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Real-Time Web-Based Ship Collision Risk Detection Using AIS Data and Collision Risk Index (CRI)

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Abstract: The high density of maritime traffic in Indonesian waters, particularly in the Lombok Strait and Nusa Penida region, increases the risk of ship collisions, especially among vessels lacking adequate navigation systems. This study presents the development of a web-based system for real-time ship monitoring and collision risk assessment using Automatic Identification System (AIS) data. The system integrates a backend powered by FastAPI and MongoDB with a frontend built using React JS. AIS data is collected from a base station and processed to detect ship encounters using the DBSCAN clustering algorithm combined with Haversine distance to identify encounter detection. The risk assessment applies the Collision Risk Index (CRI) method by calculating DCPA (Distance to Closest Point of Approach) and TCPA (Time to Closest Point of Approach), allowing for graded risk categorization. Real-time risk notifications are delivered via WebSocket, and the interface includes interactive maps, ship detail views, and maritime weather information from the BMKG API. The system achieved high responsiveness, with an average detection time of 0.0075 seconds per ship and an end-to-end response time of approximately 61 milliseconds. Functional and usability tests show that the system effectively supports early detection of collision risks and improves maritime situational awareness. The proposed solution is scalable and applicable for maritime safety monitoring in busy sea routes, contributing to safer navigation and proactive decision-making.

Keywords: AIS; Collision Risk Index; DBSCAN; ship monitoring; maritime safety; web-based application

INTRODUCTION

Indonesia's vast maritime territory positions the fisheries sector as a vital backbone of the coastal economy. Thousands of small vessels, such as fishing boats, operate daily to harvest marine resources and support national food security. According to data from Statistics Indonesia (Badan Pusat Statistik, BPS), 62,248 vessel arrivals were recorded in Indonesian waters in 2023. The high volume of maritime traffic is inherently associated with various operational risks, including the potential for ship collisions. This risk is particularly pronounced among small vessels often not equipped with advanced navigation systems such as the Automatic Identification System (AIS). Nevertheless, AIS data from nearby vessels can be leveraged to enhance the accuracy of ship movement monitoring, especially in congested maritime zones, thereby reducing the likelihood of collisions. Furthermore, poor weather conditions, limited visibility, and inadequate inter-vessel communication significantly exacerbate the risk of maritime accidents. National Transportation Safety Committee (Komite Nasional Keselamatan Transportasi, KNKT) reported a total of 483 fishing vessel accidents in Indonesia between 2018 and 2021, resulting in 443 fatalities (darilaut.id, 2022). These incidents not only lead to substantial material losses and casualties but also pose a serious threat to the sustainability of the fisheries sector and the safety of coastal communities whose livelihoods depend on marine resources.

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Ship collisions at sea can occur due to a complex interplay of factors, ranging from human errors—such as poor navigational decisions, lack of situational awareness, and negligence in adhering to safety procedures—to external elements like unpredictable extreme weather conditions, including storms, high waves, and dense fog that significantly reduce visibility. The inability to accurately monitor vessel positions and detect potential collision risks, particularly in densely trafficked maritime areas, is a major contributor to the high incidence of maritime accidents. The consequences of such collisions extend beyond substantial material losses, including vessel damage and cargo loss, to severe threats to human safety—impacting crew members and local fishermen operating near the incident area. Moreover, these accidents may lead to significant environmental degradation, such as the spillage of hazardous substances that contaminate marine ecosystems and disrupt aquatic life. This pressing situation underscores the urgent need for innovation in ship monitoring technologies and the implementation of collision risk assessment methods, such as the Collision Risk Index (CRI). CRI-based detection enables early warning of potential collisions and facilitates improved inter-vessel communication, particularly in real-time operational contexts, enhancing overall maritime safety.

AIS is an automatic tracking system for maritime traffic management and vessel identification. It transmits data over Very High Frequency (VHF) radio channels, encompassing essential information such as vessel identity, geographic location, speed, and course. These data are periodically broadcast by AIS transceivers installed on vessels. They can be received by coastal stations, nearby ships, and satellites within signal range, thereby enabling real-time vessel monitoring (Bachtiar et al., 2024). AIS is widely used to monitor fishing fleet activities and enhance maritime navigation safety. The transmitted data typically includes the IMO number, vessel position, speed, and direction, facilitating effective monitoring of ship movements along shipping routes (Zhang & Li, 2022). The geographic position data, expressed in coordinates (latitude and longitude), enables real-time tracking, which is highly beneficial for mapping vessel trajectories and issuing early warnings in the event of potential collision risks due to vessel proximity. Overall, AIS data provide comprehensive information about a ship's profile, including nearby ship capabilities not typically found in other electronic navigation instruments (Setiyantara et al., 2023). Although several studies have developed AIS-based vessel monitoring systems, most approaches primarily focus on tracking and visualization without embedding quantitative collision risk assessment into real-time applications (Enda et al., 2021; Herianto et al., 2024). Models such as the Ship Intrusion Collision Risk (SICR) (Li et al., 2023) provide risk estimation, yet they are not integrated into web-based monitoring platforms capable of delivering proactive and real-time collision alerts. This gap highlights the absence of a comprehensive system that combines AIS data processing, clustering-based encounter detection, quantitative risk evaluation, and web-based visualization to support maritime situational awareness. Accordingly, this study aims to bridge this gap by developing a real-time web-based monitoring system that integrates AIS data, DBSCAN-Haversine clustering, and CRI computation. The objectives are threefold: (1) to design and implement a web-based system for real-time ship monitoring and collision risk detection, (2) to dynamically quantify encounter risks using DBSCAN-Haversine and CRI, and (3) to evaluate the system's responsiveness, usability, and contribution to enhancing maritime safety.

