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Coastal Guard: Enhancing Maritime Border Security Through Real Time Surveillance and Predictive Alerts

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Abstract
Maritime security is of paramount importance for coastal nations, given the numerous challenges posed by illegal border crossings, smuggling activities, and environmental hazards. Traditional surveillance methods have limitations in effectively monitoring vast maritime borders in real time and predicting potential security breaches. Additionally, fishermen operating in these areas are often exposed to risks such as adverse weather conditions and maritime hazards due to limited access to timely information. Hence, there is a critical need for innovative technological solutions to enhance border surveillance, communication, and coordination among maritime authorities and stakeholders. In response to these challenges, the aim of the project is to develop a solution to address the shortcomings of traditional border surveillance systems This project introduces an integrated border alert system that combines weather monitoring, hazard alerts, and seamless integration with maritime authorities. Leveraging Long Short-Term Memory (LSTM) neural networks, the FBAS aims to bolster surveillance and response capabilities. The Border Net Model, is going to develop with LSTM neural networks, enables predictive border classification, while the Alert System issues timely notifications to stakeholders. The Weather Data Provider API ensures access to up-to-date meteorological information, enhancing decision-making. Additionally, features such as alert systems for adverse weather conditions and maritime hazards ensure the safety of fishermen and other maritime activities. Through its innovative features and capabilities, the proposed system aims to bridge the gaps in traditional surveillance systems and provide comprehensive protection for maritime borders.

Keywords: *Maritime security, Border surveillance, LSTM neural networks, Hazard alerts, Weather monitoring, Fishermen safety, Real-time notifications, Smart surveillance.*

1. Introduction
Coastal zones are increasingly vulnerable to a range of threats, including illegal maritime operations, smuggling, unauthorized entries, and unpredictable environmental conditions. Conventional surveillance strategies primarily reliant on manual patrolling and static systems often fall short when it comes to delivering real-time insights or forecasting potential threats. Additionally, many fishermen and maritime workers continue to operate in high-risk environments without timely access to alerts or accurate data. To tackle these pressing concerns, this project proposes Coastal Guard, an intelligent and automated maritime surveillance and alert system. Coastal Guard integrates Long Short-Term Memory (LSTM) neural networks to enable accurate threat detection and risk prediction, thereby improving situational awareness in real time. Alongside this, the system incorporates live weather data through a real-

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time API, ensuring environmental conditions are monitored and alerts are issued promptly to those at sea. At the core of this solution lies the Border Net framework, a predictive engine designed to process historical and real-time data for hazard detection and threat classification. The system's features such as intelligent alert triggers, predictive classification, and a centralized dashboard help maritime authorities coordinate and respond more effectively to emerging situations. By shifting from manual methods to smart automation, Coastal Guard not only addresses gaps in legacy surveillance systems but also promotes better coordination, safer marine navigation, and quicker response times. It plays a crucial role in safeguarding coastal zones and supporting the needs of all maritime stakeholders, including security agencies and the fishing community. Given the rise in cross-border threats, piracy, and severe weather incidents, modern coastal defence demands smarter solutions. Coastal Guard rises to this challenge by utilizing advanced predictive technologies and a modular architecture that seamlessly integrates with current maritime systems. The platform supports automated operations, adaptive learning, and streamlined communication making it a sustainable, scalable approach to maritime security. Through a combination of data-driven prediction, real-time alerting, and centralized monitoring, Coastal Guard aims to minimize human error, enhance safety, and establish a secure, responsive maritime border management system for the future.

2. Literature Review

Traditional maritime surveillance systems, including manual patrolling and basic radar, are limited in real-time monitoring and lack predictive capabilities. Existing solutions like AIS and satellite tracking are often expensive and not integrated with intelligent forecasting models. Previous research has applied machine learning for anomaly detection, but models like SVM and Decision Trees struggle with time-based predictions. While LSTM networks have recently shown promise for pattern recognition in sequential data, most systems still lack real-time environmental integration and effective stakeholder communication. Coastal Guard addresses these gaps by combining LSTM-based prediction, live weather monitoring, and automated alerting into a single platform, offering a smart, scalable solution for coastal security.

2.1 Detecting Intentional AIS Shutdown in Open Sea Maritime Surveillance Using Self-Supervised Deep Learning

The Coastal Guard initiative strengthens maritime security by offering real-time monitoring and AI-powered predictive alerts. It leverages LSTM neural networks for identifying potential threats, the Border Net Model for border classification, and a live alert system to notify authorities. Furthermore, it includes weather tracking and hazard notifications to protect fishermen, ultimately enhancing overall maritime safety and operational effectiveness.

