Academic Education Publishing House

Industry Science and Engineering Vol. 1 No. 10, 2024

Recognition Methods of Shipboard Automatic Ship Identification System Non-Compliance Use and Their Advantages and Disadvantages Analysis

Kelong Li, Hailin Zheng

School of Naval Architectrual and Marintime, Zhejiang Ocean University, Zhoushan, Zhejiang, China

Abstract: This paper introduces the identification methods of illegal use of shipborne AIS and its advantages and disadvantages. With the development of the shipping industry, automatic ship identification system (AIS) plays an important role in ensuring the safety of ship navigation at sea. However, some ships use shipborne AIS in violation of regulations in order to evade maritime supervision, which brings serious hidden dangers to maritime traffic safety. The article first expounds the AIS system, relevant regulations and illegal use, and then mainly introduces four identification methods, analyzes its principles, advantages and limitations. Finally, it is pointed out that each method has its own advantages and disadvantages. In practical applications, it can be flexibly selected or combined according to scenarios and needs. At the same time, the algorithm should be continuously improved and data quality control should be strengthened to improve the recognition accuracy and the level of maritime traffic safety management.

Keywords: Automatic Ship Identification System; Illegal Use of Automatic Ship Identification System; Electronic Fence; AIS-R; Strengths and Weaknesses Analysis

1. Introduction

At the end of April 2021, Maritime Transportation Safety Law of the People's Republic of China has passed (hereinafter referred to as the "MTS Law"). The law, which was formally implemented in September of the same year, strengthens accountability and provides for stricter legal responsibilities. For the offense of "Penalty for failure to turn on the automatic identification system of the ship", the penalty provisions have been adjusted significantly[1].

With the continuous advancement of economic globalization, the shipping industry has ushered in rapid development. The number and size of ships are increasing day by day, and the traffic density in port waters is also increasing day by day. The use of Automatic Ship Identification System (AIS) has played a key role in enhancing the safety of life at sea and improving the safety and efficiency of navigation. The rapid development of the shipping industry has made Automatic Ship Identification System (AIS) a key technology to ensure the safety of maritime navigation. AIS realizes the automatic identification of ships based on a series of algorithms, such as through the collection and processing of ship dynamic information (such as position, speed, course, etc.) and static information (such as ship code, name, type, etc.), and uses the VHF frequency band for information transmission. In terms of information processing, it involves big data technology to analyze and mine massive ship AIS data to achieve accurate judgment of ship behavior. At the same time, AIS technology is closely related to VTS (Vessel Traffic Management System), and ship information provided by AIS can assist VTS to better manage maritime traffic and significantly improve ship navigation safety[2].

In recent years, artificial intelligence, machine learning and other information technologies have made rapid development, providing technical support for the automatic identification of AIS violations. Powerful computing power and rich data resources enable complex algorithm models to be trained and applied, so as to achieve efficient analysis and processing of AIS data.

At present, a variety of identification methods have been studied and applied in the field of AIS technology. However, these methods face some challenges in practical application, such

as data accuracy, environmental interference and other issues. The purpose of this paper is to summarize the identification methods used in violation of AIS, introduce their principles, analyze their advantages and disadvantages, and provide technical support for improving the level of maritime traffic safety management.

2. Overview of AIS Technology and Brief Description of Illegal Use

2.1 AIS System

As an automatic ship identification system (AIS) called Automatic Identification System, it is mainly used for maritime security and communication between ships and ships, and ships and shores. The system of AIS mainly consists of three parts: GPS receiver, AIS transceiver, and VHF transceiver[3]. AIS can record daily ship trajectory information in various sea areas around the world, generating massive data, which plays an important role in ship trajectory prediction, ship abnormal behavior detection, and ship path planning. The MMSI code is a 9-digit integer, which is used as the unique identifier of a ship, and the first three digits of the MMSI code are 412, 413, and 414 for Chinese ships, and each ship is given a globally unique identifier after it is manufactured, which will be accompanied by the ship until it is dismantled, so the MMSI code can be used as the unique identifier of a ship in the processing of AIS data. The AIS system follows the ITU-RM.1371 international standard, the data format is unified[4]. AIS information is an important foundation for maritime security, maritime supervision, judicial investigation, and service to water users, and plays an important role in ensuring the safety of ship navigation and promoting the economic development of ports[5].