Building upon the preceding discussion, this study designs and implements a web-based system for vessel movement monitoring and early collision risk detection, employing the CRI approach. The system architecture adopts a Client-Side Rendering (CSR) strategy to ensure a fast and responsive user experience. Data processing and page rendering are performed on the client side, enabling real-time vessel position updates with minimal latency. AIS data stored in the database is asynchronously processed on the backend to support continuous monitoring and analysis. An interactive map interface visually presents key navigational parameters such as vessel position, heading, speed, and inter-vessel distance. Furthermore, the system has an early warning feature dynamically analyzes AIS data to identify potential collision risks. When a threat is detected, the system delivers real-time notifications on the user interface, allowing relevant parties, such as maritime authorities or vessel operators, to take prompt preventive action. The development of this system is expected to contribute to enhanced maritime safety, particularly in high-traffic sea areas.

LITERATURE REVIEW

Previous studies on maritime monitoring systems with methodological and conceptual parallels provide a valuable foundation for comparative analysis and offer insights to inform research development that builds upon and extends prior efforts. One notable example is the work by (Tedyyana et al., 2023), which addresses maritime accident risks and the lack of real-time data coverage in the waters surrounding Bengkalis Island through the development of the Shipboard Marine Automatic Righting Arm Stability and Tracking (SMARST) system—a web-based vessel monitoring platform. SMARST incorporates features such as real-time vessel tracking, an early warning mechanism for vessel inclination, live weather updates, secure data protocols, and a user-friendly interface. The system utilizes the MQTT communication protocol and JSON format, enabling efficient real-time data exchange between vessels and backend servers. The findings demonstrate that SMARST enhances tracking precision, improves the safety of fishing operations, and supports more efficient maritime management practices.

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These results highlight the growing importance of real-time, data-driven monitoring systems in ensuring maritime safety, which directly informs the motivation and framework of the present study.

Another relevant study by (Li et al., 2023) introduced the Ship Intrusion Collision Risk (SICR) model, which utilizes a dynamic elliptical ship domain to improve maritime navigation safety by enabling more precise detection and quantification of collision risks. The model incorporates AIS data to account for ship speed, heading, and maneuverability in various encounter scenarios, including head-on, overtaking, and crossing situations. The findings suggest that SICR offers enhanced early warning capabilities and recommend initiating cooperative collision avoidance when SICR values range between 0.5 and 0.6, with the most effective evasive actions occurring between 0.3 and 0.5. Despite its demonstrated advantages, the model still encounters limitations, particularly in integrating environmental variables and achieving high-accuracy trajectory predictions—challenges that warrant further exploration to support the development of robust autonomous navigation systems.

In efforts to integrate AIS data into more comprehensive marine intelligence systems, (Wright et al., 2019) explored a broader scope of AIS applications through ocean observation, including vessel tracking, maritime safety planning, resource management, and weather forecasting. Their approach integrates both real-time and historical AIS data to analyze traffic patterns through heatmap visualizations and utilizes application-specific messages to convey environmental information. The study explored scenarios such as oil spill risk mitigation and the dissemination of storm alerts to vessels. The findings highlight that AIS data can effectively identify high-density maritime zones, reduce navigational hazards, and enhance maritime operational safety by enabling timely responses to extreme weather events. The successful integration of AIS with meteorological systems across multiple test locations further underscores its role as a strategic tool for maritime situational awareness and operational decision-making.

A more implementation-oriented contribution was presented by (Enda et al., 2021), who developed a backend application based on AIS data for vessel traffic monitoring in the Strait of Malacca, one of the world's busiest maritime routes. The system was implemented using Python (Flask) and PostgreSQL, featuring real-time reception, conversion, and storage of both static and dynamic AIS messages. A data filtering algorithm was employed to optimize storage efficiency, reducing data volume by 18.45%. Experimental results showed an average packet size of 43.76 bytes and a processing delay of approximately 5.06 seconds. The system demonstrated its effectiveness in enhancing vessel traffic surveillance, data efficiency, and maritime safety in the Strait of Malacca, while offering potential for further development through the addition of extended features and analytics capabilities.

To address the challenges of GPS signal noise in vessel positioning, (Herianto Herianto et al., 2024) developed a web-based ship monitoring system employing the Kalman Filter method to enhance location estimation accuracy. The system was designed following the Waterfall development model, which included stages such as requirements analysis, system design, implementation, verification, and maintenance. Experimental results demonstrate that the integration of Kalman Filter significantly reduces positional noise and yields more accurate estimations compared to conventional methods. The resulting web application enables real-time vessel tracking, thereby supporting enhanced navigation, surveillance, and operational efficiency. These findings suggest that signal-smoothing algorithms like Kalman Filter are instrumental in improving the reliability of AIS-based monitoring systems.