2.2 Benchmarking Vision-Based Object Tracking for USVs in Complex Maritime Environments

The Coastal Guard initiative boosts maritime security by employing AI-powered vision-based tracking for Unmanned Surface Vehicles (USVs), enabling real-time surveillance and predictive threat identification. It combines deep learning models with sophisticated control techniques for smooth and effective tracking, which has been validated through both simulations and real-world testing.

2.3 Generative AI Threats to Maritime Navigation Using Deceptive ISAR Images

The paper examines the rising threat of AI-generated fraudulent Inverse Synthetic Aperture Radar (ISAR) images in maritime navigation. Using Generative Adversarial Networks (GANs), malicious actors can produce highly convincing yet deceptive radar images, which could result in navigational dangers like collisions or incorrect identifications. It emphasizes how Advanced Persistent Threats (APTs) could take advantage of these weaknesses to manipulate radar systems, creating considerable risks for maritime security.

2.4 Structure Guided Global and Local Attention Transformer for Image Inpainting of Obscured Ships in Maritime Surveillance

The SGGLAT model presents an innovative deep learning method to improve maritime surveillance by reconstructing images of ships hidden behind

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obstacles such as buoys, rocks, or other objects. It employs a two-phase process, initially using the Edge Global and Local Attention Transformer (EGLAT) to restore structural features, followed by texture refinement through the Texture Global and Local Attention Transformer (TGLAT). Additionally, the Active Masked Patch Removal Algorithm (AMPRA) enhances precision by gradually removing masked areas, ensuring a smoother and higher-quality image restoration.

3. Proposed System

The proposed system is an advanced web-based solution designed to enhance maritime security by overcoming the limitations of traditional surveillance systems. It aims to improve real-time monitoring, detect potential security threats, and safeguard fishermen operating in high-risk maritime areas. By integrating several cutting-edge technologies, the system provides a more efficient and proactive approach to surveillance, communication, and coordination among maritime authorities and stakeholders. The system leverages Long Short-Term Memory (LSTM) neural networks to enhance surveillance capabilities and perform predictive border classification. Using the Border Net Model, it can accurately analyse and classify potential threats along maritime borders. Additionally, the system features an Alert System that sends timely notifications to relevant authorities, enabling quick responses to emerging threats. The Weather Data Provider API ensures the system has access to the latest meteorological information, improving decision-making and enabling authorities to address environmental hazards effectively. Key functionalities of the system include real-time alerts for adverse weather conditions and maritime hazards, helping to protect fishermen and other maritime operations. By enabling seamless communication and coordination with maritime authorities, the system ensures a swift and organized response to any potential risks. Overall, this system aims to address the gaps left by traditional surveillance methods and offers a comprehensive solution to secure maritime borders.

3.1 System Architecture

The architecture of the Coastal Guard project allocation and monitoring system is structured to support effective maritime project oversight, collaborative coordination, and intelligent automation. It is composed of three fundamental layers: the presentation layer (frontend), the application logic layer (backend), and the data layer (database), as depicted in Fig. 3.3.1. The frontend presents a user-friendly interface enabling officers and maritime authorities to log in, indicate their area of operation or preference, and monitor task status in real time. Higher officials like regional heads and project coordinators can view project assignments, oversee operational loads, and generate security and performance reports. The backend is responsible for key logic such as validating unique project titles, intelligently assigning tasks based on operational roles, and managing predictive alert systems through LSTM-based models. The data layer handles secure storage and quick retrieval of project information, weather data, alert histories, and user credentials. This architectural setup ensures a robust, responsive system tailored to real-time coastal surveillance and efficient project tracking. The system's features such as intelligent alert triggers, predictive classification, and a centralized dashboard help maritime authorities coordinate and respond more effectively to emerging situations. By shifting from manual methods to smart automation, Coastal Guard not only addresses gaps in legacy surveillance systems but also promotes better coordination, safer marine navigation, and quicker response times. It plays a crucial role in safeguarding coastal zones and supporting the needs of all maritime stakeholders, including security agencies and the fishing community. Given the rise in cross-border threats, piracy, and severe weather incidents, modern coastal defence demands smarter solutions. Coastal Guard rises to this challenge by utilizing advanced predictive technologies and a modular architecture that seamlessly integrates with current maritime systems. The platform supports automated operations, adaptive learning, and streamlined communication making it a sustainable, scalable approach to maritime security. Through a combination of data-driven prediction, real-time alerting, and centralized monitoring, Figure 1 shows System Architecture.