2.2 Requirements of Relevant Laws and Regulations for AIS Duty

Ashok Srinivasan, Maritime Safety Manager at BIMCO[6], said: "Closing AIS may violate regulations in some countries and risk fines. Worse, the risk of ship collisions will increase. AIS is a great help to ship safety by enabling neighboring ships and shore stations to keep track of the dynamic and static information of all ships on the nearby sea surface in a timely manner so that necessary avoidance actions can be taken. Ships without AIS information may send confusing signals to other ships[6]."

According to the International Convention for the Safety of Life at Sea (SOLAS Convention), all international ships of 300 gross tonnage and above, non-international cargo ships of 500 gross tonnage and above, and passenger ships regardless of size should be equipped with an automatic identification system (AIS) on board. Ships equipped with AIS should keep AIS in operation at all times. As well as the Maritime Traffic Safety Law of the People's Republic of China, the Vessel Safety Supervision Code of the People's Republic of China, and the People's Republic of China Inland River Vessel Crew Watch Rules and other laws and regulations require that ships should maintain 24-hour uninterrupted watch of AIS during navigation, berthing and operation, and timely update the name and time of arrival and departure. The ship's AIS should always be on, unless the ship is facing an imminent safety hazard, such as the captain discovering the threat of piracy, hijacking, kidnapping, etc. If it is necessary to take this action, it should be recorded in the ship's log and the reasons for the decision should be stated[7].

2.3 Illegal Use of AIS

There are two main types of irregular use of AIS.

The first category is equipment operation violations. Malicious shutdown of AIS can make it more convenient for vessels that may be involved in other violations, such as inland waterway vessels participating in marine work missions, unauthorized cargo transfer or transportation of dangerous goods at sea, and smuggling of oil and sand.

For example, A ship intentionally turned off AIS. A ship departed from a port at about 0000 on September 27, 2020, and the position was at E at 14:23:17. The AIS system could not obtain follow-up location information. It sank at N at 14:18 on September 29, 2020, with 16 people on board, 1 dead and 10 missing. After checking the AIS system records, the ship traveled from the Pearl River Delta to western Guangdong many times, deliberately turned off AIS many times, and modified the MMSI code without authorization[8].

The main reason for this situation is that some

ships engage in illegal activities, such as smuggling "oil" at sea, transporting dangerous goods at sea without authorization, sandstone operations, etc. deliberately tampering with AIS information or shutting down equipment to evade supervision. There are also some crew members with weak safety awareness, believing that the correct use of AIS equipment is not important, there is a chance mentality, and they operate the equipment at will [9].

The second category is poor maintenance and management. The failure of equipment to send and receive signals normally is usually difficult for the ship to detect, which requires the crew to have a high degree of responsibility when on duty, and frequently check the data information on the AIS display screen to detect problems in time. However, after the problem was detected and the ship was shut down and restarted, the ship's station was able to resume normal operation. The reason for this is that if the equipment is left on for a long period of time, the continuous operation of the equipment may cause problems with some of the electronic components (especially for equipment that is more than 5 years old), and the equipment may crash[10].

In addition, AIS equipment relies on the antenna for its transmitting and receiving functions, so if such a situation occurs, you can check whether the antenna signal connection cable of the main unit of the AIS equipment has been unplugged or not. For Class A AIS equipment, anomalies in the ship's position signals may also occur when the external GNSS device connector is unplugged[11]. When the antenna is not connected, and the installation relative position of the VHF antenna of the AIS equipment and the antenna of other radio equipment does not meet the specification requirements, the distance of the signal transmitted by the shipborne AIS equipment will be limited, and only the AIS signal of the close-range ship can be received, and it can only be recognized by the close-range ship. The unconnected AIS antenna is difficult to detect because when the shore-based system cannot obtain the information of the ship, it is impossible to know whether the ship has arrived at the port, but the boarding inspection shows that everything is normal and can only be detected through the AIS detector[12].

