving and emission reduction. In order to control the emission of greenhouse gases such as carbon dioxide, the global carbon emission trading mechanism and the ship energy efficiency design index (EEDI) established by the International Maritime Organization (IMO) are progressing in an orderly manner, and the reduction of greenhouse gas emissions in shipping industry has become an inevitable trend. At the same time, energy saving and emission reduction technology can also effectively reduce energy consumption and operating costs. At present, measures for energy saving and emission reduction of ships mainly include: 1) using clean energy (LNG, solar energy, etc.); 2) designing ships with less resistance; 3) making engines more energy-efficient; 4) using energy efficiency control technology.

Human cost. The latest shipping survey released by Moore Stephens, an international accounting and shipping consultancy, shows that ship operating costs are expected to rise by nearly 3% in 2014 and 2015, with crew wages and maintenance costs being the main factors contributing to the increase in operating costs. Reducing ship Manning and even realizing unmanned operation of ships is an important development goal of shipping industry in the future. With the continuous improvement of ship's intelligence level, the development of unmanned engine room duty, assistant driving technology and fault self-diagnosis technology makes the ship's crew less and less.

Ship safety. In ship collision accidents, 89%~96% of accidents can be attributed to human's own causes, including obvious and potential causes. Once safety accidents occur, such as the sinking of the Oriental Star in China and the sinking of the South Korean "Time" ship, it will cause serious consequences such as casualties, dangerous goods leakage, traffic interruption and so on. Intelligent technologies such as condition monitoring and fault diagnosis technology, safety early warning technology and information perception technology can improve ship safety. Intelligent ships are
widely regarded as the next technological revolution in shipping industry. In manufacturing, "the Fourth Industrial Revolution" describes how "intelligent devices" will replace humans to manage, optimize and control machines. In business, "Internet of Things" improves our quality of life by mapping and translating people's personal habits into automation devices using sensors and digital technology. In this context, intelligent ship is no longer a common technology, but a concrete embodiment of the utilization and development along with the development trend of science and technology. This trend includes sensors, robotics, big data, new materials, communication technology and so on mentioned in the report. The application of these technologies can be transited to the field of intelligent ships.

3. The Concept of Intelligent Ship

The definition of Intelligent Ship Code is: Intelligent Ship refers to the use of sensors, communications, Internet of Things, Internet and other technical means to automatically perceive and obtain information and data of ship itself, marine environment, logistics, ports and other aspects, and based on computer technology, automatic control technology and large data processing. Analytical techniques. In order to make the ship safer, more environmentally friendly, more economical and more reliable, it is necessary to realize intelligent operation in the aspects of ship navigation, management, maintenance and cargo transportation. Here "intelligence" can be understood as "thinking", which can take into account the specific tasks and various information acquired, and formulate a series of optimal decisions that meet the requirements of ship navigation safety, economy and environmental protection. In 2006, the International Maritime Organization (IMO) put forward the concept of e-Navigation, which collects, synthesizes and displays maritime information on board and on shore by means of electronic information, and achieves the mutual communication of information among ships, ships, shore and shore in order to achieve the ultimate goal of ship safety, economic navigation and environmental protection. This is the original concept of smart ships. Intelligent ships can be divided into four stages of development: the first stage is limited to remote monitoring and data analysis of ship equipment; the second stage is based on cloud computing, Internet of Things and large data analysis technology, and provides safety, environmental protection and efficiency optimization suggestions for ship timing by connecting shore centers. Now semi-automatic navigation; the third stage of intelligent ships on the basis of ship data analysis, to add port logistics information, seamless connection between ship and shore information, real-time and dynamic completion of navigation, ship schedule and port operation optimization; the fourth stage of intelligent ships will achieve full autonomy unmanned and port automation. Handling and Logistics.

At present, the intelligent ship is in the transitional stage from the first stage to the second stage.

4. Key Technologies of Intelligent Ships

The Intelligent Ship Code divides the functions of Intelligent Ship into Intelligent Navigation, Intelligent Ship Hull, Intelligent Engine Room, Intelligent Energy Efficiency Management, Intelligent Cargo Management and Intelligent Integration Platform, which basically covers all the functions of Intelligent Ship. In order to achieve and improve the above functions, it is necessary to further study and deepen the technologies of ship-related information perception, communication and navigation, energy efficiency control, route planning, condition monitoring and fault diagnosis, distress warning and rescue, integration of pilotage and autonomous navigation.

