

# Smart Sea Navigation and Border Alert System

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## Abstract:

The project presents a Smart Sea Navigation and International Maritime Boundary Line (IMBL) Border Alert System designed to enhance maritime safety and navigation awareness among fishermen. Many fishermen unintentionally cross international maritime boundaries due to limited access to real-time navigation information, potentially resulting in legal consequences, vessel confiscation, detention, and serious safety risks. The proposed system integrates GPS-based real-time location tracking, geographical distance calculation, IMBL boundary detection, weather and cyclone alerts, a mobile application, centralized cloud monitoring, and an IoT-enabled embedded device based on ESP32. The system continuously monitors the vessel's location and generates proactive alerts when approaching the IMBL. A Warning Zone of 5 km and a Danger Zone of 500 meters are implemented to provide sufficient time for fishermen to change their course and avoid accidental border crossing. To ensure reliable operation even when internet or mobile connectivity is unavailable, the system incorporates an offline fail-safe alert mechanism consisting of a buzzer, voice notifications, LED indicators, and an OLED display. In addition, real-time weather and cyclone alerts provide fishermen with timely information about adverse sea conditions, further improving their safety. The integration of GPS, ESP32, IoT communication, cloud database, mobile application, weather services, and a centralized monitoring dashboard provides a comprehensive maritime safety solution. The proposed system aims to reduce accidental IMBL crossings, improve navigation awareness, provide early warnings during hazardous weather conditions, and contribute to safer and more reliable fishing operations.

**Keywords — GPS, IMBL, ESP32, IoT, Maritime Safety, Border Alert, Fishermen, Cloud Monitoring, Weather Alert, Cyclone Alert.**

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## I. INTRODUCTION

Fishermen operating near international maritime boundaries face serious risks due to unintentional border crossing. The International Maritime Boundary Line (IMBL) separates national waters, and crossing this boundary can result in arrest, penalties, and diplomatic complications. Traditional navigation systems provide basic GPS positioning but do not offer proactive boundary alerts or centralized monitoring. Moreover, fishermen often lack real-time weather and cyclone updates while at sea.

To address these challenges, this project proposes a Smart Sea Navigation and Border Alert System that integrates GPS tracking, boundary detection algorithms, mobile application interface, cloud synchronization, weather monitoring, and embedded alert mechanisms into a unified maritime safety solution.

## II. OBJECTIVE

In this project, we are going to develop a Smart Sea Navigation and IMBL Border Alert System

using GPS, ESP32, mobile application, and cloud monitoring technologies.

The system is designed to continuously track the real-time location of fishing vessels and calculate the distance from predefined International Maritime Boundary Line (IMBL) coordinates using geographical distance algorithms.

It will process live GPS data in real time and classify the vessel position into Safe Zone, Warning Zone (5 km before boundary), and Danger Zone (500 meters before boundary). The system will generate proactive alerts through buzzer, voice notification, LED indicators, and OLED display when the vessel approaches restricted maritime zones.

Additionally, the project integrates weather and cyclone alert monitoring through API services to provide safety updates during adverse sea conditions. The mobile application and Python-based dashboard will synchronize vessel data using cloud database services, enabling centralized monitoring and real-time supervision.

The objective of this system is to enhance maritime safety, prevent unintended border violations, and provide an intelligent, reliable, and fail-safe navigation support solution for fishermen.

### III. SYSTEM ANALYSIS

In this project, we will design a Smart Sea Navigation and IMBL Border Alert System using GPS, ESP32 microcontroller, mobile application, and cloud-based monitoring technologies. This system does not rely only on internet connectivity, but also includes an offline fail-safe boundary detection mechanism within the embedded device.

The system uses real-time GPS data and geographical distance calculation algorithms such as the Haversine formula to determine the distance between the vessel and predefined International Maritime Boundary Line (IMBL) coordinates.

The vessel location will be continuously monitored and classified into Safe Zone, Warning Zone (5 km before boundary), and Danger Zone (500 meters before boundary).

