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Optimizing Ship Safety Using SAR Images, Iot-Driven Weight Management, Obstacle Detection And Border Alert System

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Abstract: This project focuses on developing a comprehensive system for ship detection, passenger monitoring, and maritime safety using Synthetic Aperture Radar (SAR) imagery and IoT-based automation. Initially the system detects the ships using SAR images and employs an infrared (IR) sensor, connected to an ESP32 microcontroller, to count passengers boarding the ship. Once the passenger count exceeds a preset threshold, the system activates DC motors to automatically close doors. underwater UV sensor detects obstacles, and a crack sensor monitors the ships structural integrity. To improve maritime security, the system incorporates RF modules to monitor border crossings and GPS tracking to trace the ship's location, even when network coverage is lost. Additionally, a sink detection mechanism is integrated to send alerts via Telegram if abnormal tilting or potential sinking is detected.

Keywords: SAR images, RF Modules, ESP32 module, GPS, UV Sensors, IR Sensors, ADXL Sensors.

I. INTRODUCTION

Maritime transportation is a crucial component of global logistics, facilitating the movement of passengers and goods across oceans and waterways. However, ensuring safety and monitoring vessel activities remain significant challenges due to unpredictable weather conditions, human errors. Traditional monitoring systems often lack real-time capabilities, leading to delays in detecting emergencies like boat sinkage or border breaches. Synthetic Aperture Radar (SAR) technology has emerged as an efficient tool for maritime surveillance, providing clear images in all weather and lighting conditions.

SAR provides real-time tracking and surveillance, enabling operators to detect potential risks, such as nearby vessels or adverse weather conditions. Meanwhile, IoT devices, such as sensors and connected systems can monitor the health of the ship. By combining SAR's situational awareness with the predictive capabilities of IoT, ship safety can be significantly improved, reduces the risk of accidents and improves emergency response.

This interconnected approach also enhances decision-making and allows for quicker and more effective interventions when safety concerns arise.This project integrates SAR-based vessel detection with IoT-driven automation to monitor and manage ship operations efficiently. The use of ESP32 microcontroller-based sensors allows real-time passenger counting, automated door control, and safety alerts, ensuring optimal passenger management and preventing oversar ship imaging. By combining GPS tracking, RF modules for border detection, and Telegram notifications, the system ensures comprehensive situational awareness and automated responses to potential threats.

The proposed system addresses the gaps in existing maritime safety protocols by incorporating advanced technologies for automated monitoring, passenger safety, and emergency management. The use of IoT devices, combined with robust SAR imaging, ensures a high level of accuracy in detecting ships, tracking vessel locations, and managing onboard safety, significantly reducing the risk of accidents and enhancing maritime security.

1.1 Motivation

Ensuring the safety of maritime transportation is critical due to the increasing volume of passengers and cargo on water routes. Traditional manual oversight often results in delayed responses to emergencies, making the case for a more automated and reliable system. The motivation behind this project is to leverage modern technologies like SAR and IoT to enhance the safety of maritime operations, reduce human error, and enable faster emergency responses.

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1.2 Objectives

The main goal of this work is to develop a SAR-based ssystem for real-time detection of ships and maritime activities and to implement an IR sensor for accurate passenger counnting and automated door control when safe limits exceeds and using RF modules for border alert, tilt sensors for detecting unusual movements in ship, UV sensors for obstacle detection, GPS for ship locaation tracking and to enable real-time alerts via telegram for emegencies like sinking, border crosssing, structural damages and ensure prompt responses.

II. METHODOLOGY

The primary task is to identify the hardware components which are suitable for this work. Block diagram consist of hardware components which are interconnected with each other. The main component is Node MCU which supports Wi-Fi and Bluetooth.