Information Perception Technology

Ship information perception refers to a technical means by which ships can acquire various information about themselves and their surroundings based on various sensing devices, sensing networks and information processing equipment, so as to enable ships to navigate safely and reliably. A typical intelligent ship environment perception system is shown in Figure 2. The information of ship perception can be divided into its own state information and surrounding environment
information. The self-state information includes the state information of all kinds of equipment in engine room, bridge and cargo compartment, as well as the position, speed and course of the ship. It mainly relies on the existing sensors such as pressure, temperature, speed, liquid level and so on. Ambient environmental information includes surrounding ship and obstacle information, surrounding meteorological conditions, water depth, video surveillance information, audio surveillance information, water velocity and direction, beacon position, navigable area, etc. It mainly relies on AIS, maritime radar, video camera, laser sensor, lidar sensor and wind speed sensor. Wind direction sensor, visibility acquisition equipment, log, bathymeter, voyage data recorder (VDR), electronic chart (electronic channel chart) and ship-shore interactive information acquisition. There are many kinds of signals involved in the process of perception, large amount of data, redundancy and conflict between information, which deserve further study.

Figure 2 Intelligent Ship Environment Perception System

Communication Navigation Technology
Communication technology is used to realize the information exchange between various systems and equipments on ships, as well as between ships and shore stations, ships and navigation aids. Common communication modes mainly include: VHF (Very High Frequency), Maritime Network, Maritime Satellite, Mobile Communication Network (Mobile Phone Network), etc. Navigation technology is used to guide ships from one point of a given route to another, usually including positioning, destination selection, path calculation and path guidance. Navigation technologies commonly used by ships include early radio navigation and satellite navigation, which are now widely used. Beidou Satellite Navigation System provides a new development opportunity for China's ship navigation field.

Energy Efficiency Control Technology
In 2007, 1.04 billion tons of CO2 were emitted by world shipping vessels, of which about 870 million tons were emitted by international shipping, accounting for 3.3% and 2.7% of the total global CO2 emissions in that year, respectively. In order to improve ship energy efficiency and reduce greenhouse gas emissions (energy saving and emission reduction), the International Maritime Organization (IMO) proposed EEDI (energy efficiency index for new shipbuilding design) and EEOI (energy efficiency index for ship operation). The development of intelligent ships should conform to the development trend of "green ships". The internal relationship between navigation environment, loading capacity, draft capacity, main engine power (rotational speed) and EEOI should be analyzed. On the premise of ensuring ship safety and operational efficiency, ship speed, loading capacity and draft should be
optimized and controlled. To minimize EEOI index, routes, etc. The relationship between environmental factors and ship energy consumption deserves further study. The energy efficiency management control strategy of ship clean propulsion system considering environmental factors is shown in Figure 3.

Route planning technology
Route planning refers to the intelligent real-time selection of ship's position and channel in order to optimize the route and achieve the goal of safety, efficiency, green and environmental protection, according to the traffic flow control information in navigational waters, vessel density in the forward channel, company's shipping schedule information, channel flow distribution information and channel navigation difficulty information. At present, the commonly used route planning methods include: linear programming method, mixed integer programming model, genetic algorithm, simulated annealing, particle swarm optimization algorithm and other intelligent algorithms (solving stochastic travel time problem). Liu Hao and others use genetic algorithm to plan the route as shown in Figure 4.

State Monitoring and Fault Diagnosis Technology
The condition monitoring technology is a kind of equipment operation state prediction technology, which is based on monitoring the development trend of equipment vibration. By understanding the health status of equipment, it can be judged that the equipment is in a stable state or is deteriorating. In the future, based on large data, multi-scale analysis method can be used to construct equipment condition monitoring system for ship fault diagnosis.
Fault diagnosis technology is to grasp the operation status of marine machinery equipment in operation or without dismantling the equipment, analyze and process the useful information obtained from the test of the diagnosed object, judge whether the state of the diagnosed object is in abnormal state or fault state, and judge whether the deteriorated state occurs. Parts or components, and determine the cause of failure, as well as predict the development trend of deterioration. Its purpose is to improve the efficiency and operational reliability of the equipment, prevent accidents in the future and avoid the occurrence of faults. Due to the small number of intelligent ship crew, the requirement of self-monitoring and fault diagnosis technology for ship equipment status is higher. By using large data analysis technology and intelligent diagnosis technology, potential faults can be detected and handled as soon as possible, so as to ensure the safety and reliability of the ship in the course of navigation.

distress early warning and rescue technology
Occasionally, water traffic accidents, especially collisions and grounding accidents, often cause serious economic losses and casualties. Whether at sea or in inland waters, ship collision is the most common type of water traffic accidents, accounting for a large proportion of all water traffic accidents. Ship distress warning and rescue technology can effectively reduce the incidence of accidents and reduce the loss of accidents. Wuhan University of Technology and other units have developed a ship collision early warning system in bridge area to ensure the safety of navigation of ships in bridge area, as shown in Fig. 5.