Based on the calculated distance, the system will automatically trigger alert mechanisms including buzzer sound, voice notification, LED indicators,

and OLED display updates. Additionally, weather and cyclone alert information will be integrated using API services to enhance maritime safety. The system will also synchronize real-time vessel data to a cloud database for centralized monitoring through a mobile application and Python dashboard.

### System Requirements

- ESP32 Microcontroller for processing and decision making
- GPS Module (Neo-6M or equivalent) for real-time location tracking
- GSM Module or Internet Connectivity for cloud communication
- Android Smartphone for mobile application
- Computer system with minimum 4GB RAM for dashboard monitoring
- Firebase Realtime Database for cloud synchronization
- Weather API for real-time weather and cyclone alerts
- Buzzer, Speaker, LED Indicators and OLED Display for alert mechanisms



- The system will obtain live GPS coordinates from the vessel and process the data in real time using embedded boundary detection logic.
- The ESP32 microcontroller will analyze the distance from IMBL coordinates and determine

the vessel's safety zone status.

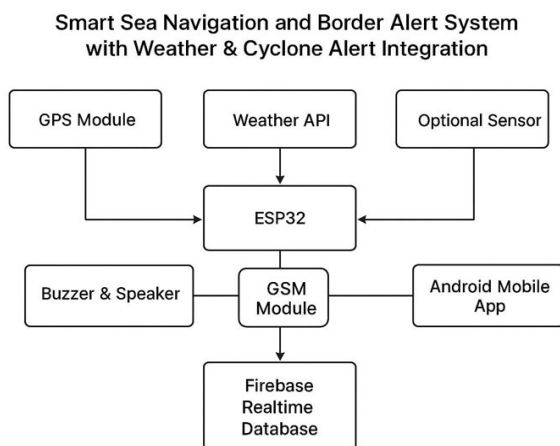
**Input:** Live GPS coordinates and real-time weather data

**Output:** Zone classification (Safe / Warning / Danger), alert notifications (buzzer, voice, LED), OLED display updates, and real-time monitoring on mobile application and dashboard.

A predefined set of IMBL boundary coordinates will be stored in the system. The detected vessel location will be compared with these coordinates using geographical distance calculation techniques. After detecting a zone change, the system will generate immediate alerts and update the cloud database.

Finally, a simple and user-friendly mobile interface and monitoring dashboard will display vessel location, zone status, alert logs, and weather conditions in real time, ensuring proactive maritime safety.

#### IV. SYSTEM ARCHITECTURE



The Smart Sea Navigation and IMBL Border Alert System Architecture represents the structured integration of embedded hardware, cloud communication, mobile application, and centralized monitoring. The process begins with the GPS Module, which continuously captures real-time latitude and longitude coordinates of the fishing vessel. These coordinates are transmitted to the ESP32 microcontroller, which acts as the core processing unit of the system.

Simultaneously, weather and cyclone information is obtained through a Weather API when internet connectivity is available. Optional sensors, if integrated, can also provide additional environmental data to enhance safety monitoring. All these inputs are fed into the ESP32 for processing and decision-making.

Once the GPS data is received, the ESP32 performs boundary detection by comparing the vessel's coordinates with predefined International Maritime Boundary Line (IMBL) coordinates stored in the system. Using geographical distance calculation algorithms, such as the Haversine formula, the system determines whether the vessel is in the Safe Zone, Warning Zone (5 km before boundary), or Danger Zone (500 meters before boundary).

Based on the calculated zone status, the system activates the Alert and Notification mechanisms. The buzzer and speaker generate audio alerts, LED indicators provide visual warnings, and the OLED display shows real-time zone information to the fisherman. This ensures proactive notification before the vessel crosses restricted maritime boundaries.

For remote monitoring and data synchronization, the processed location data is transmitted through the GSM module or internet connectivity to the Firebase Realtime Database. The cloud database acts as the communication bridge between the embedded system and the application layer.

