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Seafarer Safety Protection Using Standalone RSSI Technology

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Abstract- Man overboard (MOB) accidents are a major risk in maritime operations, where even a few minutes' delay can result in loss of life. Traditional detection methods, such as manual observation or CCTV monitoring, are often unreliable, especially in adverse weather conditions. This paper proposes an automatic seafarer safety system using standalone embedded technology and Received Signal Strength Indicator (RSSI)-based tracking. The system integrates a wearable device equipped with fall detection sensors and an RSSI transmitter, a shipboard receiver with a graphical user interface, and an emergency flotation mechanism. The proposed system provides early detection of MOB incidents, sends real-time alerts to the ship captain, and ensures immediate safety through an automatic inflation mechanism. Simulation results demonstrate that the system can reliably detect MOB events and track the person's location within a reasonable range, enhancing safety for both crew and passengers.

Keywords- Seafarer safety, Man overboard (MOB), MEMS sensor, RSSI tracking, Embedded systems, E-navigation.

I. INTRODUCTION

The maritime industry plays a critical role in global trade and transportation, yet it faces significant safety challenges due to harsh and unpredictable marine environments. Among the most dangerous incidents is the man overboard (MOB) scenario, where crew members or passengers fall into the water. Such events are highly time-sensitive, and even minutes of delay in detection or response can result in serious injury or fatalities.

Traditional detection methods, such as manual observation and surveillance cameras, are often inadequate. Poor visibility, adverse weather, and rapid vessel movement hinder early detection. Advances in embedded systems, wireless communication, and sensor technology present opportunities to improve MOB detection and rescue. Wearable devices with MEMS-based fall detection sensors, combined with Received Signal Strength Indicator (RSSI) wireless tracking, enable real-time monitoring of seafarers' positions.

This paper proposes an integrated system that combines fall detection, RSSI-based localization, and an automatic flotation mechanism. Upon detecting a fall, the system immediately alerts the ship captain via a display module, activates visual and auditory alarms, and deploys a flotation device if necessary. This approach ensures rapid response and significantly enhances maritime safety.

Implementation aligns with international E-navigation strategies and provides a scalable solution for both commercial vessels and passenger ships. By reducing dependency on manual observation and enhancing automation, this system addresses the limitations of existing safety measures and mitigates the risks associated with MOB incidents.

II. LITERATURE SURVEY

The review of existing literature provides a foundation for understanding the technological evolution of Man Overboard (MOB) detection, intelligent maritime monitoring, and safety management systems. Several studies have aimed to enhance maritime safety through innovations in wireless communication, intelligent decision support, and edge-based anomaly detection.

Early research focused on the development and evaluation of wireless systems for detecting persons overboard. For instance, the study titled *"Man Overboard Detecting Systems based on Wireless Technology"* investigated the feasibility of using low-power radio technologies such as LoRa (Low Power Wide Area Network) for tracking individuals who fall overboard on passenger vessels. The study included field tests, analyzing radio wave propagation and signal attenuation caused by water submersion. Results demonstrated that while LoRa technology offered promising range and low power consumption, the propagation limitations of radio signals in water hindered reliable real-time detection. The authors suggested that multimodal integration with sensors, vision systems, or AIS beacons is necessary for robust detection.

Expanding on automated detection needs, *"The Need of Man Overboard (MOB) Detecting and Tracking System—Descriptive Analyses"* provided a comprehensive assessment of MOB incidents and the inefficiencies in existing maritime emergency protocols. Despite established IMO and ILO conventions, most rescue operations still depend on human observation and manual reporting. The study reported that only a small percentage of MOB cases resulted in successful rescues, primarily due to delayed detection and lack of automatic alert systems. Surveillance cameras and primitive fall-detection devices were available on some modern ships but were not standardized. The authors strongly recommended integrating automated detection and audio-visual alarm systems on ship bridges to improve early warning capability.

Technological advancement in satellite-based rescue systems was demonstrated in *"The Design and Development of Man Overboard Alarm and Rescue Terminal"* by Huang Peng-fei et al. Their research presented a compact rescue terminal using the Beidou short message communication module, interfaced with an STM32 microcontroller to transmit real-time distress information. The proposed system converted location and distress data into AIS and Beidou short messages relayed via VHF maritime channels. This approach reduced response time and improved search and rescue efficiency by ensuring immediate notification of the crew and maritime authorities.