The main reason for this problem is that the crew does not have enough knowledge about the operation and maintenance of AIS equipment and lacks systematic training, which leads to incorrect operation and faults that can't be dealt with in time in the process of using the equipment. The shipping company's technical training and guidance to the crew is not in place, and it has not established a perfect procedure for the operation and maintenance of the equipment.

3. Methods of Identifying AIS Use Violations

3.1 Electronic Fence System Identification

Electronic fence system, combined with shipboard GPS system, AIS, shore-based CCTV, VTS, ship dynamic management system, ship entry/exit reporting system, etc., builds a virtual "electronic fence" in the area of port terminals and marine operation points, and controls in real time the number of ships in the area, their status, location and detailed information such as traffic conditions in the relevant waters, and compares it with the ship entry/exit reporting data in the ship entry/exit reporting system in real time to check whether the ships have reported their entry and exit in accordance with the regulations. Meanwhile, during the period of comparing the information of ship entry and exit report, we will carry out evidence collection operation for the ships with problems, and investigate them through various methods such as VHF inquiry, on-site inspection, and water patrol, so as to enrich the content of pre- and post-supervision of ship entry and exit declaration, and thus enhance the efficiency of maritime management[13].

When the ship enters the virtual "electronic fence" area, the CCTV or VTS system will automatically capture or track the ship when the virtual "electronic fence" system is not confirmed, and issue an early warning to remind the management to verify the situation. See Figure 1 for details.

Electronic fence system identification is a multi-sensor fusion identification method based on Internet of Things technology, which also applies VTS comprehensive information comparison technology. Its principle involves the collaborative work of multiple systems and

the real-time processing and comparison of data. The following is the detailed principle:

(1) Multi-source data fusion: Integrate multi-source data such as shipborne GPS, AIS, shore-based CCTV, VTS, ship dynamic management system, and ship entry and exit reporting system to comprehensively obtain ship location, identity, dynamic, static information, and regional traffic conditions[14].

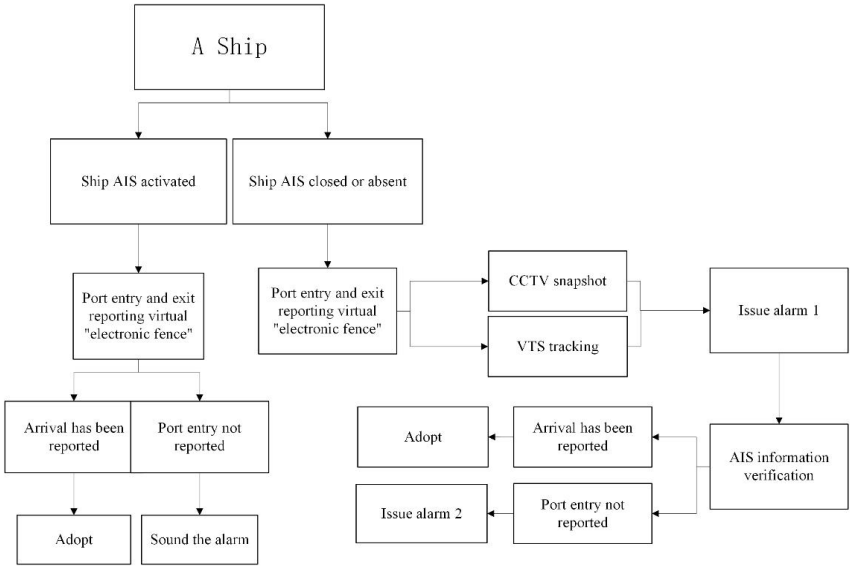

Figure 1. Workflow Diagram of the Virtual "Electronic Fence" System[13]