The Android Mobile Application retrieves data from Firebase and displays live vessel tracking, alert notifications, and weather updates to the fisherman. At the same time, the Python-based Monitoring Dashboard provides centralized supervision, enabling authorities or monitoring personnel to track vessel movement in real time and observe alert logs.

This structured architecture ensures reliable operation in both online and offline conditions. Even if internet connectivity is lost, the ESP32 continues boundary detection and alert generation using stored IMBL coordinates. By integrating embedded intelligence, cloud synchronization, and real-time

application interfaces, the system provides an efficient and proactive maritime safety solution.

## V. MODULES

### a. GPS Location Tracking Module

- The process begins with capturing real-time latitude and longitude coordinates of the fishing vessel using the GPS module.
- This serves as the primary input to the system. The GPS module continuously receives satellite signals and provides accurate geographical positioning data to the ESP32 microcontroller.
- The system updates the vessel location at regular intervals to ensure continuous monitoring.
- This real-time location tracking forms the foundation for boundary detection and navigation assistance.

### b. Weather and Cyclone Alert Module

- The Weather and Cyclone Alert Module integrates real-time environmental data into the system.
- When internet connectivity is available, the system fetches weather information and cyclone alerts using a Weather API.
- This module analyzes sea conditions such as wind speed, temperature, and storm warnings to provide safety notifications to fishermen.
- In case of adverse weather conditions, alert messages are displayed in the mobile application and dashboard, enhancing maritime safety awareness.

### c. Core Processing and Decision-Making Module (ESP32)

- The ESP32 microcontroller acts as the central processing unit of the system. It receives GPS coordinates and compares them with predefined International Maritime Boundary Line (IMBL) coordinates stored in memory.
- Using geographical distance calculation

algorithms such as the Haversine formula, the ESP32 determines whether the vessel is in the Safe Zone, Warning Zone (within 5 km), or Danger Zone (within 500 meters).

- This module performs real-time decision-making and ensures that boundary detection continues even during internet failure, providing reliable offline functionality.

### d. Alert and Notification Module

- The Alert and Notification Module is responsible for generating proactive warnings based on zone classification.
- When the vessel enters the Warning Zone, the system activates buzzer alerts and visual LED indicators.
- Upon reaching the Danger Zone, stronger alerts such as continuous buzzer sound, voice notifications through the speaker, and OLED display updates are triggered.
- This module ensures that fishermen receive timely alerts before crossing restricted maritime boundaries.

### e. Communication and Mobile Application Module

- This module enables communication between the embedded device and the Android mobile application.
- When internet connectivity is available, the processed vessel data is transmitted through GSM or Wi-Fi to the Firebase Realtime Database.
- The mobile application retrieves this data and displays live navigation status, zone classification, and weather updates. It also provides alert notifications and user-friendly visualization of vessel movement.

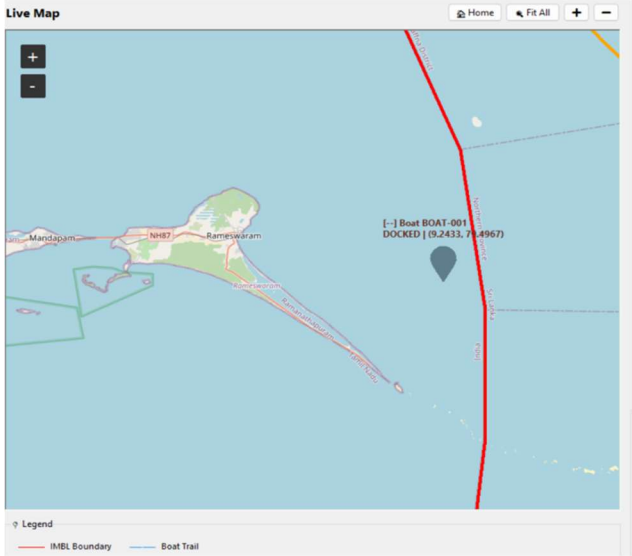
### f. Communication and Mobile Application Module

- The Cloud Database and Monitoring Module ensures centralized supervision and data storage. Firebase Realtime Database stores vessel coordinates, zone status, and alert logs in real time.