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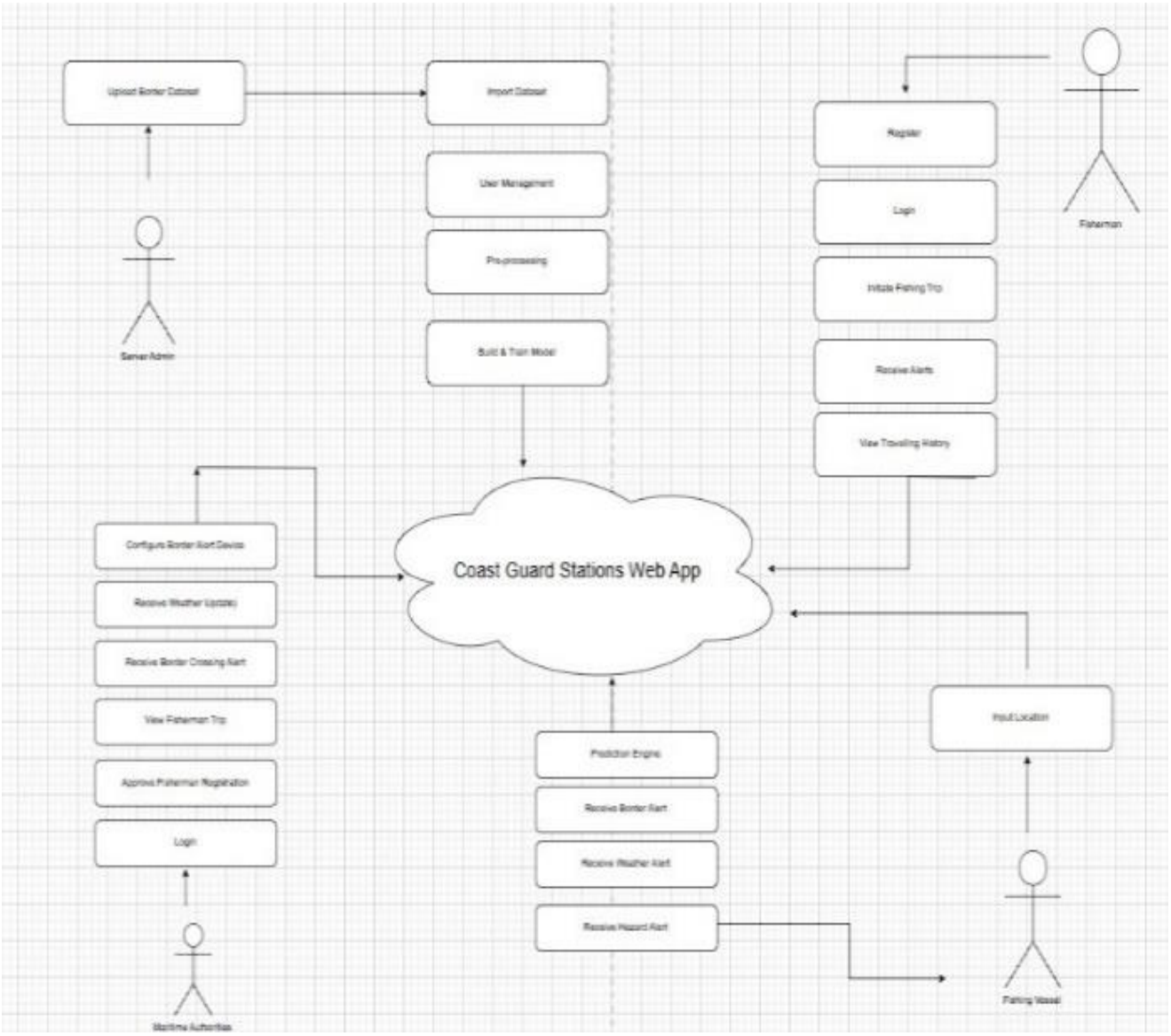

Figure 1 System Architecture

3.2 Working Process

User authentication: Coast Guard officers, maritime authorities, server admins, and authorized fishermen securely log in through a multi-tier authentication system. This ensures restricted access and data integrity across various user roles enabling only verified individuals to access operational features and datasets. Fisherman Registration and Trip Initialization: Fishermen register themselves through the web interface and await approval from maritime authorities. Once approved, they can initiate fishing trips by inputting their location, which integrates directly with the Coast Guard system to ensure constant monitoring and trip logging. Real-Time Alerts and Predictive Monitoring: The system employs LSTM-powered predictive models to compute and issue real-time alerts concerning potential border crossings, hazardous weather conditions, and environmental threats. This allows fishermen and coast guard units to receive timely notifications, minimizing risks and ensuring rapid response. Intelligent Task Handling for Maritime Authorities: Authorities receive alerts, review registered fishing trips, and can configure or manage border alert devices directly from the system.