(2) Area limitation and monitoring: In specific areas such as port terminals and offshore operation points, a virtual "electronic fence" boundary is set through software. This boundary can be a polygon area based on geographical coordinates, or it can be set to other shapes such as circles and rectangles according to actual needs. Facing the needs of statistical analysis of maritime big data, usually focusing on ports and berths, and drawing circles with specific values as radii, the electronic fence range of a specific sea area is calculated and generated. The electronic fence system correlates the collected data of each system with the virtual electronic fence area. For example, when a ship enters the area, its GPS location information will be judged whether it is within the electronic fence range, and the AIS information will also be included in the system for comprehensive analysis[15].

(3) Forensics investigation: VHF interrogation, on-site inspection, water cruise, etc. are used to investigate and collect evidence for abnormal ships. Through VHF interrogation, you can directly communicate with the ship to understand the actual situation of the ship; on-site inspection and water cruise can directly observe the appearance and actual operation status of the ship to obtain more intuitive evidence.

Through the above principles, the electronic fence system can identify detailed information such as the number, status, location, and flow conditions of ships in the control area in real time, so as to achieve effective supervision and identification of ships, and timely detect abnormal situations such as illegal use of AIS.

Limitations of the method: The maritime electronic fence system needs to have the ability to process a large amount of ship data, including position, speed, heading and other information. When there are too many ships, the data processing capacity of the AIS system may be insufficient, resulting in slower data processing and slower information verification. When multiple ships send AIS data at the same time, there is a risk of conflict, resulting in incorrect or lost information transmission. This may cause problems in automatic identification and localization of ships and increase ship collisions.

3.2 Identification of AIS Signal Emission Strength Variations

According to the change law of the signal strength of the shipborne AIS, it is possible to identify whether the shipborne AIS is being operated illegally. This method is based on cluster analysis in big data mining and analysis. Since the AIS system is widely used around the world, a large amount of data is

generated every moment. By cluster analysis of a large number of AIS signal emission intensity data, the change law of signal emission intensity can be better understood and identified, and a more effective means for ship monitoring and management can be provided. For a specific area or time period, the collected AIS signal emission intensity data can form a huge data set. Such a large amount of data provides sufficient samples for cluster analysis, making the clustering results more accurate and reliable.

Fabio Mazzarella[16] An anomaly detection tool has been developed to identify AIS switch transitions in ship tracking data. Since AIS is a self-reporting system for ships, it is crucial to validate the trustworthiness of the AIS information in order to fully exploit the potential of this technology for a wide range of applications, from knowledge discovery to the detection of anomalies in ship movements. It has been demonstrated how critical information about signal strength is and how it must be analyzed on the basis of parameters that remain constant over time (e.g., ship and receiving station antenna heights), those that vary with geographic location (e.g., antenna orientation map, shadowing during reception), and those that vary over time (e.g., atmospheric conditions). This analysis allows for the creation of two robust normal models (one based on single-ship behavior and the other for the base station) that represent the baseline of the anomaly detector[16] . The principle of anomaly detection is as follows:

(1) Establish a normal model: Signal strength needs to be analyzed in terms of parameters that remain constant over time (such as ship and receiving station antenna height), parameters that change with geography (such as antenna pattern at reception, shading), and parameters that change over time (such as atmospheric conditions). This analysis allows for the establishment of two robust normality models (one based on single ship behavior, the other for base stations), representing the baseline of anomaly detectors.

(2) Comparison and detection of abnormalities: By comparing the real-time monitored AIS signal strength with the established normal model, if the signal strength deviates from the normal model beyond a certain threshold, it is considered that there is an abnormal situation, which may suggest that the AIS device has been artificially shut down or there are other illegal uses.