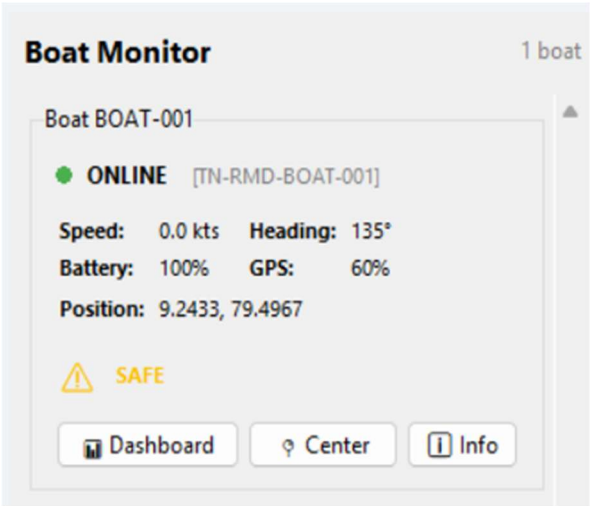
- The Python-based monitoring dashboard retrieves this data and provides live tracking of fishing vessels.
- This allows authorities or monitoring personnel to supervise maritime movement and respond proactively if necessary.
- The cloud integration ensures synchronization between embedded device, mobile application, and monitoring dashboard.

