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Research on the Application of AIS Data Analysis Technology in Shipping

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Abstract

Due to the popularity of Automatic Identification System (AIS), the shipping industry has accumulated a large amount of data, providing rich resources for data analysis. AIS data analysis has been widely used in many fields such as route optimization, water traffic management, environmental controlling, economics and trade, and is an indispensable part of the modern shipping industry. As technology develops, its application scope and depth will continue to expand. This paper summarizes the main areas of application of AIS data analysis technology in the shipping industry. It analyzes how AIS can improve the efficiency, safety and environmental sustainability of the shipping industry from the fields of maritime management and environmental protection. It also provides insight and decision-making for the shipping market. Provided important support.

Keywords

Automatic Identification System (AIS); Maritime Management; Big Data Technology; Ship Trajectory; Water Transportation.

1. Introduction

AIS is a system used for ship positioning and information exchange during water navigation. AIS is designed to improve safety on the water, reduce the risk of ship collisions, provide navigational data, and assist search and rescue operations in emergencies [1]. As the level of informatization and intelligence in shipping continues to improve, more and more ships are equipped with AIS equipment, AIS signal coverage is also increasing year by year, and AIS data is growing like a blowout. AIS uses satellite positioning and VHF technology to allow ships to communicate with each other on the water and exchange position information, ship identification information, navigation information, safety information, and port docking information. This information can be monitored and analyzed at monitoring centers, other ships, and land base stations to improve navigation safety, assist navigation decisions, and promote efficient management of maritime traffic. Overall, ship AIS systems play an important role in modern maritime transportation.

Big data is increasingly used in the shipping industry, which can effectively promote innovation, efficiency and service upgrades in the port and shipping industry, and promote government regulatory reform and innovation and the precise supply of public services. As an important data source for shipping, massive AIS data is an important way for big data technology to be applied to the shipping industry, providing a data foundation for the intelligence of the shipping industry [2]. Research based on massive AIS data has become a research hotspot in the industry, with many applications in smart maritime management, channel calculation, abnormal ship detection, port feature analysis, etc.

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2. AIS Data Analysis Technology in Maritime Management

2.1 Ship Trajectory

Ship trajectory analysis is the process of collecting and analyzing ship AIS data to understand the behavior and movement patterns of ships on the water. This analysis helps to understand the ship's course, speed, anchoring position and possible sailing intentions. Scholars process AIS data through data mining, machine learning, statistics and other methods to analyze the ship's trajectory.

Han et al. used the DBScan algorithm to perform cluster analysis on ship trajectories to discover ship behavior patterns and navigation rules [3]. The research results provide useful reference for maritime traffic management, ship behavior prediction and other aspects. Xiao et al. studied the problem of ship trajectory fusion and prediction based on multi-source information, and proposed a ship trajectory fusion and prediction method based on Kalman filtering and neural network [4]. This method integrates information from multiple sensors such as AIS, radar, and satellites to improve the accuracy and reliability of the trajectory, and uses neural networks to predict future trajectories. The research results have practical application value in improving maritime traffic efficiency and optimizing navigation routes. Yang et al. proposed a ship trajectory anomaly detection and prediction method based on bi-LSTM. This method uses bi-LSTM neural network to model the ship's historical trajectory to predict the ship's trajectory [5].

2.2 Virtual Fence

Water virtual fence is a system that uses information technology to restrict or monitor ships in a specific area. It monitors the entry and departure of ships by setting virtual boundaries and triggers alarms or takes other measures [6]. Sun et al. set up electronic fences around the port, monitored the entry and exit of ships through real-time analysis of AIS data, and promptly issued alarms or triggered other security measures to prevent unauthorized ships from entering or leaving the port and protect the security of the port [7]. There are sensitive areas in waters, such as water protection areas, aquatic life habitats, water turbines, water operation sites, etc. Electronic fences can be used to protect sensitive areas and are set up in their surrounding waters to control the entry and activities of ships to ensure the protection of these areas and the integrity of the ecosystem. Read et al. created electronic fences around the boundaries of the protected area based on the AIS system, which effectively reduced violations within the protected area [8].

2.3 AIS Beacon

AIS navigation beacon is a new type of radio navigation beacon and a new navigation aid facility based on AIS data analysis technology. Through AIS navigation technology, the navigation conditions of ships in nearby waters can be grasped in real time, providing a basis for planning routes and maintaining safety. Al S navigation beacons are divided into three types: physical AIS navigation beacons, virtual AIS navigation beacons, and synthetic AIS navigation beacons. AIS navigation beacon technology can also be combined with other navigation technologies, such as with the Electronic Chart Display and Information System (ECDIS), which can display visual headings, routes, ship names and other information of all ships, improving maritime communication functions and providing A method of voice and text communication with ships identified through AIS is provided to enhance the ship's global awareness.