Although prior studies have explored AIS-based vessel monitoring systems and enhancements in data processing and visualization, most focus solely on real-time tracking without incorporating quantitative collision risk assessment. While models like SICR (Li et al., 2023) address collision risk, they are not embedded into real-time web applications. To fill this gap, the present study develops a real-time web-based monitoring system that integrates CRI assessment using AIS data. This approach aims to enable early detection of potential collisions and support proactive maritime navigation decisions.

METHOD

This section outlines the methodology employed in the design and implementation of a real-time web-based ship monitoring system integrated with CRI assessment. The system architecture is designed to support ship tracking, early collision risk detection, and weather data visualization using AIS information. The proposed approach involves both frontend and backend services that operate collaboratively to deliver timely situational awareness and decision support in maritime navigation, as illustrated in Fig. 1.

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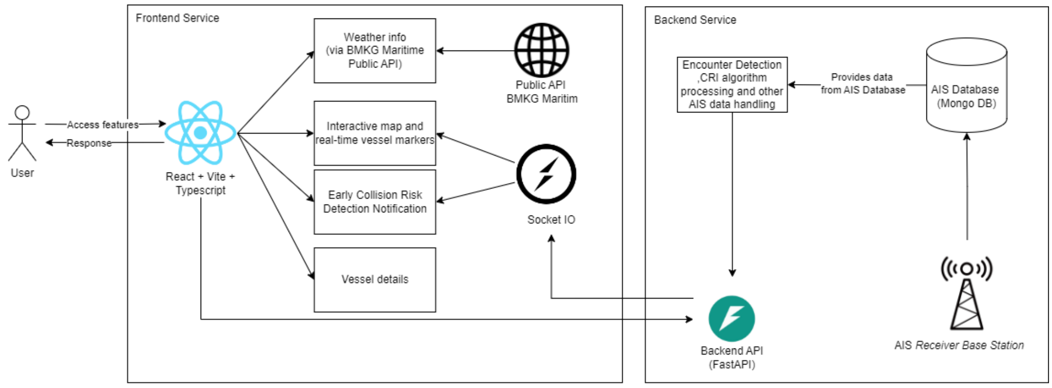

Fig. 1 System Architecture of the Real-Time Web-Based Ship Monitoring and Collision Risk Detection Platform

Fig. 1 illustrates the overall architecture of the proposed system, which is composed of two main components: the backend service and the frontend service. These components are designed to work in an integrated manner to provide real-time vessel monitoring and collision risk assessment using the Collision Risk Index (CRI) algorithm.

On the backend, AIS data collected from the AIS Receiver Base Station is stored in a MongoDB-based AIS database. The backend service leverages FastAPI as the core framework to handle AIS data processing and CRI computation. The CRI calculation pipeline begins by defining a region of interest and applying clustering techniques to group vessels that are spatially and temporally close. Subsequently, the system identifies the type of ship encounters based on COLREGs (International Regulations for Preventing Collisions at Sea), classifying them into three scenarios: head-on, crossing, and overtaking. Based on the identified encounter type, the system evaluates the potential for collision using the CRI metric. The computed CRI values are then transmitted through Apache Kafka, which serves as the event streaming platform to disseminate results to other system components.

The frontend service developed using React with Vite and TypeScript, functions as the user interface layer and supports interactive features. Real-time communication between the backend and frontend is facilitated via Socket.IO, enabling users to receive instant updates on vessel movements and collision risk assessments. The frontend includes several key modules: (1) an interactive map with real-time vessel markers, (2) a weather information panel integrating live data from the BMKG Maritime Public API, (3) an early warning notification panel for collision risk, and (4) a vessel detail viewer displaying ship-specific attributes. This comprehensive integration between backend analytics and frontend visualization allows the system to deliver real-time maritime situational awareness and timely collision risk alerts, thereby supporting safer navigation and proactive decision-making at sea.

1. Encounter Detection

To enable early collision risk detection, one of the initial and critical processes is determining the region of interest (ROI)—a spatial area that represents the scope for encounter analysis. This region is essential for optimizing system performance by narrowing the computational focus to specific maritime zones where interactions between vessels are likely to occur. As illustrated in Fig. 2, the ROI delineation helps identify clusters of vessels that are spatially close and potentially involved in an encounter scenario.

Fig. 2 Visualization of Region of Interest (ROI) for Ship Encounter Detection

Fig. 2 illustrates the spatial definition of a region of interest (ROI) in the waters surrounding Nusa Penida, where multiple vessels are operating in close proximity. This stage serves as the foundation for vessel encounter

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detection, which is a key precursor to assessing potential collision risk. The ROI framework marks a specific observation area to facilitate efficient analysis and filtering of vessel data, as suggested by (Pratomo et al., 2020), thereby streamlining computational efforts and enhancing system responsiveness.

