Anchorage Area Detection

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Mooring area detection represents one of the key technological problems that must be solved in the development of Maritime Autonomous Surface Ships (MASS). Anchoring operation is one of the key operations of ships, which is affected by various factors. The research on anchorage area detection focuses mainly on the safety distance between anchoring ships and methods of mooring area detection.

Keywords: maritime safety ; MASS ; single anchor mooring ; intelligent detection of mooring position

1. Background

Mooring area detection is one of the key technological problems in MASS that must be solved at each development stage, and concerns the development of the MASS mooring area detection system, anchorage safety, utilization rate of anchorage space and other related engineering problems [1][2]. The International Maritime Organization (IMO) established the importance of MASS and classified relevant laws and regulations. Besides, the IMO published the initial definition of MASS and four stages of development at its 99th Maritime Safety Conference [3][4][5]. Meanwhile, major developed countries and regions such as the United States and the European Union have launched specific development goals and plans for the development of MASS. Lloyd's Register of Shipping, Bureau Veritas and other classification societies all pay more attention to the development of MASS [6][7]. In terms of digital technology, China proposed building a comprehensive digital information infrastructure that integrates "Space-Earth Integration" and "Cloud-Network Fusion", which will promote the rapid development of MASS and smart ports. In 2022, Ministry of Communication of China proposed the planning objective of "Enhance the Ship-shore Coordination in the Whole Process of Ship Navigation, Support the Intelligent Auxiliary Navigation in All-weather and Complex Environments [8] and Promote the Application of Individual Smart Ship Technologies Such as Green Smart Ships and Autonomous Navigation, Improve the Shore-based Collaborative System for Ship Intelligent Navigation" [9][10]. "Standard for Intelligent Ships" (China Classification Society, Version II) indicates that intelligent ships are those ships which automatically perceive and obtain information and data on the ship itself, marine environment, logistics and port by making use of sensors, communication, the Internet of Things, the Internet and other technical means, and achieve intelligent operation in terms of ship navigation, management, maintenance and cargo transportation based on computer technology, automatic control technology and big data processing and analyzing technology, so that ships can become safer, more environmentally friendly, economical and efficient. Additionally, the functions of intelligent ship normally consist of seven levels [11][12]. Additionally, the "Standard for Intelligent Ships" puts forward the requirements for anchoring autonomous decision making, which should enable the evaluation and implementation of anchorage plans based on real-time detection, signals and data receiving, as well as the limitation of the ship anchoring and maneuvering capability.

It could be states that the development of intelligent ship technology is flourishing, and it has become the carrier and a breakthrough of the digital technology and economy of the shipping industry. Definitions of intelligent vessels and MASS are products that Chinese and foreign experts as well as researchers formulated at the stage of the development of vessel intelligence. Additionally, its essence is to adopt different technical routes, thus achieving autonomous navigation and management. The mooring area detection is one of the key technologies that must be possessed by ships for autonomous and intelligent navigation. It is necessary for ships to detect the mooring area at the departure port, the destination port and the vicinity of the route, thus meeting the needs of emergencies, goods loading and unloading, boarding and disembarking, and waiting for berthing. In navigation practice, due to the lack of methods of scientific mooring area detection, the ships usually choose a larger anchorage circle radius to ensure their anchoring safety, which objectively results in a waste of anchorage space resource. Additionally, some space in the anchorage could be considered as mooring area. However, due to the lack of detection capacity, those anchorage space resources are wasted. Therefore, determining a suitable dropping anchor position and maintaining the mooring safety in operations are major challenges that intelligent and MASS systems need to undertake at different development stages. Intelligent mooring area detection is a strategy and technology that relies on various vessel sensors, fuses multi-source data, adopts

relevant detection technologies to detect positions qualified for anchor operations, and conducts safety monitoring of the mooring position. Moreover, as for the development of intelligent vessels, mooring area detection is one of the key technologies related to their mooring safety and the utilization rate of anchorages space. More importantly, the mechanism of mooring area detection must be revealed, thus filling in the lacuna in mooring area detection, and promoting the development of related theories of intelligent vessels.

Anchoring operation is one of the key operations of ships, which is affected by wind, wave and current, ship maneuverability [13][14][15], the accurate positioning of ships [16][17], congestion of anchorage [18], water depth, bottom material grip force [19], anchoring chain length, anchorage circle radius [20], safety distance between the anchoring ships [21] and the algorithm of the anchorage area detection. At present, the research on anchorage area detection focuses mainly on the following two aspects.