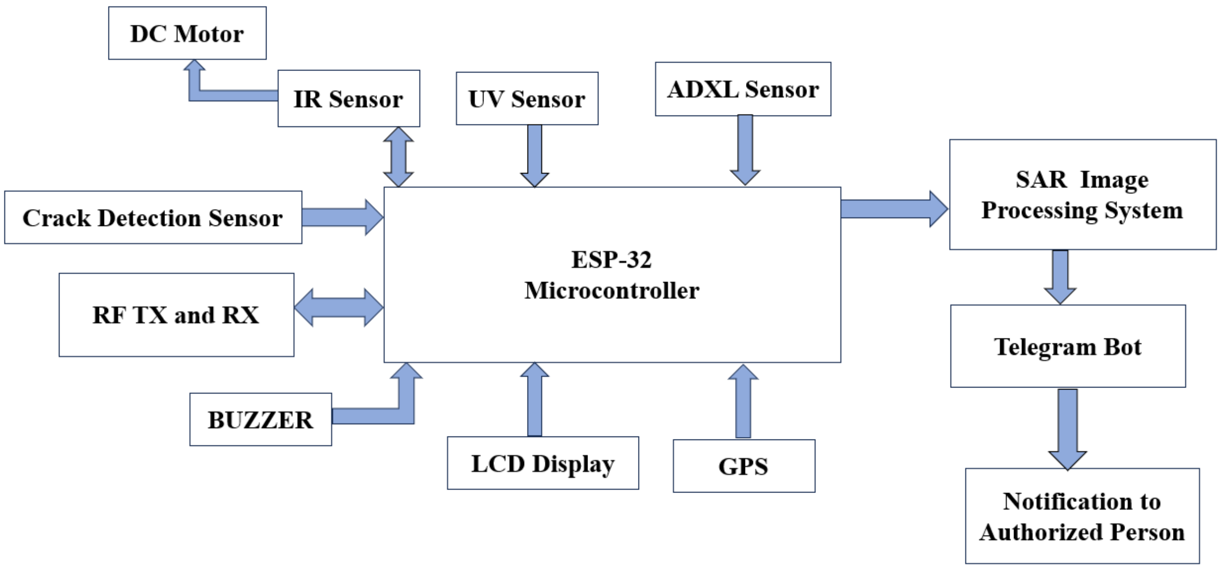

Fig: 1 Block Diagram of Optimizing Ship Safety

HARDWARE USED:

- ESP-32 Microcontroller
- IR Sensors.
- DC Motors.
- RF Modules.
- Buzzers.
- GPS.
- UV Sensors.
- ADXL Sensors.
- Crack Detection Sensors.
- LCD Display.
- **Output Device:** High-Resolution Monitor (1920x1080 or higher).

SOFTWARE USED:

- **Operating System:** macOS, Windows 10 or higher.
- **Coding Language:** Python (Python 3.8 or higher).
- **IDE:** Jupyter Notebook (Anaconda Navigator).
- **UI Framework:** Tkinter (Python GUI).

- **Libraries/Frameworks:**
  - OpenCV for image processing.

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- TensorFlow or PyTorch for machine learning models.
- ESP32 library for microcontroller integration.
- Telegram API for notification system.
- NumPy and Pandas for data manipulation.

Node MCU : NodeMCU is a low-cost, open-source, Wi-Fi enabled microcontroller board based on the ESP8266 chip. It provides a platform for building IoT projects, allowing users to connect sensors, actuators, and other devices to the internet.

SAR Imagery for Vessel Detection: The core technology for detecting ships and vessels in the vicinity is Synthetic Aperture Radar (SAR). SAR images are captured by satellite-based or airborne radar systems, providing high-resolution images of the sea surface even in poor visibility conditions, such as fog or during the night. The SAR technology uses radar signals that bounce off objects, including ships, allowing for the identification and tracking of vessels on the water.

IR Sensors : An infrared (IR) sensor, connected to an ESP32 microcontroller, counts the number of passengers as they board the boat. The IR sensor detects the heat signatures of passengers and calculates the number of people entering the boat.

DC Motors : Once the passenger count exceeds this threshold, the ESP32 microcontroller triggers an **action to the** system which automatically activates DC motors that close the ship's doors to prevent additional passengers from entering, ensuring that the ship does not exceed its safe capacity.

UV Sensors : To improve safety further, the system integrates an underwater UV sensor that detects obstacles in the water. The UV sensor emits ultraviolet light and detects reflections from objects submerged in the water.

ADXL Sensors : To improve safety further, the system integrates an underwater UV sensor that detects obstacles in the water.

RF TX and RX : To improve maritime security, the system incorporates RF modules to monitor border crossings. These RF modules use radio frequency identification (RFID) technology to track the boat's position relative to predefined border areas.

GPS : The system also integrates GPS tracking to provide real-time position information for the boat. GPS receivers are embedded in the boat's system, and the location data is continuously sent to a central server.