To determine the ROI and group vessels within it, clustering techniques are applied—most notably the DBSCAN algorithm (Density-Based Spatial Clustering of Applications with Noise)(Idris et al., 2023). DBSCAN is well-suited for maritime environments because it can detect arbitrarily shaped clusters and differentiate noise from meaningful vessel groupings based on spatial density. By leveraging DBSCAN, the system can accurately isolate vessel encounters from surrounding traffic, thereby improving the reliability of subsequent CRI calculations. In this context, encounter detection within the ROI acts as the strategic entry point to the overall early collision risk detection pipeline.

After detecting vessels within the region of interest (ROI), the next stage in the early collision risk assessment framework involves determining the encounter situation. This refers to the condition where two or more vessels are moving toward each other or are in close navigational proximity, thereby increasing the potential for collision. Such conditions are especially critical when the inter-vessel distance becomes sufficiently small to affect mutual maneuvering and safety (Zaccone, 2021). Ship encounter is typically classified into three distinct types, namely head-on, overtaking, and crossing, which are differentiated by the relative directions. Specifically, crossing encounter is further categorized into two subtypes based on the position from which the give-way ship methods, either crossing behind (from the stern) or in front of (from the bow) (van Iperen, 2015),(Hassel et al., 2019). Table 1 shows ship encounter categories and relative direction criteria.

Table 1 Ship Encounter Situation Categories

Encounter Situation	Criteria
Overtaking	$\varphi \leq 25$
Head On	$165 \leq \varphi \leq 195$
Crossing give way ship passing at bow	$25 < \varphi < 165$ or $195 < \varphi < 335$ $\alpha \leq 90$ or $\alpha \geq 270$
Crossing give way ship passing at stern	$25 < \varphi < 165$ or $195 < \varphi < 335$ $\alpha < 90$ or $\alpha < 270$

2. Collision Risk Index

CRI is a quantitative metric used to evaluate the likelihood of a collision between two vessels at sea. It is computed based on AIS-derived parameters such as vessel position, speed, course, and proximity. These data are processed through a specific algorithm that evaluates dynamic ship encounters by integrating spatial and temporal risk indicators. The CRI model assesses the risk level by incorporating two primary variables: Distance to Closest Point of Approach (DCPA) and Time to Closest Point of Approach (TCPA) (Chen et al., 2015; Nguyen et al., 2018).

The CRI aims to determine potential collision risks using both static and dynamic obstacle analysis. According to (Liu et al., 2016), if the computed CRI equals zero, it signifies no risk or that a collision cannot occur. Conversely, a CRI value of one represents the highest potential for collision. When the value lies between 0 and 1, it indicates varying levels of collision likelihood depending on the specific context and encounter conditions. The CRI is calculated using the following equation (Li et al., 2022; Lisowski, 2001):

$$\text{CRI} = \left(\alpha 1\left(\frac{DCPA}{Ds}\right)^2 + \alpha 2\left(\frac{TCPA}{Ts}\right)^2 + \alpha 3\left(\frac{D}{Ds}\right)^2\right)^{-\frac{1}{2}} \quad (1)$$

This risk index allows maritime systems to proactively assess vessel proximity and prioritize alerts or evasive maneuvers. By integrating CRI into a real-time monitoring framework, the system can provide early collision warnings and support safer navigation in high-traffic maritime zones.

RESULT

This section summarizes the implementation of the proposed web-based ship monitoring system, emphasizing the integration of backend, frontend, and data infrastructure to support real-time vessel tracking and collision risk assessment. AIS data is collected from a receiver base station at Udayana University and stored in a MongoDB database. The implementation includes AIS data acquisition, server–client integration, CRI computation, API provisioning, and real-time communication via WebSocket. The system visualizes vessel positions and collision alerts through an interactive user interface, aligning with the previously designed system architecture to enhance maritime situational awareness.

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1. Interactive Map Interface for Real-Time Vessel Monitoring

The main page of the application serves as the central interface for monitoring vessel movements within the Badung Strait and the surrounding waters of Nusa Penida. Upon loading, the interactive map is automatically centered at coordinates −8.7179076, 115.4741212, as illustrated in Fig. 3. The monitoring region is delineated by a polygon representing the maritime boundaries of Nusa Penida and is complemented by port icons to enhance users' spatial understanding of key locations within the observation area. Each ship displayed on the map is represented by a triangular icon, with its color dynamically assigned based on the vessel type. This color-coding scheme facilitates immediate visual differentiation between vessel categories, thereby improving the efficiency and clarity of identification and tracking processes. The use of distinct shapes and colors contributes to a more informative and user-friendly monitoring experience, especially in congested maritime zones.