2. Safety Distance Between Anchoring Ships

In the literature, [22] analyzes the differences of relevant specifications of the anchorage circle radius under different situations, and an optimal selection of the anchorage circle radius in the regression equation model and algorithm according to different wind conditions was proposed. In [23], the position of the anchor chain hole was taken as the dropping anchor position, converted from the position of GPS antenna to the anchor chain hole with the mathematical model. In [24], the conceptual difference between the ship position and anchor position was pointed out. In [25], the difference and relation between anchor position and dropping anchor position was analyzed, and an estimation method was put forward. In [22][26][27], a regression analysis and data mining were applied to calculate the anchorage circle radius and the distance between anchoring ships, which were intelligent to a certain degree. However, as it was a comprehensive analysis of various situations, it could not reflect the maximum safety radius. Some Japanese researchers considered the maneuvering difficulty of a ship passing through anchoring ships and introduced the distance model between two adjacent anchoring ships [22]. The length of the anchoring chain was mainly determined by the external force of wind, wave and current, water depth and the grip force coefficient of the bottom material [28]. A safety evaluation anchorage model of the Tianjin port was introduced by Wu et al., based on the safety distance model of two anchoring ship, and the process of dragging anchor, drift direction and the speed of dragging anchor were studied [18]. Li put forward a relative safety distance model from the anchoring ship to waterways, including locations such as areas with an intensive traffic flow [21]. In [29], a calculation method was proposed for the anchoring safety distance based on ship drift motion and ship collision risk. A fixed-point anchoring scheme was then proposed, comprehensively considering the basic turning radius of a single anchoring ship and the distance between anchoring ships with maneuvering difficulty [30]. The safety distance between anchoring ships is also influenced by the captain’s risk appetite and pressure mode [20].

In conclusion, the current anchorage circle radius mainly considers factors such as chain length, catenary and the projected length of the anchor chain, horizontal chain and ship length into consideration, which revealed a shortcoming, namely, the insufficient consideration of factors such as ships carrying hazardous goods, ship parameter, the distance from anchor chain hole to the bow and stern centerline, trim angle and water depth. Hence, the existing anchorage circle radius model and radius value cannot fully reflect the engineering practice background. The safety distance between anchoring ships should be set based on the safety radius of two ships, and the navigation impact of passing ships in the anchorage area should also be taken into consideration. Therefore, it is necessary to fully consider factors including ships carrying hazardous goods, ship parameters, ship loading conditions, anchorage depth as well as the risk of ships sailing in the anchorage area. Additionally, the practical background of anchoring engineering will be fully reflected by the distance model.

3. Method of Mooring Area Detection

Some valuable work was carried out on MASS mooring area detection. The essence of mooring area detection is to detect a circular anchor area, which can be obtained by the method of Euclidean space distance, image identification [31] [32] and so on. In [33], the adaptive genetic algorithm was applied to optimize the automatic detection results of mooring area based on the gray system and an artificial neural network, and the final detection results of mooring area were output while the artificial intelligence system completed the regional detection of the mooring area. However, the anchorage circle radius and safety distance model were inaccurate. In [28], the disc packing algorithm was applied to optimize anchorage space utilization and specify the anchor position. In [34], the calculation model of the anchorage space capacity of standard ships was established based on the Monte-Carlo algorithm. In [19], the Multi-Objective Anchorage Planner (MOAP) algorithm was studied based on safety and efficiency, and verified with historical data and the Monte-Carlo algorithm. The MOAP algorithm could provide safer anchorage planning while maintaining the same optimization level. The Monte-Carlo algorithm can provide a fast simulation method. In [35], the reliability calculation of anchorage capacity

and the redundancy optimization model was proposed, which would effectively solve the problem of optimizing anchorage space utilization under the influence of anchorage capacity uncertainty.

In conclusion, the current research of anchorage detection mainly focuses on the length of the anchoring chain, anchorage radius, safety spacing of anchoring ships, anchorage planning, utilization rate of anchorage space and so on. The factors mentioned above could play a certain supporting role in the detection of mooring area. Only a few of studies have applied the Adaptive Genetic Algorithm [13] to optimize the automatic detection results of the mooring area in the gray system and artificial neural network system and the artificial intelligence system to detect the mooring area, and to output the final detection results of mooring area. However, the anchorage radius and anchor spacing model used in this method might be inaccurate.

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