LCD Display: The system uss LCD Display to dispaly the unusual movements in ship.

Telegram Alerts : The system is designed to send real-time alerts through Telegram to notify the boat's crew and authorities if there is a risk of sinking or other emergencies.

III. IMPLEMENTATION

The propised system consists several key components and technologies to integrate and ensure real-time monitoring and notifications. The system begins with SAR-based ship detection can continuously scan the surrounding waters, identifying nearby vessels to avoid potential collisions. IR sensors play a role in passenger management, with the ability to count the number of passengers entering in ship. The IR sensor feeds data to an ESP32, which processes passenger counts and controls the DC motor accordingly. If the passenger limit exceeds pre-defined count, the system automatically triggers servo motors to close doors and sends alerts to authorized persons and the system ensures that the number of passengers does not exceed safety limits by automating gate operations. UV sensors are used to detect underwater obstacles and provides early warnings to the crew. Moisture sensors are used for structural integrity and they are connected to an ESP32 to monitor the boat's hull or critical structural area to detect the cracks in ship, if any cracks detected the system triggers an alert and ensures the timely maintenance and prevents potential accidents. ADXL sensors are connected to an ESP32 to monitor the boat's orientation and stability and detects abnormal tilt angles or sinking events and triggers immediate alerts to ensure passenger safety.Additionally, an RF module is selected for long-range communication and interfaced with an ESP32 to send and receive border related alerts. The system monitors the ship's proximity to predefined geographical borders and sends alerts if the ship approaches or crosses the boundaries. An high-precision GPS module (e.g., u-blox NEO-6M) is selected for accurate location tracking. A suitable LCD (e.g., 16x2 or 20x4 character display) is used for real-time data visualization.

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The LCD is interfaced with an ESP32 to display system status, sensor readings, and alerts and provides the operator with immediate visual feedback on various system parameters and alerts. The buzzer is connected to an ESP32 to sound alarms based on specific triggers such as object detection, border crossing, structural cracks and if any chance of sinking event.Finally, to provide immediate alerts, a Notification System is implemented using Telegram API to send automated messages to concerned persons during emergencies.

IV. RESULTS

As discussed above initially the proposed model will be helpful in maintaining the ship safety and the system effectively monitors the ship movements. The result of optimizing ship safety been displayed in the fig 2, 3 and 4.

The below fig 2 shows the prototype of Ship

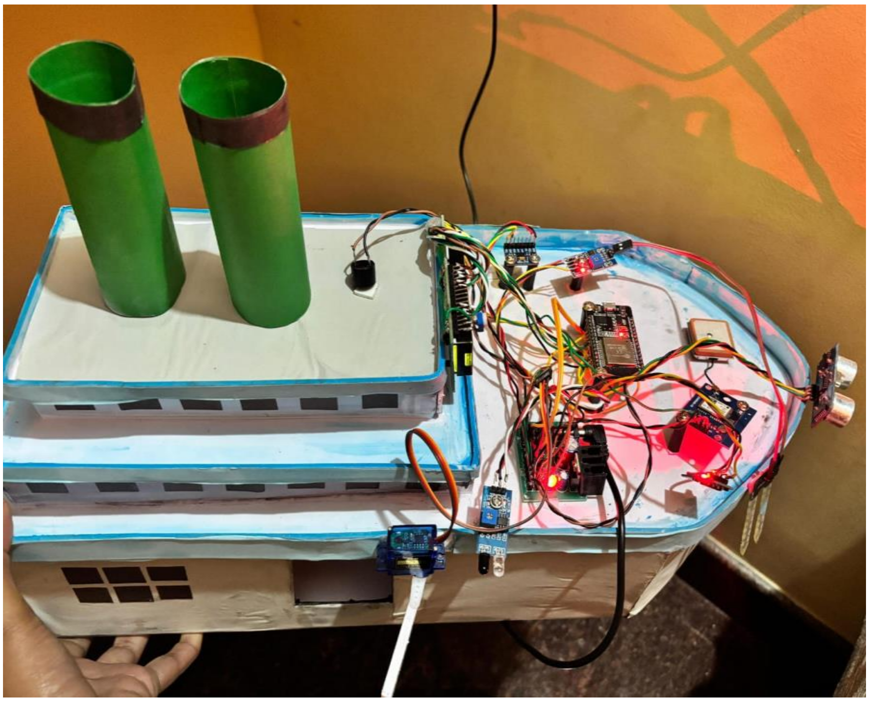

Fig . 2 Prototype of model.