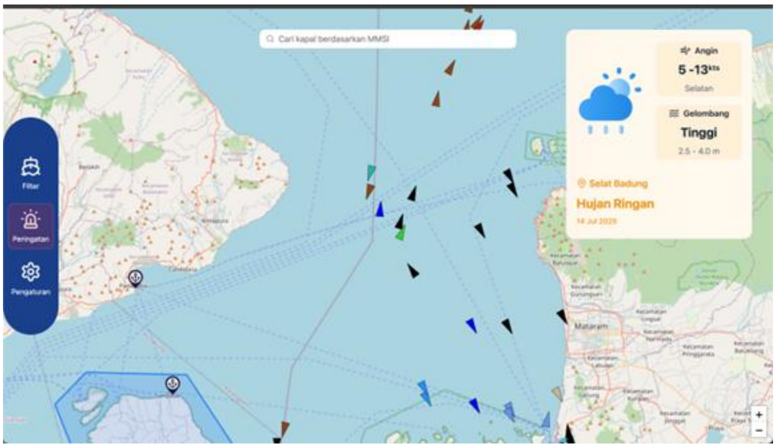

Fig. 3 Interactive map interface on the system's homepage

Fig. 3 displays the interactive map user interface, which serves as the primary component on the system's homepage. To render the map on the client side, the system employs the Leaflet mapping library, which enables dynamic visualization of vessel positions in real time. In addition to the map, the homepage integrates several key features, including vessel search and filter functionalities, as well as live weather information tailored to the maritime conditions of the Badung Strait region. These components collectively enhance user interaction and situational awareness, supporting more efficient maritime monitoring and operational decision-making.

2. Vessel Data Search and Filtering Module

The monitoring system is equipped with search and filtering features designed to enhance user interaction and navigational efficiency. One of the key functionalities is a responsive auto-complete search tool, which allows users to input the first four digits of a vessel's MMSI as a keyword. The system then dynamically generates relevant search results that can be directly selected. This feature enables users to quickly access detailed information about the desired vessel, thereby streamlining the identification process and improving overall user experience, as illustrated in Fig. 4.

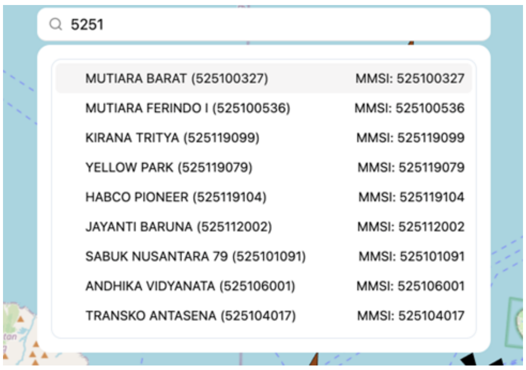

Fig. 4 Auto-complete vessel search interface displaying MMSI-based results on the system's interactive map.

Fig. 4 demonstrates the vessel search interface, which allows users to locate specific ships by entering relevant keywords. When a user inputs at least the first four digits of a vessel's MMSI (Maritime Mobile Service Identity), the system dynamically generates a list of matching results, including vessel names and their respective MMSI

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numbers. Upon selecting a result, the system redirects the user to a detailed vessel page, where comprehensive information is provided. Complementing the search feature, the system also includes a real-time vessel filtering capability designed to streamline monitoring by displaying only selected vessels. As illustrated in Fig. 5, users can access the filtering panel from the left-central menu, select the vessels of interest, and automatically adjust the map view to hide unselected vessels. This targeted filtering enhances situational awareness by reducing visual clutter and enabling focused observation of high-priority ships. Such functionality not only improves operational efficiency but also facilitates timely decision-making in maritime monitoring tasks.

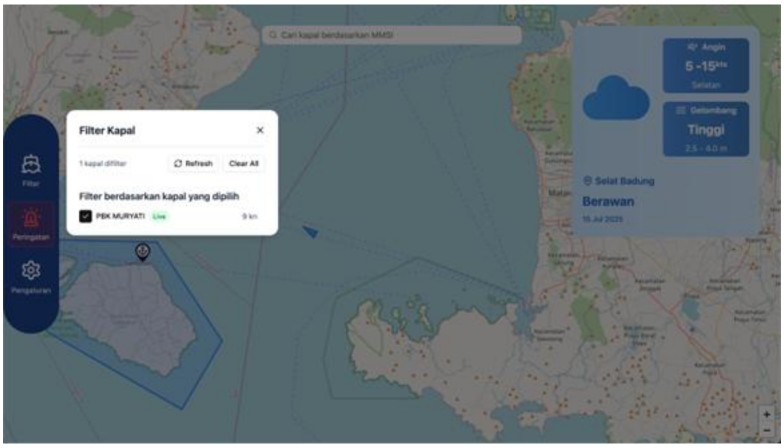

Fig. 5 Vessel Filtering Interface for Targeted Monitoring on the Interactive Map

3. Collision Warning Interface

The collision warning feature is designed to support comprehensive monitoring of potential vessel collisions. This interface allows users to access a dynamically generated list of collision predictions, which are automatically categorized by risk levels—namely critical, high, medium, and low. As illustrated in Fig. 6, each warning contains essential information, including the identities of the vessels involved, inter-vessel distance, DCPA, TCPA, and a computed CRI value that quantifies the associated risk level. In addition to numerical indicators, the system provides a concise situational description and actionable recommendations to assist users in making swift and informed decisions. When a user selects a warning item, the system highlights the corresponding vessel's position on the interactive map, thereby facilitating spatial identification and real-time condition monitoring. This feature is also equipped with risk-level filtering capabilities, enabling users to narrow their focus to incidents that require the most urgent attention. Collectively, this design improves situational awareness and enhances decision-making efficiency in maritime monitoring operations.