Limitations of the methodology: Given that AIS is a self-reporting system, one of the main shortcomings of the technology is the high error rate of the data and its susceptibility to alteration. Therefore, verifying the reliability of AIS data has become a key point to fully exploit the safety potential of this technology and its application. It is difficult to detect whether a ship's AIS system has been shut down for malicious purposes to cover up the ship's illegal behavior, due to the irregular and irregular reporting intervals of the AI, which vary from a few seconds to a few minutes. Moreover, radio wave propagation signals are extremely complex in the marine environment, which has a great impact on the Received Signal Strength Indicator (RSSI) of the base station.

3.3 Determining Data Reception Speed Recognition

During the voyage of the ship, the ship dynamic information is usually broadcast once every 2 to 180 seconds, and the amount of AIS data is huge[17]. The reporting frequency of different ship types is detailed in Table 1. When the ship slows down and stops, the device may shut down. After shutdown, the system will no longer receive data sent by the ship.

Table 1. Ship Types and Reporting Frequency

ship's condition	Reporting frequency
anchor vessel	3 minutes/times
Vessels with a speed of 0-14 knots	12 seconds/time
Vessels with a speed of 0-14 knots and changing direction	4 seconds/time
Vessels with a speed of 14-23 knots	6 seconds/time
Vessels with a speed of 14-23 knots and changing direction	2 seconds/time
Vessels with a speed in excess of 23 knots	3 seconds/time
Vessels with a speed in excess of 23 knots and undergoing a change of direction	2 seconds/time

Judging the data receiving speed Identification is a technical method used to identify whether

the shipborne AIS is used illegally. Its core principle is based on the law of data transmission during normal navigation and operation of the ship and the change characteristics of data receiving speed when the equipment is turned off. The method also applies technologies such as edge computing in the field of Internet of Things. In application scenarios such as ship identification, edge devices can monitor the receiving speed of AIS (ship automatic identification system) data in real time, detect abnormal situations in time and deal with them without transferring all data to the cloud for analysis, thereby improving the efficiency and reliability of the system. The following is the detailed principle:

(1) Basis for shutdown judgment: When the ship slows down and stops, the device may shut down. At this time, the system will no longer receive the data sent by the ship. By judging the speed of the data recently received by the ship, if it is less than or equal to the set shutdown speed threshold (that is, the upper speed limit before shutdown), it may be that the signal caused by shutdown has not been received. Set the threshold value of shutdown speed to **v0** (this value is determined according to different ship types and normal operation conditions). If the calculated data reception speed **v≤v0**, it is preliminarily determined that the ship may be in shutdown or abnormal state.

(2) Data continuity judgment: Further request the latest two pieces of data for the ship through the interface. If the ship is shutting down the AIS device after a deceleration stop, then the last two pieces of data must be in a deceleration state and the speed should be less than or equal to the speed limit before the shutdown. If these conditions are met, the ship is considered to have had a shutdown event. Through the understanding of the ship's normal data transmission rules and the judgment of the data reception speed and continuity when the equipment is turned off, it is possible to identify whether the ship-borne AIS is shut down illegally.

Limitations of this method: It's easy to be disturbed by many factors, such as water current, wind and waves, and other natural factors may lead to fluctuations in the actual speed of the ship, thus affecting the accuracy of the judgment. At the same time, it is difficult to set the threshold value of speed change, and it is not easy to determine an appropriate threshold value of speed change to judge the AIS shutdown, and too high a threshold value may lead to omission of judgment, while too low a threshold value may lead to misjudgment. For deliberate camouflage, it is difficult to identify, and this method may not be effective if the ship deliberately avoids identification by controlling its speed.

3.4 Comparative Identification of AIS and land-Based Trajectories

The International Maritime Organization has proposed the construction of the AIS-R model land-based backup navigation system[18]. The AIS shore station locates the coastal ship by means of electronic ranging, and judges the reliability of the AIS information by comparing whether the AIS trajectory information of the corresponding ship and the trajectory information calculated by the AIS shore station are the same. In this identification method, it is necessary to integrate data from different formats and sources from the AIS system and land-based sensors. This involves a series of data processing operations such as data cleaning, format conversion, and time synchronization. Data Transmission Service and processing technology in the Internet of Things can ensure that data from different data sources can be effectively integrated to provide an accurate data basis for subsequent comparative analysis.