**VI. OUTPUT**

**PYTHON MONITORING DASHBOARD**



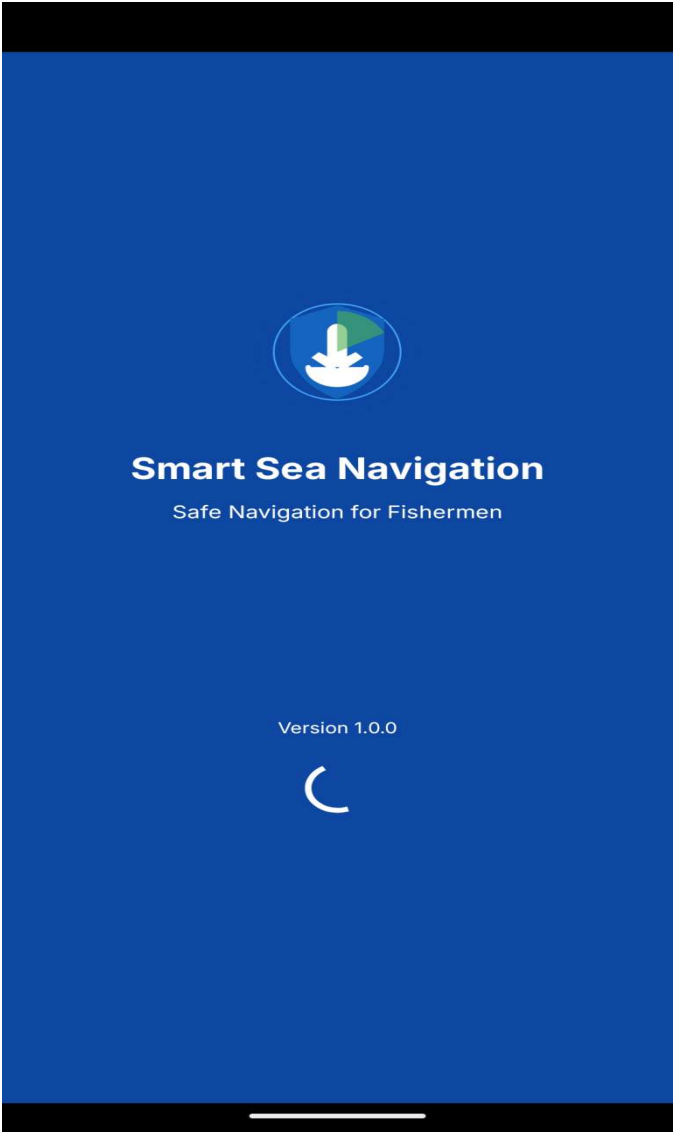
**LIVE MAP**



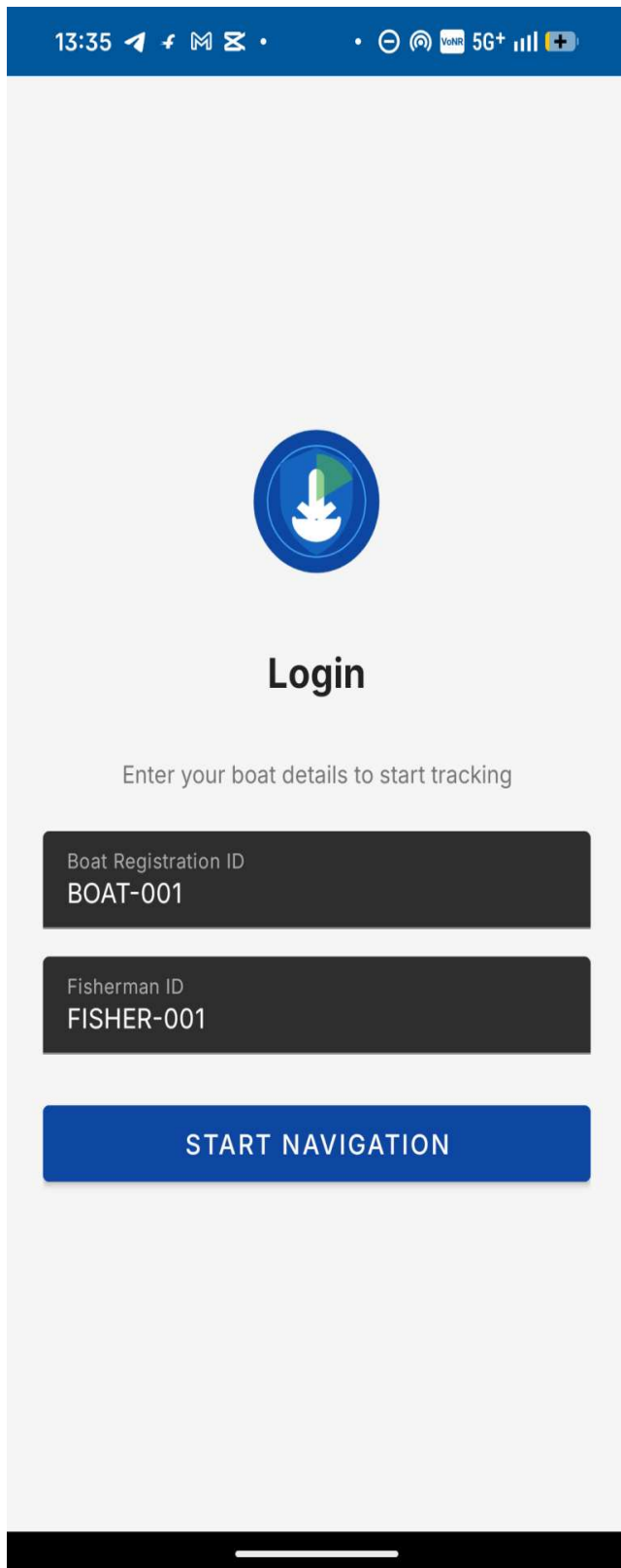
**BOAT MONITOR**



**WEATHER PANEL  
 ANDROID APP FOR FISHERMEN**



**LOADING SCREEN**



The screenshot shows a mobile application login screen. At the top, there is a status bar with the time 13:35 and various icons. Below the status bar is a blue header bar. The main content area has a light gray background. In the center, there is a blue circular icon with a white boat and a green checkmark. Below the icon, the word "Login" is displayed in a large, bold, black font. Underneath "Login", the text "Enter your boat details to start tracking" is shown in a smaller, gray font. There are two input fields: the first is labeled "Boat Registration ID" and contains the text "BOAT-001"; the second is labeled "Fisherman ID" and contains the text "FISHER-001". Below these fields is a large blue button with the text "START NAVIGATION" in white. At the bottom of the screen, there is a black bar with a white horizontal line in the center.