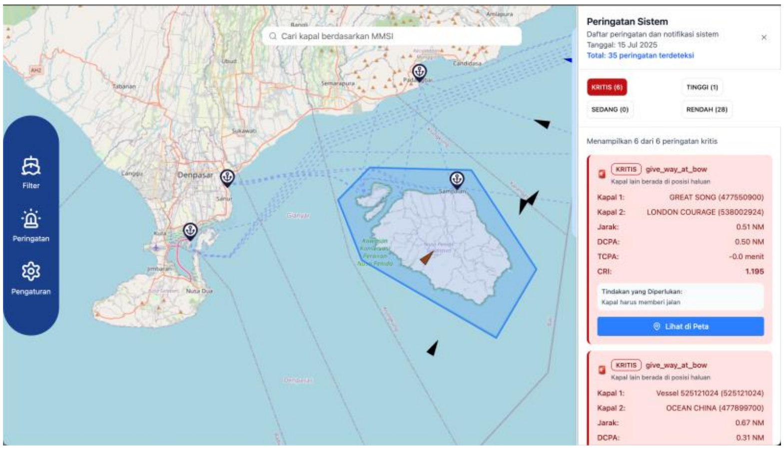

Fig. 6 Collision warning panel displaying critical risk encounters

The visualization presented in Fig. 6 reinforces the practical value of the system's collision warning functionality. The panel highlights ongoing encounters assessed as high-risk, classified into multiple levels of severity (e.g., critical, high, medium, and low). This real-time contextualization aids users in rapidly identifying threats and prioritizing actions based on situational urgency. The visual emphasis on involved vessels through automatic map highlighting supports intuitive navigation, while the integration of suggested actions directly within

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the warning card exemplifies how the interface bridges the gap between risk detection and operational response. Overall, Fig. 6 demonstrates the system's ability to deliver actionable maritime situational awareness for enhanced navigational safety

4. Vessel Detail Page

The vessel detail page is designed to provide a comprehensive overview of individual ships selected by the user, either through search results or directly from the interactive map interface on the system's homepage. As illustrated in Fig. 7, this feature displays critical vessel-specific information, including ship name, MMSI number, current speed, heading direction, and the vessel's latest known location—visualized through a map snapshot for intuitive spatial reference. In addition to static attributes, the system also presents a temporal trajectory log that records the ship's movement history within a defined time frame. This allows users to trace navigation patterns or route deviations during the voyage. By consolidating this essential data into a single interface, the vessel detail page becomes a pivotal component for enabling users to perform real-time positional validation, conduct navigational analyses, and make data-driven decisions with greater accuracy and timeliness.

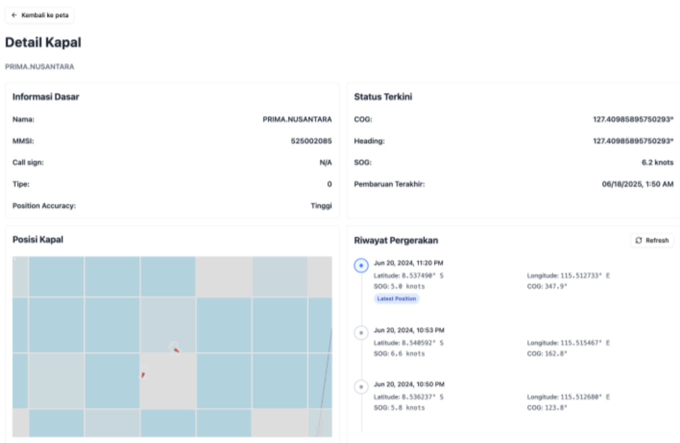

Fig. 7 Vessel detail page displaying real-time attributes, map reference, and historical movement log.

As shown in Fig. 7, the vessel detail page is purposefully designed to offer a user-friendly yet information-rich interface. One of the key features is the embedded map snapshot that displays the vessel's most recent position, enabling users to identify the ship's current location without navigating back to the main map interface. This design promotes monitoring efficiency by consolidating all relevant information into a single, accessible interface.

5. System Performance Evaluation

The system's performance was evaluated to gain a comprehensive understanding of processing efficiency across its operational pipeline. Experimental results indicate that the average detection time for a single vessel is approximately 0.007551 seconds, representing the system's fastest response for individual ship identification. In terms of end-to-end processing time, which spans from server-side data loading to the delivery of the Collision Risk Indicator (CRI) prediction to the client, the system achieved a total latency of 0.061005 seconds, or roughly 61 milliseconds. This duration comprises several key stages: data loading (0.020837 s, 34.2% of total time), detection algorithm processing (0.020380 s, 33.4%), and CRI prediction (0.001496 s, 2.5%). Following processing, the predicted results are transmitted to the user interface via the WebSocket protocol, with an average transmission time of 0.012735 seconds for a payload size of 12,127 bytes, yielding an estimated throughput of 952,265.78 bytes per second. These findings demonstrate that the developed system exhibits very high responsiveness. Individual ship detection requires less than 8 milliseconds, while the complete data flow from ingestion to client-side display consistently remains below 61 milliseconds. This high processing speed supports real-time maritime monitoring with minimal latency, thereby significantly enhancing the system's reliability for timely and accurate collision risk detection.