The ground-based backup positioning and navigation technology of AIS-R mode mainly uses electronic detection technology to obtain the relative position between the ship and the public mobile communication base station of AIS and the MF transmitting station, and locate it. This R positioning method can make full use of the existing shore-based devices, thus eliminating the infrastructure construction expenditure of a large number of shore-based devices. It is currently the most affordable land-based backup positioning system, and it is also a new method that IMO is actively exploring in various countries [18]. The principle of the AIS-R mode land-based backup navigation system is detailed as follows:

(1) Basic positioning technology: The

ground-based backup positioning and navigation technology of AIS-R mode mainly uses electronic detection technology. By arranging the positioning base station system on the coast, the base station uses electronic ranging to locate the coastal ship. Specifically, the positioning system calculates the distance between the AIS shore station or MF transmitting station and the ship through the flight time of the signal. For each positioning base station, the time of flight (TOF) of the signal is measured by sending and receiving the signal. According to the speed of radio wave propagation (usually approximated to the speed of light **c**), the distance **d** between the base station and the ship is calculated using the formula **d** = **c** × TOF.

(2) Trilateral positioning algorithm: Then the specific position of the ship is calculated through the trilateral positioning algorithm. Assuming that the positioning system works in a line-of-sight environment, each positioning base station is the center of the circle, and the distance between the base station and the ship is the radius. The arc intersection drawn at multiple base stations in space is the actual position of the ship. Let the coordinates of the three positioning base stations be (their distances to the ship are d1, d2, d3, respectively. According to the principle of trilateral positioning, the position coordinates of the ship are determined by solving the following equations (x, y) [19].

$$\begin{cases}(x-x_1)^2+(y-y_1)^2=d_1^2\\(x-x_2)^2+(y-y_2)^2=d_2^2\\(x-x_3)^2+(y-y_3)^2=d_3^2\end{cases} \quad (1)$$

Generally, the position coordinates of the ship are obtained by solving the equations (such as iterative method, matrix method, etc.).

(3) Data acquisition and preparation: On the one hand, the trajectory information sent by the ship's own AIS system is obtained, including dynamic information such as the ship's position, speed, heading, and static information such as the ship's identity. On the other hand, the corresponding trajectory information is calculated through the AIS-R mode land-based backup navigation system.

(4) Comparison and judgment: Compare the ship's AIS trajectory information with the trajectory information calculated by the AIS shore station. If the two are the same or within a reasonable margin of error, the AIS information is considered reliable; if there is a significant difference between the two, it may suggest that there is a problem with the AIS equipment or it has been used illegally, such as the AIS may be shut down, tampered with, etc. Through the construction of AIS-R mode land-based backup navigation system for ship positioning, and compare the ship's own AIS trajectory with the land-based computing trajectory, so as to realize the identification of illegal use of AIS and the judgment of the reliability of AIS information.

Limitations of this method: The AIS-R mode land-based backup navigation system uses electronic ranging to track and localize the target ship, but due to obstacles and weather factors, the lack of a straight-line distance between the base station and the target may cause the signal to reach the target only by means of penetration or reflection, which results in the measured distance being greater than the actual distance, generating a non-visual distance error.

4. Comparison And Analysis of Four Identification Methods

According to Table 2, for marine ecological protected areas, large-scale aquaculture areas, and marine pastures with key protection, the electronic fence system identification method may be more suitable, albeit at a high cost, to effectively monitor specific areas [20]. On general shipping routes, the identification method for judging the speed of data reception may be a relatively low-cost option. In the investigation of major marine accidents, the high accuracy of AIS and land-based trajectory identification methods is more valuable, albeit at a higher cost.