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Intelligent matching and alert distribution ensure that alerts are never missed and are routed to the appropriate teams for swift action. Integrated Surveillance and Response Coordination: The platform bridges communication between server admins, maritime officials, and field agents via centralized dashboards that monitor alerts, device status, fishing vessel locations, and weather updates. Coordinators can track progress and manage alert-based operations efficiently. Automated Reporting, Tracking History, and Notifications: The system automatically logs travel histories, generates operation reports, and evaluates alert responses. Fishermen and authorities alike receive automated notifications regarding system events such as approval statuses, weather shifts, border proximity, or hazard zones. Weather and Hazard Alert System: The solution integrates with a Weather Data Provider API to offer up-to-date meteorological insights. Combined with machine learning capabilities, the system proactively warns users about upcoming threats, reducing human dependency and improving maritime operational safety.

3.3 Security and Transparency

- Security: The system ensures that only authorized users coastal officers, project supervisors, regional coordinators, and command-level officials can access specific functionalities and sensitive information. This controlled access helps maintain confidentiality and prevents misuse or data breaches.
- Transparency: A transparent operational environment is maintained for all stakeholders by enforcing key principles such as data integrity. Task-related information, officer preferences, and real-time progress updates are securely stored and protected against unauthorized modifications, ensuring trust and clarity across the board.
- Decentralization: Progress data and operational logs are stored in a secure, decentralized manner to enhance reliability and reduce the risk of tampering. This approach strengthens the system's trustworthiness and ensures consistent monitoring and accountability across all levels of the coastal defense network.

3.4 Advantages of the Proposed System

- Predictive Border Surveillance with Smart Alerting: The Coastal Guard system leverages LSTM-based models to proactively identify potential border breaches and maritime risks. This predictive capability allows for timely alerts and smarter deployment of resources, reducing reliance on manual surveillance and increasing overall efficiency.
- Seamless Integration of Maritime Stakeholders: By integrating fishermen, coast guard authorities, and server admins into a unified web application, the system promotes real-time communication and streamlined coordination. Features like live trip tracking, alert approvals, and hazard warnings ensure that all stakeholders remain informed and synchronized.
- Minimized Risks for Fishermen and Improved Safety Protocols: Through constant location tracking, weather monitoring, and hazard alerting, the system provides fishermen with real-time insights that significantly reduce the risks of navigating dangerous waters. This enhances overall maritime safety and situational awareness.

4. Methodology

The development of the Coastal Guard Border Surveillance and Fisherman Monitoring System adopts a structured, modular methodology to ensure high performance, intelligent automation, and secure operation. The process is segmented into clearly defined phases, including system architecture design, secure authentication, trip registration, predictive alerting, real-time monitoring, and automated reporting.

4.1 System Design and Architecture

The Coastal Guard platform is built as a centralized, web-based solution that integrates a responsive frontend, a logic-driven backend, and a secure database to ensure seamless operation. The system architecture is modular, allowing easy scalability and maintenance. The frontend provides dashboards for fishermen to register their trips and for maritime authorities to monitor activities and alerts. The backend manages the business logic, including LSTM-based prediction models for hazard and

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border breach detection, while the database securely stores all trip histories, user profiles, alert logs, and operational data. This modular design ensures that the system can efficiently support multiple user roles, maintain high performance, and adapt to future technological upgrades.

4.2 User Authentication and Access Control

To restrict access to authorized personnel and maintain data integrity, a secure login mechanism is implemented within the system. Users are authenticated using credentials provided by maritime authorities, such as fisherman IDs and officer access codes. Role-based access control is strictly enforced to ensure that users can only access functionalities appropriate to their role. Fishermen are permitted to register trips and receive real-time alerts, maritime officers have the authority to monitor active trips and validate system alerts, while server administrators manage the system's overall operations, including device statuses and backend configurations. This controlled access guarantees system security, operational efficiency, and minimizes unauthorized data exposure.