13:35

Weather Partly Cloudy  
28°C | 15 km/h SE

STATUS SAFE

Simulation Speed 10x

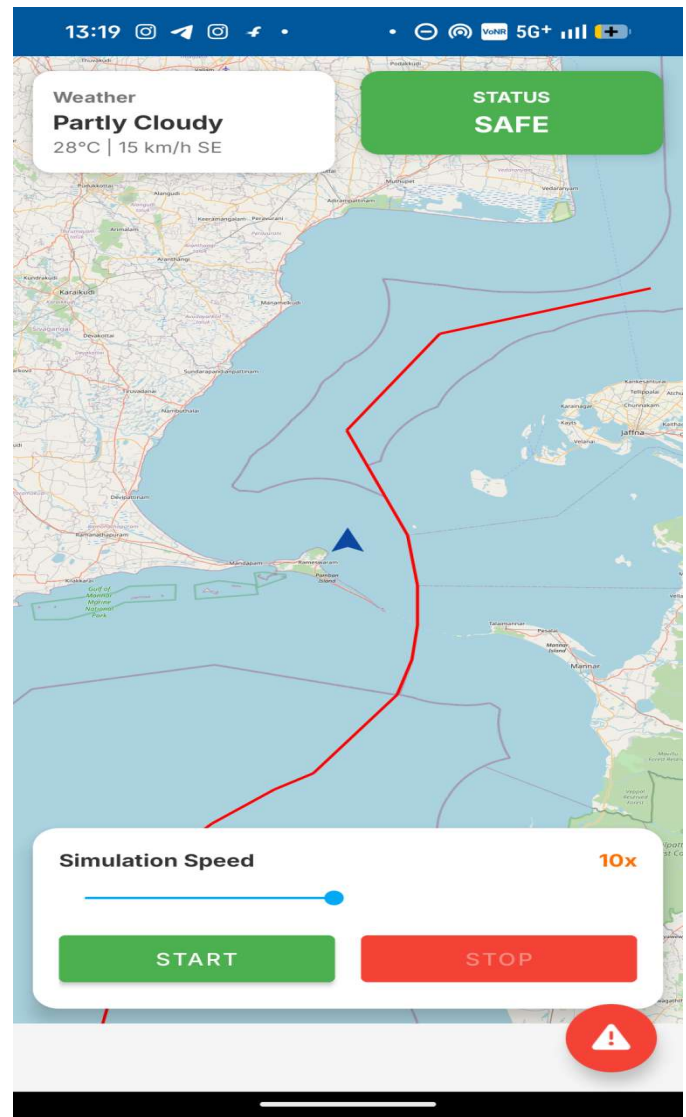
START STOP

Boat Registration ID  
BOAT-001

Fisherman ID  
FISHER-001

START NAVIGATION

LOGIN PAGE



## HOME PAGE

## VII. CONCLUSION

The Smart Sea Navigation and IMBL Border Alert System enhances maritime safety by providing a proactive and intelligent solution to prevent unintentional border crossing by fishermen. By integrating GPS-based real-time location tracking, boundary distance calculation, weather and cyclone alert integration, and embedded alert mechanisms, the system ensures timely warning before reaching restricted maritime zones. The implementation of ESP32-based offline boundary detection ensures reliable operation even during internet failure, making the system practical for real-world sea conditions. The integration of mobile application,

cloud database, and Python-based monitoring dashboard enables centralized supervision and real-time vessel tracking. This project demonstrates the effective use of IoT, embedded systems, and cloud technologies to solve a socially impactful problem. The system can be further enhanced by incorporating satellite communication modules, emergency SOS features, and advanced maritime analytics to provide even more comprehensive protection for fishermen.

## VIII. REFERENCES

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