6. Software Validation and Testing

To ensure that the specified requirements of a software system are fully met, a thorough process of validation and testing is essential. This step plays a critical role in verifying that the application performs as intended under various conditions. Without proper testing, the system may produce unexpected errors that could potentially cause significant inconvenience or harm to end users (Wulandari et al., 2022). Table 2 presents the results of system

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testing, which were obtained based on predefined testing scenarios and the actual implementation process of the developed system.

Table 2 Functional Testing Results of the Monitoring System

No	Test Area		User Area	
	Test Scenario	Process	Expected Feature Outcome	Actual Result
1	Map Display	Opening the main homepage of the website	The application successfully displays an interactive map visualizing vessel movements in real-time based on AIS data, particularly in the Badung Strait and surrounding maritime zones.	As expected
2	Vessel Search and Filtering	Entering a keyword in the search bar and applying filters using the filter menu located on the left center of the homepage	The application successfully implements vessel search and filtering functions based on name or MMSI, and enables visualization of vessels according to the selected type or category.	As expected
3	Collision Warning Notification	When a collision condition or a CRI value exceeding the threshold is detected, a notification appears on the top-right of the homepage	The application successfully generates alarms and notifications automatically when potential ship collision predictions are detected, allowing users to take preventive action promptly.	As expected
4	Warning Menu	When a ship is predicted to face a critical collision risk, the bell icon in the warning menu flashes	The application successfully displays a warning menu that filters ship collision data based on risk levels and shows a list of predicted collisions by severity as selected by the user.	As expected
5	Local Weather Information	Opening the main homepage of the website	The application successfully displays local weather information, enabling users to access real-time maritime weather conditions in the Badung Strait region.	As expected
6	Vessel Detail Information	Selecting a moored vessel by clicking its icon on the map, or searching the vessel name and selecting it from the result list	The application successfully presents a detailed vessel information page that includes current position, ship identity, and movement history in an integrated and user-friendly interface.	As expected

The functional testing results in Table 2 confirm that the core components of the system operate reliably and as expected. All tested features—including interactive map display, vessel search and filtering, collision warning notifications, and vessel detail pages—performed correctly under predefined scenarios. Notably, the system successfully generated real-time collision alerts and displayed relevant vessel information, supporting efficient monitoring and decision-making. While the results demonstrate good system stability and responsiveness, further testing under higher data loads and extended geographic coverage may be necessary to fully assess the system's robustness in operational environments.

DISCUSSIONS

The experimental results validate the efficacy of the proposed web-based system for real-time vessel monitoring and collision risk assessment. The system successfully integrates AIS data processing, encounter detection using DBSCAN, CRI computation, and interactive visualization through a responsive user interface. The low processing latency—averaging 0.007551 seconds per ship and 0.061005 seconds end-to-end—demonstrates the platform's suitability for real-time maritime operations. The effectiveness of key features, including collision warnings, vessel filtering, and detailed ship profiles, was confirmed through functional testing, with all modules performing as expected under various scenarios. These findings affirm that the system provides reliable situational awareness and enhances decision-making by enabling early detection of high-risk encounters. Compared to prior AIS-based systems that often lack quantitative risk indicators or real-time interactivity, the integration of CRI into a dynamic web platform represents a significant advancement. However, future work should explore scalability across wider maritime zones and evaluate system performance under higher data loads to ensure robustness in more complex operational environments.

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CONCLUSION

This study presents the development and evaluation of a web-based vessel monitoring system that integrates AIS data, encounter detection, and CRI computation for real-time maritime safety assessment. The system successfully visualizes vessel movements, detects potential collisions using spatial clustering, and delivers dynamic CRI-based alerts through a responsive user interface. Performance testing revealed low-latency processing, with an average detection time of 0.007551 seconds per vessel and an end-to-end response time under 61 milliseconds—demonstrating the system's readiness for real-time deployment. Functional validation further confirmed the reliability of key features, including map rendering, vessel search, collision warnings, and ship-specific information access. By embedding CRI calculations directly into a live monitoring framework, the system offers enhanced situational awareness and supports timely decision-making for maritime navigation and surveillance. Future work may focus on extending the system to broader geographic regions, incorporating environmental variables, and evaluating its performance in high-traffic conditions to strengthen its applicability in more complex operational contexts.

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REFERENCES

Bachtiar, A., Trilia, D., Hia, H. A. F., Zafirawan, R. A., & Supriyadi, A. A. (2024). Pengawasan Maritim Efektif Melalui Implementasi Automatic Identification System (Ais) Untuk Jalur Pelayaran Surabaya-Makassar. Majalah Ilmiah Globe, 26(2), 57–66. https://doi.org/10.24895/gl.2024.26.2.57-66

Chen, D., Dai, C., Wan, X., & Mou, J. (2015). A research on AIS-based embedded system for ship collision avoidance. 2015 International Conference on Transportation Information and Safety (ICTIS), 512–517. https://doi.org/10.1109/ICTIS.2015.7232141

Darilaut.id. (2022). 2018-2021, Sebanyak 483 Kecelakaan Kapal Perikanan Indonesia. https://darilaut.id/berita/2018-2021-sebanyak-483-kecelakaan-kapal-perikanan-indonesia