Comprehensively speaking, each method has its unique advantages and disadvantages. See Table 3. for details. The identification method of electronic fence system is suitable for key monitoring in specific areas; the identification method of AIS signal emission intensity change is more direct for equipment status monitoring; the identification method of judging data receiving speed is simple and intuitive but easy to be interfered; the identification method of comparing the AIS and land-based trajectory is highly accurate but complicated in data processing.

Nowadays, the existing shipboard AIS shutdown event recognition methods are under

continuous development and improvement, but still face challenges in data quality, complex environmental interference, and the effect of multi-method fusion. In practical application, one or more methods can be flexibly selected and combined according to specific scenarios and needs. For example, in offshore busy ports, it can be combined with the electronic fence system and the identification method of comparing AIS and land-based trajectory; for ocean voyage monitoring, the identification method of the change of AIS signal emission intensity may be more suitable. In addition, while combining the methods, we should also continuously improve the machine learning algorithms and deep learning algorithms of AI automatic recognition and strengthen the processing of corresponding recognition data, so as to enhance the basic functions of the four types of recognition methods, thereby optimizing the management and operation of the VTS system, and improving service quality and efficiency.

Table 2. Comprehensive Comparison of Different Identification Methods

Identification methods	recognition accuracy	Applicable Scenarios	cost investment
Electronic fence system identification method	mid-to-high	Specific restricted areas such as harbors, no-navigation zones, protected areas, etc.	A fencing system is required, including monitoring equipment and software, which is costly, especially for large areas
AIS Signal Transmitter Strength Variation Recognition Method	mid-to-high	Various sea areas, but more affected by weather and electromagnetic interference	Requires high-precision signal receiving and analyzing equipment, which is costly and requires regular calibration and maintenance
Determine the data receiving speed identification method	mid	Scenarios that require high data transmission stability, such as shipping-intensive areas	Relatively low, mainly due to inputs of data analysis software and related equipment
AIS vs. land-based trajectory identification methods	high	Scenarios requiring precise trajectory comparisons, such as tracking navigation violations, marine accident investigations, etc.	Requires access to land-based trajectory data, which may involve interfacing with different systems and data integration at a high cost

Table 3. Analysis of advantages and Disadvantages of Different Identification Methods

Identification methods	dominance	inferior
Electronic fence system identification method	It is able to specify a specific monitoring area, accurately monitor the entry and exit of ships, and detect abnormalities in the area in a timely manner; the system is relatively simple to set up and operate.	Relying on preset fence boundaries, limited applicability to unclear boundaries or complex waters; susceptible to geographic interference; not sensitive enough to detect weak signals or intermittent shutdowns inside the fence
AIS Signal Transmitter Strength Variation Recognition Method	Directly reflect the working status of ais equipment, regardless of geographic restrictions, real-time continuous monitoring, to find subtle changes	Susceptible to external interference factors, such as electromagnetism, weather, etc.; difficult to define the range of normal fluctuations in signal strength, requiring a large amount of data calibration; high monitoring equipment and technical requirements, high cost
Determine the data receiving speed identification method	Visualize the status of the equipment through the change of data receiving speed; more sensitive to short-term anomalies	Easy to be affected by network transmission and other factors leading to misjudgment of speed fluctuations; difficult to accurately distinguish between equipment problems and transmission link problems
AIS vs. land-based trajectory identification methods	Integrates multiple data sources to improve identification accuracy; can detect anomalies inconsistent with land-based trajectories	Need to acquire and integrate multiple trajectory data, data processing is complex; accuracy and time synchronization of different data sources may be problematic

5. Conclusion

The purpose of this paper is to provide a useful reference for strengthening the management of maritime radio order and improving the level of maritime traffic safety management. The article introduces four identification methods, each with its own advantages and disadvantages. Electronic fence system identification can monitor a specific area, but it is limited by the geographical environment; AIS signal emission intensity change identification can reflect the status of the equipment, but it is vulnerable to interference and data verification is difficult; judging data reception speed identification is more intuitive, but it is vulnerable to natural factors interference; AIS and land-based trajectory comparison identification accuracy is high but data processing is complex. Practical application requires flexible selection or combination of methods according to scenarios and needs, while continuously improving algorithms and strengthening data quality control to improve identification accuracy and maritime traffic safety management level.