The below fig 3 shows the detection of ship using SAR images

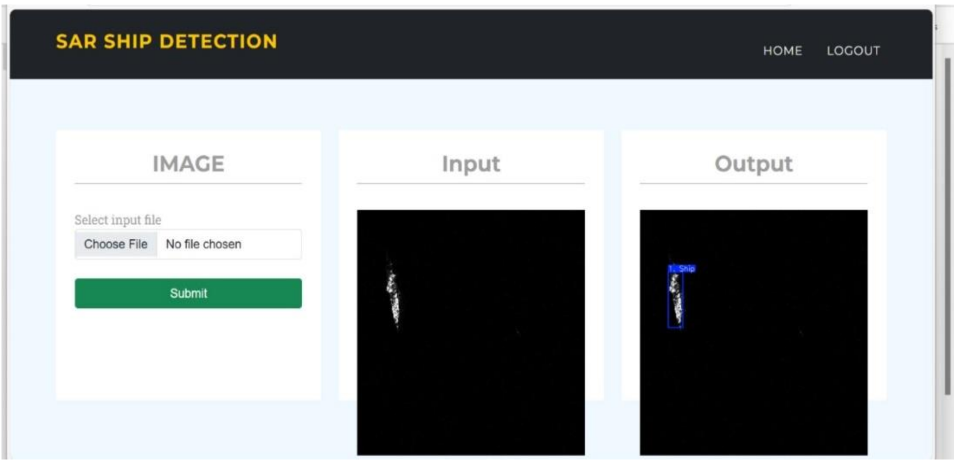

Fig .3 Detecting ship in SAR image.

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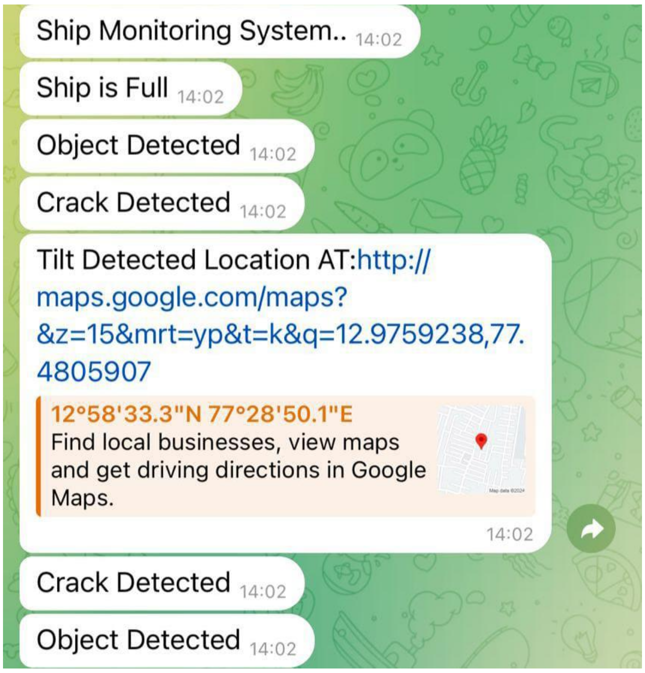
The Fig 4 shows the Notifictions sent through Telegram Application about movements of ships.



V. CONCLUSION

In conclusion, this project presents a comprehensive and innovative solution for enhancing maritime safety through the integration of Synthetic Aperture Radar (SAR) technology, IoT-enabled passenger monitoring, and automated emergency response mechanisms. By effectively detecting ships, accurately counting passengers, and promptly responding to potential sink incidents, the system aims to significantly reduce the risks associated with overcrowding and emergencies in maritime transportation. The use of real-time data processing and communication via Telegram ensures that relevant authorities are notified instantly, facilitating timely intervention when needed. Overall, this project not only contributes to improved safety standards in maritime operations but also sets the stage for future advancements in automated systems, paving the way for smarter and more efficient waterborne travel.

FUTURE SCOPE

As the maritime industry increasingly explores autonomous ships, this system can be further enhanced to integrate with autonomous navigation and decision-making systems, providing real-time data for autonomous vessels to make safety-related decisions on their own.

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