4.3 Fisherman Registration, Trip Submission, and Alert Generation

Once authenticated, fishermen can register their fishing trips by submitting key information such as departure location, timing, and intended fishing zones through the web interface. The system validates the submitted details against operational protocols and active maritime zones. During their active trips, the system continuously monitors their location and uses LSTM predictive models to identify potential threats, such as unauthorized border proximity, hazardous weather conditions, or environmental anomalies. In case of any predicted threat, real-time alerts are automatically generated and transmitted to both the fishermen and the corresponding maritime authorities. The smart allocation and alerting logic ensure that threats are quickly identified and communicated, improving operational safety and minimizing response time.

4.4 Real-Time Monitoring, Supervisor Interaction, and Progress Logging

After Throughout the trip lifecycle, maritime authorities can monitor the real-time location of registered fishermen, receive predictive alerts, and validate the status of ongoing trips. The system provides supervisors with an intuitive dashboard to track vessel movements, assess weather-related risks, and verify compliance with security protocols. Supervisors can interact with the fishermen by sending safety messages or directives in response to alerts or suspicious activities. All activities, including trip updates, alerts raised, and authority responses, are automatically logged by the system to maintain transparency and accountability. This real-time interaction and continuous monitoring ensure operational efficiency, quick incident response, and provide a historical log for post-operation analysis and decision-making.

5. Implementation

The implementation of the Coastal Guard Border Surveillance and Fisherman Monitoring System involves the integration of multiple functional modules including predictive alerting, web-based communication interfaces, secure databases, and real-time monitoring. The deployment process ensures that each component is tightly coupled with system objectives such as maritime safety, smart surveillance, and proactive decision-making. The following outlines the structured implementation process adopted for the Coastal Guard platform.

5.1 System Architecture

The Coastal Guard system architecture is composed of four core components working in unison to deliver real-time performance and data-driven decisions:

- Frontend (User Interface): A responsive web interface is built to provide fishermen, maritime officers, and administrators with access to key functionalities like trip registration, alert tracking, and monitoring dashboards. The interface is designed for clarity, usability, and responsiveness across devices.
- Backend (Server & Logic Layer): The backend, developed using frameworks such as Node.js or Django, manages server-side logic including predictive computations, user authentication, and alert dispatch mechanisms.
- Database: A structured database (e.g., PostgreSQL or MongoDB) securely stores critical information such as user credentials,

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registered trips, real-time GPS data, weather conditions, and system-generated alerts.

- Notification System: A dedicated module is responsible for sending time-sensitive alerts and updates to users through emails, in-app messages, or SMS, ensuring stakeholders are always informed during high-risk scenarios.

5.2 Predictive Alerting and Risk Computation

A central feature of the system is its predictive intelligence powered by LSTM (Long Short-Term Memory) neural networks. The alert engine follows a step-by-step process:

- Trip and Zone Registration: Fishermen submit trip details, including route preferences, which are recorded and tracked for risk analysis.
- Predictive Computation: The system continuously analyzes environmental data and spatial proximity to border zones using pre-trained LSTM models.
- Threat Detection and Classification: Based on thresholds and prediction scores, the system identifies patterns indicative of maritime threats such as unauthorized zone entry or severe weather.
- Smart Alert Dispatch: Verified alerts are automatically sent to concerned parties' fishermen, coast guards, and monitoring officials minimizing manual intervention and enabling quick responses.

5.3 Web Interface Functionality

The user-facing side of the platform is designed using modern front-end libraries like React.js, providing a dynamic and real-time interface:

- Fisherman Panel: Allows users to register trips, view safety alerts, and receive guidance from authorities.
- Authority Dashboard: Enables maritime officials to monitor active trips, respond to alerts, and verify zone breaches or emergency triggers.
- Admin Console: Offers system-wide oversight, with capabilities for managing user accounts, model configurations, and generating operational summaries.

5.4 Security and Access Management

Given the sensitivity of border surveillance and user data, multiple security mechanisms are implemented:

- Role-Based Access Control (RBAC): Ensures that users (fishermen, officers, admins) have access only to features relevant to their role.
- Data Encryption: All data transmissions are secured using industry-standard SSL/TLS protocols to protect against interception.
- Activity Logs and Audit Trails: Every system operation is logged, ensuring transparency, traceability, and compliance with maritime authority regulations.

5.5 Testing and Validation

The Before system rollout, rigorous testing phases are conducted to ensure robustness:

- Module-Level Testing: Each module (e.g., alert engine, trip registration) is tested independently for accuracy and reliability.
- End-to-End Testing: Simulated trips and alerts are used to test how the system behaves in realistic conditions.
- User Testing: Selected fishermen and officers interact with the system in pilot mode to validate usability and gather real-world feedback.
- Stress Testing: High-load scenarios are tested to verify the system's performance under peak conditions.