In order to better play the role of AIS data analysis technology in navigation aids, related research is also increasing. Li et al. proposed a method for optimizing the layout of virtual navigation beacons based on big data analysis-assisted automatic identification system (AIS), and took the port side channel, deepwater composite channel and main channel in dense port areas as examples for application analysis [10]. Methods such as ship trajectory playback, collision risk analysis, ship trajectory line analysis, channel door line analysis, and ship navigation beacon spacing analysis for ship traffic flow can effectively find the weak points of the navigation beacon layout plan by visual means, providing a basis for the development of AIS virtual navigation beacons. Additional optimization provides strong data support. Li studied an AIS virtual beacon monitoring method based

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on redundant data, and designed an integrated module for virtual beacon broadcasting, monitoring and alarming in the digital waterway system. Li [11] studied an AIS virtual beacon based on redundant data.

2.4 Ship Collision Avoidance

Through AIS data analysis technology, ships can grasp the navigation conditions of ships in the surrounding sea areas in real time, thereby adjusting routes, speeds, etc. in a timely manner to avoid collision accidents. AIS data analysis technology will significantly improve the ability and efficiency of ships to avoid collisions, identify potential collision risks in real time, and enhance the understanding of the current navigation environment.

Many scholars have conducted research in this area. Rong et al. proposed a method based on the sliding window algorithm for identifying collision avoidance behavior from ship trajectories. This approach is useful for understanding the collision avoidance behavior of ships in potential collision scenarios [12]. Liu et al. proposed a quantitative analysis method for quantifying collision risk. This method combines the static and dynamic information of AIS and proposes a time-varying motion trajectory model that helps identify high-risk hotspot areas [13]. You et al. selected ship AIS data in the waters near Zhoushan Island and performed preprocessing operations such as dynamic and static data matching, data cleaning, data sorting, and trajectory interpolation to analyze the ship's collision avoidance behavior [14]. Zhang et al. collected, stored and analyzed AIS data to obtain historical ship trajectory information and motion parameters, thereby mining deep information on ship behavior, COLREGs (International Regulations for Preventing Collisions), good seafarers' habits and ordinary seafarers' practices, and analyzing ship maneuvering. Experience and characteristics of behavior [15]. Wang et al. proposed a hybrid modeling method based on neural networks to calibrate ship navigation, planning and collision avoidance models to cope with ship collision avoidance and autonomous ship decision-making in complex environments [16].

2.5 Ship Pilot

AIS data analysis can be used to assist ships in safe navigation in complex waters. When ships plan routes, AIS data can be used to analyze historical navigation patterns to help determine the safest and most efficient routes. AIS data analysis can also help identify potentially dangerous areas such as shoals, narrow channels or other obstructions. The application of AIS data analysis in ship piloting improves navigation safety, enhances risk management capabilities, and optimizes navigation planning and flow management, which is crucial to the efficient and safe operation of the modern shipping industry.

Based on the wide application of AIS data in ship piloting, many scholars have carried out research in this area. Guo et al. constructed a DBN model based on collision risk during ship piloting, using AIS, radar data, PSC data and expert judgment [17]. It aims to obtain the temporal distribution of collision risks during pilotage operations, highlighting the importance of using AIS data for risk management in pilotage. Lee et al. used AIS data to analyze the arrival and departure of ships at the port, which is crucial for pilotage, especially during the stage when the ship is boarded by the pilot [18]. Zhou et al. used AIS data to obtain and update ship field parameters in real time to meet the real-time needs of maritime applications [19]. The proposed method can filter out non-dangerous targets and improve the recognition accuracy and real-time performance of nonlinear models in the ship field, providing a reference for navigation safety decision-making and ship navigation behavior analysis. Together, these studies highlight the diverse applications of AIS data in improving ship piloting, including trajectory analysis, risk management, operational optimization and decision-making in real-time navigation scenarios.

2.6 Water Traffic Accident Investigation

By analyzing AIS data, water accident investigators can better understand the dynamics leading up to the accident, including the relative position and trajectory of the vessel. In the event of a ship collision, AIS data can be used to analyze the navigation paths of the two ships to determine the cause

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of the collision. Through AIS data, AIS data can be used as key evidence to determine accident liability and damage assessment during legal proceedings and insurance claims. Analyzing AIS data can help identify common issues and risk points that lead to accidents. This information is valuable in developing new safety rules and navigation practices, and in preventing similar accidents in the future. AIS data plays a key role in the investigation of water traffic accidents. It not only helps to identify the cause of the accident and determine responsibility, but also provides valuable data support for improving navigation safety and preventing future accidents. With the advancement of technology and the improvement of data analysis capabilities, more and more scholars have carried out the application of AIS data in water traffic accident investigations.