Yansheng Li et al., in *"An Improved Design of Automatic Identification System (AIS) Based Man Overboard Device: A Multidisciplinary Product"*, detailed the design and prototyping of an AIS-based MOB device optimized for efficiency and compliance with ITU and IEC maritime standards. Using Gaussian Minimum-Shift Keying (GMSK) modulation and Direct Digital Synthesis (DDS), the system achieved high-frequency stability and signal quality. Hardware-level optimizations, including antenna design, impedance matching, and power management, extended battery life up to 36 hours and provided reliable transmission up to five nautical miles. This study highlighted the potential of compact, energy-efficient, and high-reliability MOB devices.

Later studies emphasized evaluating the effectiveness of intelligent ship navigation systems. X. Ma et al. (2020), in *"A Methodology to Evaluate the Effectiveness of Intelligent Ship Navigational Information Monitoring System"*, proposed a structured model for evaluating intelligent navigational monitoring. Their methodology analyzed subsystems such as perception, data fusion, decision-making, and communication. Using orthogonal experimental design, the study identified how subsystem performance influenced overall navigational safety. Communication and perception modules were critical in early-stage operations, while decision-making and data fusion became crucial at higher autonomy levels.

Recent research has focused on integrating artificial intelligence and edge computing to enhance maritime safety. Abdulmohsen Algarni et al. (2024), in *"An Edge Computing-Based Preventive Framework With Machine Learning Integration for Anomaly Detection and Risk Management in Maritime Wireless Communications"*, proposed a proactive framework combining edge computing and machine learning algorithms, including Long Short-Term Memory (LSTM) networks and Isolation Forests, to detect anomalies and cybersecurity threats in real time. Localized edge processing reduced latency, conserved bandwidth, and ensured data integrity in unstable maritime environments. The study highlighted the importance of predictive intelligence and autonomous risk management for resilient maritime operations.

From these studies, several key insights emerge. Single-modality detection approaches, such as LoRa-based tracking or standalone cameras, are insufficient for reliable MOB detection in dynamic maritime conditions. Hybrid, multi-sensor approaches

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integrating AIS, GNSS, vision, and wireless technologies provide greater robustness. System-level evaluation frameworks, such as Ma et al.'s orthogonal analysis, are crucial for quantifying how subsystem performance affects overall safety. Advances in embedded design and low-power microcontrollers enable compact, efficient safety devices. Finally, edge computing and machine learning facilitate proactive detection and real-time risk management, paving the way for intelligent, adaptive maritime safety systems.

III. PROPOSED METHODOLOGY

The proposed methodology focuses on designing and implementing an onboard Man Overboard (MOB) detection and safety system using wearable devices, wireless communication, and a shipboard processing unit. The system continuously monitors the position and status of crew members, detects emergency situations, and triggers automatic safety protocols to prevent casualties. The architecture is modular and divided into functional blocks for clarity, including: Sensing Unit, Signal Conditioning, Central Processing Unit, Communication Module, Alert System, and Closed-loop Feedback Operation.

A. Sensing Unit

The sensing unit serves as the core of the system. Each crew member wears a compact MOB device equipped with the following sensors:

1. RSSI-Based Proximity Sensor
Measures the received signal strength indicator (RSSI) between the wearable device and the shipboard receiver. RSSI values indicate the relative distance of the crew member from the ship and detect when a person has fallen overboard.
2. MEMS Accelerometer
Detects abnormal movements, such as falls or sudden tilts, allowing the system to identify potential man-overboard events in real time.
3. Impact / Force Sensor
Measures the force of the fall to verify that an overboard event has occurred.
4. Emergency Switch
Allows manual activation of safety protocols, such as air-inflation personal flotation devices, in case automatic detection fails.

B. Signal Conditioning and Transmission

The raw sensor outputs are first processed through signal conditioning circuits to filter noise and convert the signals into compatible digital formats. The processed signals are then transmitted wirelessly to the shipboard Central Processing Unit (CPU). Communication protocols are optimized for maritime environments to ensure accurate data reception, even in adverse weather conditions.

C. Central Processing Unit (CPU)

The shipboard CPU serves as the control hub:

- Continuously collects sensor data from multiple wearable devices.
- Compares received RSSI, accelerometer, and impact data against predefined thresholds.
- Executes emergency control actions, such as activating alarms, deploying safety devices, and logging events for post-incident analysis.
- Displays real-time crew locations and alerts on the ship's bridge GUI.