Fig. 5 Ship Collision Warning System

Autonomous navigation technology
Intelligent navigation, as defined in the Code for Intelligent Ships, refers to the analysis and processing of perceived and acquired information by means of computer technology and control technology, and the design and optimization of ship's route and speed. When feasible, with the help of shore-based support centers, ships can operate in open waters, narrow waterways and complex environments. Moving to avoid collision and realizing autonomous navigation. The research on autonomous navigation technology of foreign ships is early. The United States, Israel and other maritime powers have developed unmanned surface ships, mainly for military reconnaissance and mine clearance. At present, China has carried out research on autonomous navigation of ships, the most representative of which are "Tianxiang 1" developed by China Meteorological Administration in cooperation with Aerospace Science and Technology Group, the "prototype of surface unmanned intelligent measurement platform" developed by Qingdao Beihai Shipbuilding Heavy Industry Co., Ltd., and the "pilot" developed by Zhuhai Yunzhou Intelligent Technology Co., Ltd. (e.g. Fig. 6, Haiteng 01, developed by Shanghai Maritime University, etc.)
In summary, the seven key intelligent technologies of intelligent ships are embodied in the major intelligent modules of ships as shown in Table 1. It can be seen that information perception and communication navigation are the core intelligent technologies of intelligent ships at present, and the intelligent integration platform is the connection center of the key technologies.

Table 1 Embodiment of Six Modules in Seven Key Technologies of Intelligent Ships

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<tr>
<th>Intelligent module</th>
<th>Intelligent technology</th>
<th>Intelligent navigation</th>
<th>Intelligent hull</th>
<th>Intelligent engine room</th>
<th>Intelligent Energy Efficiency Management</th>
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5. Development Trends of Intelligent Ships

Intelligent Navigation

By using computer technology and control technology to analyze and process the perceived and acquired information, the ship's route and speed are designed and optimized; when feasible, with the help of shore-based support center, the ship can automatically avoid collisions in open waters, narrow waterways and complex environments to achieve autonomous navigation.

Intelligent Hull

The establishment and maintenance of hull database can provide assistant decision-making for safety and structural maintenance in the whole life cycle of the hull. At the same time, it can also provide assistant decision-making for ship maneuvering through automatic acquisition and monitoring of hull-related data.

Intelligent Energy Efficiency Management
Through on-line monitoring and automatic data acquisition of ship's navigational and energy consumption status, the energy efficiency status, navigation and loading status of ships are evaluated. Through large data analysis, numerical analysis and optimization technology, the results of data evaluation and analysis and decision-making suggestions are provided for ships, as well as speed optimization and longitudinal-based optimization. Solutions such as optimal stowage allocation can realize real-time monitoring, intelligent evaluation and optimization of ship energy efficiency, so as to continuously improve the level of ship energy efficiency management.

Generally speaking, some relevant theories of intelligent ships are relatively mature (such as environmental awareness technology, communication and navigation technology, condition monitoring and fault diagnosis technology) and have been applied in practice. However, some technical theories lack verification in real environment (energy efficiency control technology, route planning technology, safety early warning technology, etc.). Independent navigation technology, etc., therefore, intelligent ships are still in the stage of rapid development, not yet fully mature. With the development of ship technology and information technology, as well as the intelligent application of "big data", the emergence of intelligent ships is accelerating. In the next 10 to 20 years, the development of ship intellectualization will be an important factor to determine the future development direction of the ship industry. In addition to the key technologies such as information perception, communication navigation, energy efficiency management and control, automatic berthing, offshore, self-maintenance, automatic cleaning, automatic replacement of equipment components, self-protection will also tend to the development of intellectualization.

With the continuous development of ship intelligent technology, it will be possible to gradually change from intelligent system equipment to thinking intelligent ship, and promote safe and efficient navigation of ships.

Intelligent ship is the inevitable trend of ship development in the future. It has good application needs and development prospects. However, due to the gap between theory and technology level and cognitive level, smart ships in China still need to make breakthroughs in the following aspects:

More in-depth use of large data analysis technology, mining valuable information.

The reduction of intelligent ship personnel means that the requirement of ship safety and security is higher. It is necessary to strengthen the research of relevant theory and technology.

At present, there are many studies on autonomous driving in the ocean, and relatively few in the complex conditions of inland rivers, so it is necessary to carry out relevant research.

**References**