References

[1] Zhang D, Xue H T, Shi Y. Study on the

Application of Penalty for Failure to Turn on AIS during Navigation. China Maritime Safety, 2023, (07):54-56.
[2] Zhang Y J. Analysis of the Application of Ship Automatic Identification System in VTS. Value Engineering, 2020(11):217-218.
[3] Wu C P. Research on Trajectory Clustering and Prediction Method Based on AIS Data. Nanjing University of Information Engineering, 2022.
[4] Chen N. Research on Efficiency Evaluation of Port Service Operation Based on AIS Data. Dalian Maritime University, 2023.
[5] Sun X P, Shao H, Zheng J H, et al. Study on the Identification of False AIS Signals on Ships. China Maritime Safety, 2024, (02):47-49.
[6] Xu Y N. Risks and Impacts of Closing the Automatic Identification System on Ships. China Ocean Shipping, 2021, (11):76.
[7] Mao J Y, Tian H C, Wang H J. Behavior Analysis and Application of Potential Penalties for Shutting Down Automatic Identification System of Berthing Ships. World Shipping, 2024, 47(03):15-18.
[8] Zheng S Q. Reflections on Ship AIS Signal Loss and Safety Management. Pearl River Water Transport, 2020, (22): 109-110.
[9] Liu Z X, Zhang H B. On the Application of AIS in Maritime Intelligent IT Management and the Existing Problems. China Maritime Safety, 2019, (08):45-48.
[10]Qiu X G. Analysis of Reasons for Failure to Receive Shipboard AIS Signals and Suggestions on How to Deal with Them. Navigation, 2021, (02):51-54.
[11]Fang Y M. Cause Analysis on Shipborne AIS Equipment Signal Abnormal and Associated Countermeasures. China Maritime Safety, 2021, (02): 60-62.
[12]Qiu X G, Xu J S, Jiang Z M. Current Status of the Use of Shipboard AIS Equipment on Domestic Sailing Vessels. China Ship Survey, 2018, (05):42-46.
[13]Wu K Y. Application of Virtual "Electronic Fence" in the Supervision of Ship Entry and Exit Reports. Transportation Enterprise Management, 2020, 35(02):98-100.
[14]Su B, Wang Y J, Li X. Discussion on AIS Offshore Electronic Fence System and Its Application in Offshore Wind Farm. Marine Technology, 2021(5): 38-41.
[15]Cui Z W, Zhang Y L, Zhang F Z, et al. Siting of Maritime Electronic Fence Based on AIS Data. Journal of Navigation and Positioning, 2023, 11 (04): 49-55.
[16]Mazzarella F, Vespe M, Alessandrini A, et al. A Novel Anomaly Detection Approach to Identify Intentional AIS on-off Switching. Expert Systems with Applications, 2017, 78(JUL.):110-123.
[17]Zhen R, Shao Z P, Pan J C. A Study on the Identification of Abnormal Ship Trajectory Based on Statistic Theories. Journal of Jimei University (Natural Science), 2015, 20(3): 193-197.
[18]Deng Z S. Research on Ship Positioning System on the Base of AIS-R Model and its Realization. China Maritime Safety, 2019, (04):38-40.
[19]Xu L, Zhao Y L, Wang L M, et al. Research on a Chaotic Underwater Location Optimization Method. Foreign Electronic Measurement Technology, 2019, 38(11): 119-123.
[20]Liu G K, Li S J, Zhu X X. Applications and Challenges of Marine Electronic Fence Systems. China Radio, 2024, (02):33-35.