5.6 Deployment and Live Execution

The finalized system is deployed on a cloud environment such as AWS or Microsoft Azure using CI/CD pipelines for continuous integration. A unique domain is configured for platform access by maritime stakeholders. Post-deployment, system performance is monitored using tools like Grafana or Prometheus, ensuring minimal downtime, proactive error resolution, and efficient data handling in real-time.

6. Result and Discussion

6.1. User Registration and Access

The Coastal Guard system successfully incorporates a secure and efficient user registration module, allowing fishermen, coastal officers, system coordinators, and administrative officials to create accounts and access functionalities based on their assigned roles. Each user is authenticated via a secure login system and uniquely identified within the backend database to avoid duplication. The registration process involves input validations, secure credential handling, and role-based feature

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assignment. In future versions, enhancing security with two-factor authentication (2FA) or integrating with institutional identity providers via Single Sign-On (SSO) can further strengthen system protection.

6.2. Administrative and Monitoring Panel

A centralized admin dashboard has been developed to enable maritime authorities and coordinators to monitor all registered users, track surveillance tasks, and oversee fishermen's registered trips and ongoing activities. The dashboard is designed with simplicity and operational speed in mind, giving administrators real-time visibility over system operations. Although basic role separation has been achieved, implementing finer-grained permissions like read-only or task-approval roles could provide even stronger control. Future enhancements may also include integrated analytics for monitoring user behavior and real-time alert generation.

6.3. Trip Registration and Alert Assignment Setup

The platform allows fishermen to register their fishing trips by specifying travel areas and schedules. These entries are validated to ensure proper coverage and avoid duplication in hazard-prone zones. Simultaneously, coastal officers can configure alert thresholds and safety protocols based on weather patterns and zone proximity. The system has been tested for dynamic trip handling and accurate assignment of surveillance tasks and alerts. Introducing intelligent recommendations based on weather predictions or zone congestion could further enhance safety and operational efficiency.

6.4. Real-Time Progress Tracking and Interaction

Coastal Guard features a real-time tracking module that enables officers to monitor the live status of registered trips and respond proactively to potential threats or environmental hazards.

Fishermen receive updates about their trip conditions, and officers can update checkpoints or issue emergency advisories. The system enforces strict validation to ensure only authorized personnel can update or approve progress entries, preserving the integrity of the monitoring data. In future versions, introducing predefined milestone templates, automated risk level alerts, and time-based escalation mechanisms could significantly strengthen maritime safety workflows.

6.5. Reporting and Notifications

The reporting functionality generates instant operational summaries for coastal authorities, officers, and fishermen. These reports include trip status, threat alerts issued, and patrol workload summaries. Automated notifications ensure all relevant stakeholders are promptly informed about approaching danger zones, weather anomalies, trip deviations, and task completions. Currently, notifications are dispatched mainly through email systems; expanding to SMS alerts, push notifications, and even satellite messaging for deep-sea operations would make communication more robust. Adding visual reporting dashboards with maps, threat heatmaps, and timeline graphs would also make monitoring more intuitive and responsive.

6.5.1 Fishermen Login Page

This is the login interface of fishermen. This page allows fishermen to login and register, initiate trips, see weather updates and also access their travel history. (as figure 2).

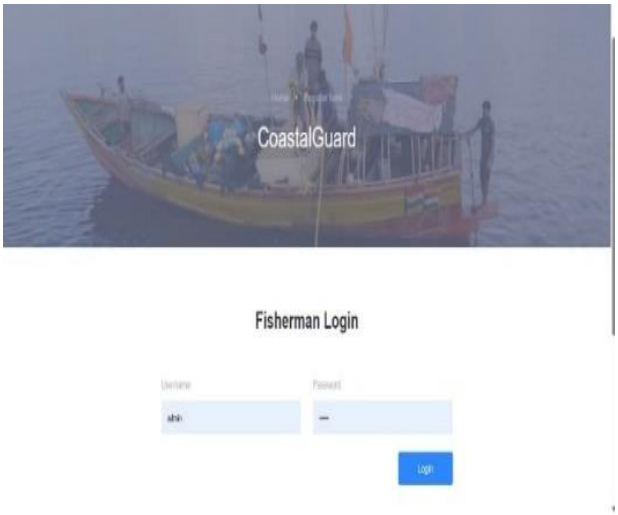

Figure 2 Student Login

6.5.2 Maritime Authority Login Page

This is the login interface for the maritime authorities. This page (as figure 3) allows the maritime authorities to access fishermen information, approve and deny trips and also monitor fishermen travel activities and history.