D. Communication Module

The CPU integrates with the ship's communication system to send alerts to both onboard personnel and external rescue teams. In the event of an MOB incident, emergency messages are transmitted using GSM, satellite communication (Beidou or AIS), or onboard radio to ensure rapid response and efficient rescue operations.

E. Alert System

- Visual Alerts: The bridge GUI highlights the crew member's position with color-coded indicators based on RSSI values.
- Auditory Alerts: Sirens and voice alerts notify bridge officers and nearby crew of an MOB incident.

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- Automatic Safety Activation: Personal flotation devices with air-inflation systems are deployed when necessary.

F. Closed-loop Feedback Operation

The system operates as a closed-loop feedback network. Sensor data is continuously monitored, processed by the CPU, and triggers control actions. The resulting changes in the environment, such as a crew member floating after device activation, are detected and verified to ensure the system's effectiveness. This feedback loop guarantees adaptive safety monitoring for real-time maritime operations.

G. System Workflow

1. Initialize wearable devices, shipboard receiver, and sensors.
2. Continuously acquire data (RSSI, MEMS, impact sensor, emergency switch).
3. Perform signal conditioning and convert raw data to digital format.
4. Transmit processed data to CPU.
5. Compare each parameter with predefined safety thresholds.
6. Trigger alerts and activate flotation devices if any parameter exceeds safety limits.
7. Log event data for post-incident analysis.
8. Repeat continuously until the ship's system is deactivated.

H. System Architecture

The architecture consists of three layers:

- Sensor Layer: Wearable MOB devices with RSSI, MEMS, and impact sensors.
- Processing Layer: Shipboard CPU that analyzes data and triggers control actions.
- Actuation and Communication Layer: Alerts, flotation systems, and emergency communication modules.

IV. RESULT AND DISCUSSION

The proposed OBC – based in – cabin monitoring and controlling system was tested by simulating different vehicle conditions and observing the response of the controller. Each sensor was connected to the PIC16F877A, and the signals were processed through the MAX232 driver for reliable communication with the on – board computer. During testing, the temperature sensor successfully detected variations in engine heat, and when the threshold was crossed, the OBC activated the cooling unit automatically. The fuel flow sensor showed consistent readings, allowing the system to identify abnormal consumption that could indicate leakage or inefficiency. The emission sensor provided accurate measurements of exhaust gases, ensuring that the vehicle operated within environmental norms.

The fluid – level sensor for engine oil, brake fluid and coolant responded effectively by generating alerts when levels dropped below in safe limit. Similarly, the battery voltage sensor tracked variations in supply, and early warnings were issued during low voltage conditions. The tyre pressure sensor helped in monitoring vehicle stability, giving timely signals in case of pressure imbalance or tilt. The smoke chamber sensor was also tested, and it triggered immediate alarms when smoke was introduced, confirming its reliability in fire hazard detection. The GSM module was able to transmit alert messages to a pre – defined mobile number during emergency conditions such as over – temperature, smoke detection, or abnormal tilt. This confirmed the effectiveness of the system in real – time communication. Overall, the results showed that the OBC could process multiple sensor inputs simultaneously and execute control actions with minimal delays.

In prolonged testing conditions, the OBC prototype was operated continuously for extended durations to assess its endurance and consistency. The system maintained reliable operation without overheating or signal drift, confirming that the embedded hardware and sensors can withstand real world automotive conditions such as vibrations, temperature variations and electrical noise. The stability of the diagnostic output under such condition is crucial, as vehicles often operates in harsh and unpredictable environments. Furthermore, calibration checks performed after multiple test cycles indicated that sensors such as the NTC thermistor and orifice flow sensor retained accuracy, validating their suitability for long – term deployment. The experiments also demonstrate the advantage of integrating Multi – Domain Monitoring into a single onboard computer. While traditional diagnostic systems often focus on either electrical faults or emission levels, the proposed OBC combined parameters from mechanical, thermal, chemical, and electrical domains. For example, when emission level rose unexpectedly, corresponding data from the fuel flow sensor was simultaneously available to cross – check whether inefficient combustion was the cause. This multi – sensor correlation capacity offers more precise diagnostics and reduces the likelihood of misinterpretation compared to single – parameter systems.