Enda, D., Agustiawan, A., Milchan, M., & Pratiwi, E. (2021). Rancang Bangun Aplikasi AIS Backend Untuk Pemantauan Lalu Lintas Kapal di Selat Melaka. INOVTEK Polbeng - Seri Informatika, 6(2), 284. https://doi.org/10.35314/isi.v6i2.2139

Hassel, M., Aalberg, A. L., & Nordkvist, H. A. (2019). An Advanced Method for Detecting Exceptional Vessel Encounters in Open Waters from High Resolution AIS Data. Proceedings of the 29th European Safety and Reliability Conference (ESREL), June, 1709–1714. https://doi.org/10.3850/978-981-11-2724-3_0038-cd

Herianto Herianto, Fajri Profesio Putra, & Muhammad Asep Subandri. (2024). Peningkatan Akurasi Pada Sistem Monitoring Posisi Kapal Menggunakan Metode Kalman Filter. Saturnus : Jurnal Teknologi Dan Sistem Informasi, 2(4), 249–260. https://doi.org/10.61132/saturnus.v2i4.354

Idris, M. A., Apriyanto, A., & Rahmawati. (2023). Pemetaan Produksi Perikanan Tangkap di Indonesia dengan Menggunakan Metode DBSCAN. Journal of Mathematics: Theory and Applications, 5(2), 80–86. https://doi.org/10.31605/jomta.v5i2.2930

Li, W., Zhong, L., Liu, Y., & Shi, G. (2023). Ship Intrusion Collision Risk Model Based on a Dynamic Elliptical Domain. Journal of Marine Science and Engineering, 11(6), 1122. https://doi.org/10.3390/jmse11061122

Li, W., Zhong, L., Xu, Y., & Shi, G. (2022). Collision Risk Index Calculation Based on an Improved Ship Domain Model. Journal of Marine Science and Engineering, 10(12), 2016. https://doi.org/10.3390/jmse10122016

*name of corresponding author

Lisowski, J. (2001). Determining the optimal ship trajectory in a collision situation. Proceedings of the IX International Scientific and Technical Conference on Marine Traffic Engineering, Szczecin, Poland, January, 192–201.

Liu, H., Deng, R., & Zhang, L. (2016). The application research for ship collision avoidance with hybrid optimization algorithm. 2016 IEEE International Conference on Information and Automation (ICIA), 760–767. https://doi.org/10.1109/ICInfA.2016.7831921

Nguyen, M., Zhang, S., & Wang, X. (2018). A Novel Method for Risk Assessment and Simulation of Collision Avoidance for Vessels based on AIS. Algorithms, 11(12), 204. https://doi.org/10.3390/a11120204

Pratomo, A. H., Kaswidjanti, W., & Mu'arifah, S. (2020). Implementasi Algoritma Region of Interest (Roi) Untuk Meningkatkan Performa Algoritma Deteksi Dan Klasifikasi Kendaraan Implementation of Region of Interest (Roi) Algorithm To Improve Car Detection and Classification Algorithm. Jurnal Teknologi Informasi Dan Ilmu Komputer (JTIIK), 7(1), 155–162. https://doi.org/10.25126/jtiik.202071718

Setiyantara, Y., Ningrum Astriawati, Pertiwi, Y., Ade Chandra Kusuma, & Thomas Wahyu Bagaskoro. (2023). Optimalisasi Pengoperasian AIS (Automatic Identification System) Dalam Upaya Menjaga Keselamatan Pelayaran. Meteor STIP Marunda, 16(1), 1–6. https://doi.org/10.36101/msm.v16i1.268

Tedyyana, A., Ratnawati, F., & Danuri, D. (2023). Platform Monitoring Berbasis Web untuk Sistem Stabilitas dan Pelacakan Kapal Nelayan. Digital Zone: Jurnal Teknologi Informasi Dan Komunikasi, 14(2), 168–178. https://doi.org/10.31849/digitalzone.v14i2.16419

van Iperen, E. (2015). Classifying Ship Encounters to Monitor Traffic Safety on the North Sea from AIS Data. TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation, 9(1), 51–58. https://doi.org/10.12716/1001.09.01.06

Wright, D., Janzen, C., Bochenek, R., Austin, J., & Page, E. (2019). Marine Observing Applications Using AIS: Automatic Identification System. Frontiers in Marine Science, 6. https://doi.org/10.3389/fmars.2019.00537

Wulandari, A. S., Saepudin, A., Kinanti, M. P., Sudesi, Z., Saifudin, A., & Yulianti, Y. (2022). Pengujian Aplikasi Sistem Informasi Akademik Berbasis Web Menggunakan Metode Black Box Testing Equivalence Partitioning. Jurnal Teknologi Sistem Informasi Dan Aplikasi, 5(2), 102. https://doi.org/10.32493/jtsi.v5i2.17561

Zaccone, R. (2021). COLREG-Compliant Optimal Path Planning for Real-Time Guidance and Control of Autonomous Ships. Journal of Marine Science and Engineering, 9(4), 405. https://doi.org/10.3390/jmse9040405

Zhang, Y., & Li, W. (2022). Dynamic Maritime Traffic Pattern Recognition with Online Cleaning, Compression, Partition, and Clustering of AIS Data. Sensors, 22(16), 6307. https://doi.org/10.3390/s22166307