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Figure 3 Staff Login

6.5.3 Admin Login Page

This is the login interface for the admin. This page (as figure 3) allows the admin to upload datasets and train models. Figure 4 shows Student Dashboard.

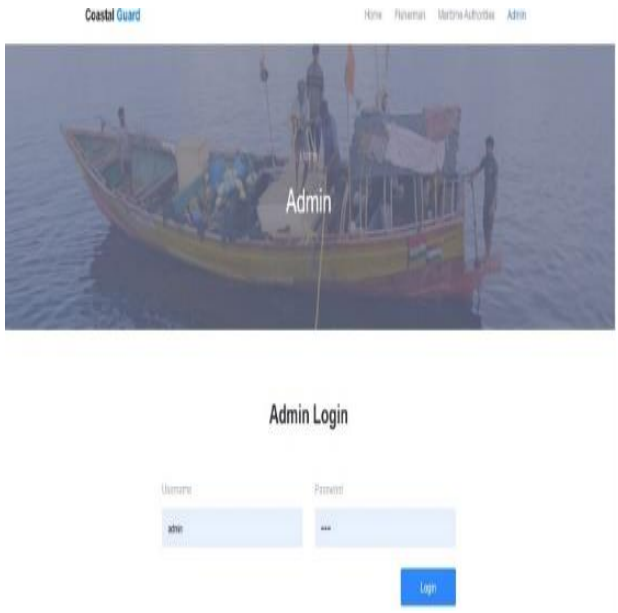

Figure 4 Student Dashboard

6.5.4 Fishermen Dashboard Page

The fishermen dashboard is a page where the registered information about the fishermen and weather data will be available. (as figure 5).

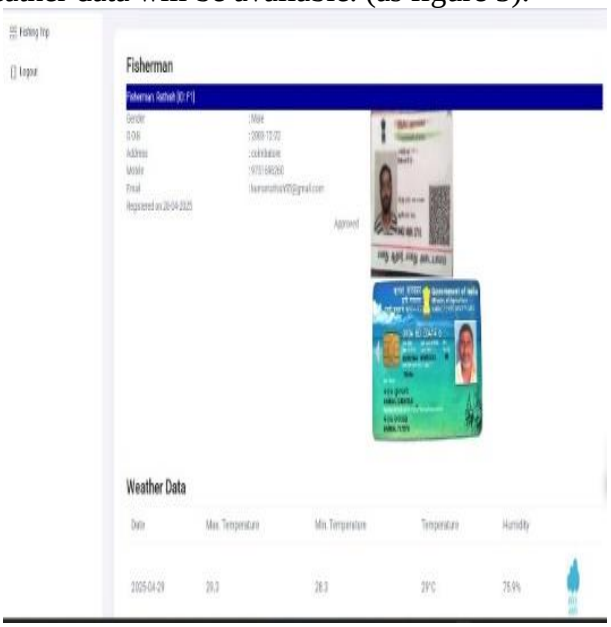

Figure 5 Student Project Details

6.5.5 E. Fishing Trip Page

The fishing trip page displays information about the fishermen's trip history and also to request, start and end fishing trips. (as figure 6).

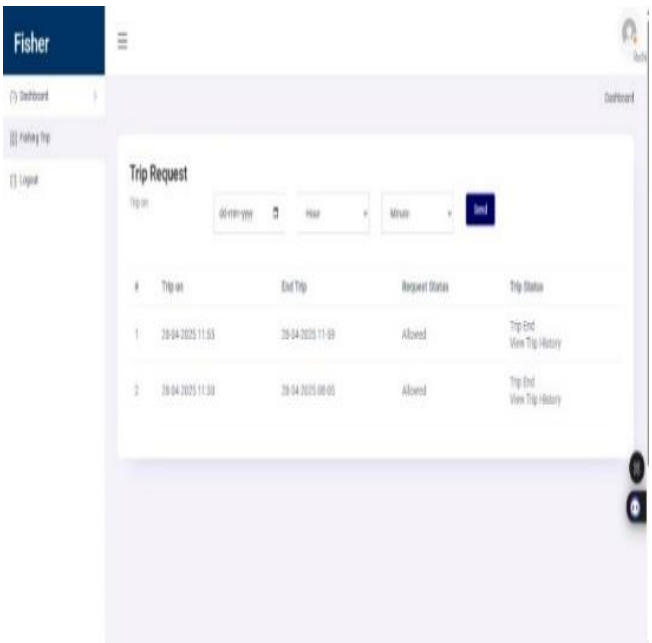

Figure 6 Staff Dashboard

6.5.6 Maritime Authority Trip Request

This page allows the maritime authorities to accept or

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deny fishing trips requested by fishermen and also access fishermen trip history and data. (as figure 7).