Another noteworthy outcome was the OBC's Fault Isolation Capacity. During deliberate fault introduction, such as restricting airflow to the engine or simulating a partial short – circuit in the battery, the system not only detected the anomaly but also identified the subsystem responsible. This diagnostic precision is especially beneficial for maintenance personnel, as it reduces troubleshooting time and supports faster corrective action. Combined with GSM – based alerts, this capability ensures that both drivers and technicians receive specific, actionable information rather than general warnings.

The safety implications of the system are also significant. The ability to detect smoke, low brake fluid, or abnormal tilt conditions in real – time provides early warnings for potential life–threatening hazards. For instance, tilt detection through MEMS sensors not only alerts the driver but also issued a GSM based message in testing scenarios, ensuring that external parties were informed during simulated roll – over conditions. Similarly, the smoke chamber integrated with the exhaust successfully triggered alarms within seconds of smoke introduction, confirming the reliability of the system in fire-hazard detection. These safety features highlight the OBC's role as not only a diagnostic tool but also a preventive safety mechanism finally, the research outcomes establish the OBC as a promising IOT – ENABLED SMART MOBILITY SYSTEMS. By extending GSM based communication to internet enabled modules, data from multiple vehicles can be aggregated in the cloud for advanced analysis. The current results not only validate the present system but also open pathways for next – generation intelligent transportation ecosystems.

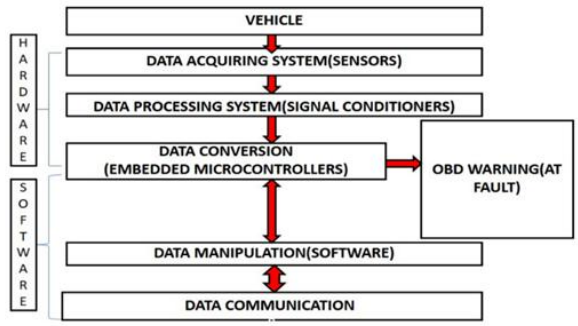

Fig. 3. Functional Block Diagram

The functional block diagram of the proposed system, shown in Fig. 2, consists of both hardware and software elements working together to ensure in – cabin sensing, monitoring and control. On the hardware side, the system begins with the vehicle as the source of different operating parameters. These parameters are collected by the data acquiring system, which includes sensors for temperature, fuel flow, emission and fluid levels. The raw signals from the sensors are passed to the data processing system, where signal conditioning circuits adjust the voltage levels and filter out noise. The processed signals are then forwarded to the data conversion unit, which is carried out by the embedded PIC16F877A microcontroller. This stage converts the analog signals into digital form for further use.

On the software side, the OBC performs data manipulation, where the digital data is analyzed and compared with predefined threshold values. The processed information is then transferred through the data communication unit, which includes GSM for external alerts. Finally, when abnormal conditions or faults are detected, the system generates an OBD warning, ensuring that the driver or monitoring unit is informed of the fault condition. Thus, the functional block diagram highlights the coordinated operation of hardware and software in achieving reliable vehicle monitoring and control.

By separating the hardware and software domains, the functional block diagram gives a clear understanding of how responsibilities are divided within the system. The hardware ensures that accurate data is captured from the vehicle & converted into a usable digital form, while the software ensures that data is properly communicated and interpretated.

CONCLUSION

This project presents an intelligent and automated system for detecting and rescuing a person who falls overboard (MOB), addressing one of the most critical challenges in maritime safety. By integrating RSSI-based wearable devices, fall detection sensors, and automated alert mechanisms, the system ensures that ship personnel are immediately informed of a man-overboard situation, enabling rapid and effective response. The real-time monitoring interface provides clear situational awareness, while edge-based processing ensures fast and reliable detection even in harsh maritime conditions.

The proposed multi-sensor approach overcomes the limitations of traditional methods that rely heavily on human observation or visual monitoring, which can be delayed or ineffective during poor visibility or rough sea conditions. By combining sensor data with automated alerts and rescue mechanisms, the system enhances the probability of survival, minimizes human error, and provides a proactive approach to maritime safety.

This research aligns with modern e-navigation strategies and demonstrates how intelligent maritime systems can protect lives at sea. Future enhancements may include the integration of machine learning for predictive detection, satellite-based tracking for extended range, and real-time communication with shore-based rescue teams. Collectively, these improvements can make maritime operations safer and more reliable, setting a foundation for the next generation of intelligent safety systems on ships.

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