The results of a statistical analysis by Bye et al. using maritime accident data and AIS data in Norwegian waters to identify conditions associated with navigation-related accidents as risk indicators [20]. Aalberg et al. compared ships involved in accidents with ships without such records, using indicators from AIS data and ship databases [21]. These indicators explain 44% of the variation in accident records and predict 36% of accident-free ships and 99% of accident-prone ships. Zhu et al. conducted a dynamic multi-period maritime accident susceptibility assessment based on AIS data and a random forest model [22]. These documents reflect the diverse applications of AIS data in maritime accident investigations, including accident reconstruction, risk analysis, responsibility attribution judgment, and maritime safety improvement suggestions. Through these studies, AIS data proved to be an important and effective tool in maritime accident investigations.

3. AIS Data Analysis Technology in Other Application Fields

3.1 Economic Statistics

AIS data analysis is widely used in economic statistics, not only providing profound insights into global trade and supply chain management, but also having an important impact on economic forecasting, environmental protection and policy formulation. AIS data can be used to monitor global cargo transport flows, which is critical for assessing international trade activity and economic trends. By analyzing shipping routes and vessel activity, AIS data helps understand changes in trade patterns, such as the movement of goods between major trading partners. AIS data can be used to assess supply chain efficiency, including vessel arrival times at ports, cargo loading and unloading speeds, and transportation route optimization. Millefiorid et al. used maritime traffic data collected through a global network of AIS receivers to analyze the impact of the COVID-19 pandemic and its prevention and control measures on the shipping industry [23]. The study relies on multiple data-driven maritime mobility indicators to quantitatively assess vessel mobility within a given unit of time.

3.2 Environmental Control

AIS data analysis technology is widely used in environmental control, helping to improve the efficiency and effectiveness of marine environmental protection, monitoring and emergency response. AIS data can be used to track ships that may discharge harmful substances, including tanker leaks, hazardous waste discharges, etc. AIS data can be used to monitor and identify potential illegal fishing activities, especially in protected marine areas. AIS data helps monitor ship activities in sensitive ecological areas and prevent these areas from being affected by shipping activities. AIS data can be used to calculate a ship's carbon emissions, especially when taking into account the ship's speed, size and route. When a maritime accident occurs, AIS data helps to quickly locate the accident ship, thereby speeding up emergency response and mitigating environmental impact.

In order to achieve real-time monitoring of air pollutant emissions, Zhang et al. proposed a real-time calculation platform for air pollutant emissions. The platform is based on automatic identification system (AIS) data and uses the dynamic power method to calculate ship air pollution [24]. The platform uses the dynamics of AIS data and the real-time nature of Flink to improve the estimation of ship air pollution emissions. In order to effectively supervise ship pollutant emissions, the Yangtze River Basin has established a joint supervision platform for ship pollutants [25]. The results of AIS

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data analysis not only effectively track ship pollutant emissions, but also provide scientific guidance for pollution reduction and the planning and construction of pollutant receiving facilities.

3.3 Epidemic Prevention and Control

In the years when the COVID-19 epidemic has been raging, water transportation has been an important part of the prevention and control of the epidemic. How to quickly identify whether a ship comes from a medium- to high-risk area is the key to improving the efficiency of waterborne epidemic prevention work. Traditional waterborne epidemic prevention and control is achieved by strengthening water patrols, carrying out regular inspections along the way, and implementing ship control at docks. This not only requires a large amount of manpower and material resources to verify ship navigation information and crew epidemic prevention information, but also affects the efficiency of water transportation. In order to improve the efficiency and accuracy of waterborne epidemic prevention, Lv et al. designed and implemented a waterborne epidemic prevention and control management platform, which enabled real-time monitoring of ships and crews and early warning of abnormal situations [26]. Through real-time analysis of AIS data, the screening efficiency of epidemic-related ships is improved, and effective classification and hierarchical control of key ships are achieved. The application of AIS data analysis in epidemic prevention and control not only helps improve the ability to monitor and respond to epidemic spread risks, but also plays a key role in maintaining the stability of global trade and supply chains.

4. Summary

AIS data analysis not only improves the safety and efficiency of maritime navigation, but also has a profound impact on environmental protection, policy making and maritime research. As technology develops, the importance of AIS data analysis will continue to grow, especially in smart shipping and automation. However, it is also necessary to pay attention to the limitations of AIS data analysis technology. If there are problems with the collected data, it will affect the results of AIS data analysis, such as wrong information and wrong judgments, failure to enter correct information, information not updated in time, etc., to avoid adversely affect navigation safety.

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