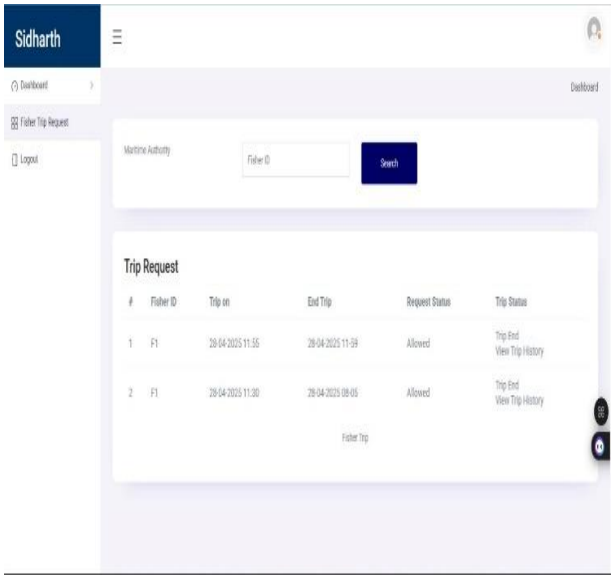

Figure 7 New Staff

6.5.7 G. Trip Page

This page is used as navigation page where the borders will be virtually defined. Figure 8 shows Review Update Page.

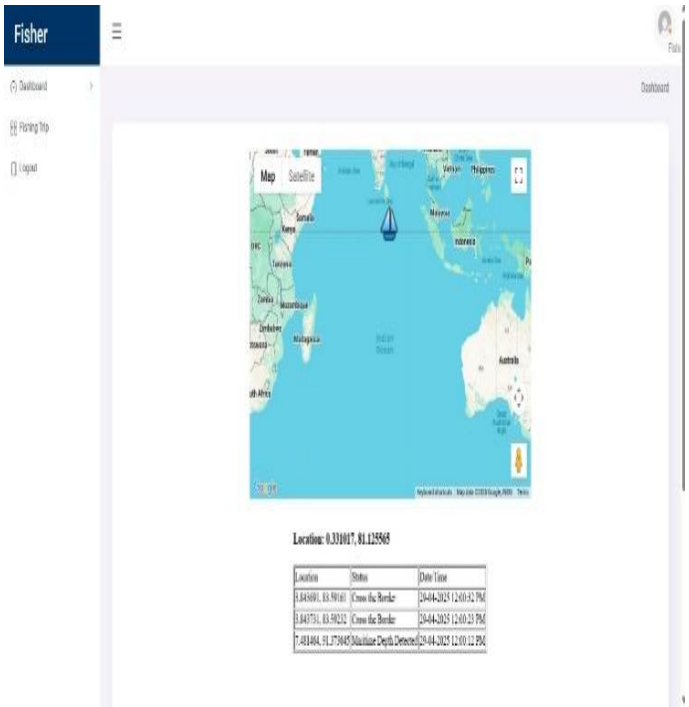

Figure 8 Review Update Page

Conclusion

The Coastal Guard Project Allocation and Monitoring System offers a smart and streamlined solution for managing maritime surveillance operations and coordination among coastal security authorities. By automating key tasks such as project allocation, progress tracking, and alert notifications, the platform significantly enhances the efficiency of maritime task management and field operations. Core features like secure official authentication, intelligent assignment of surveillance duties, and real-time operational updates promote seamless collaboration between coastal officers, supervisors, and command-level authorities. The centralized dashboard provides a clear and intuitive view of mission progress, making it easier for all users to stay informed, act swiftly, and maintain operational clarity throughout. While the system functions effectively in its current form, future improvements such as advanced threat analytics, mobile access for on-field officers, and AI-based anomaly detection could further enhance its capabilities. With ongoing enhancements, Coastal Guard has the potential to evolve into a comprehensive, long-term solution for maritime security management supporting safety, coordination, and responsiveness across coastal zones.

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