

Web-Based Extreme Weather Monitoring and Early Warning System for Traditional Fishermen Using IoT Sensor Data

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Abstract. Extreme weather can disrupt traditional fishing activities and increase safety risks, particularly when local weather information is difficult to access before departure. This study develops a web-based extreme weather monitoring and early warning system for traditional fishermen using Internet of Things (IoT) sensor data. The system integrates an ESP32 microcontroller with a DHT22 sensor, rain sensor, and anemometer to acquire temperature, humidity, rainfall, and wind-speed data at ten-second intervals. Sensor data are processed using thresholds combined with a scoring scheme, transmitted through HTTP to a PHP server, stored in MySQL, and visualized through a web dashboard. The system also provides Telegram Bot notifications at 06:00 WIB and 17:00 WIB and event-triggered warnings when the classified condition reaches the danger category. Functional testing using black-box testing produced successful results for the tested features, while Perfetto UI measurements showed response times between 0.56 and 1.34 seconds, with an average of 0.95 seconds. The implementation demonstrates that a low-cost, locally deployed IoT monitoring system can combine real-time weather observation, simple risk classification, web visualization, and automatic notification to support weather awareness before traditional fishermen depart.

Key words: Internet of Things; ESP32; extreme weather; traditional fishermen; threshold

1. INTRODUCTION

Climate change is associated with changes in atmospheric and marine conditions and an increasing occurrence of extreme weather events, including storms, heavy rainfall, and high winds [1]. For fishing activities, environmental conditions are not only an operational consideration but also a safety factor. Previous studies have shown that wind, precipitation, temperature, and other environmental variables can contribute to fishing incident risk and severity [2]–[4]. In Indonesian waters, extreme waves associated with tropical cyclones and seasonal wind patterns are also relevant to fisheries and maritime safety [5].

Traditional fishermen require weather information before departure because their activities are directly exposed to local environmental conditions. However, broad-area forecasts do not always describe the conditions at a specific local site. Climate-service research has emphasized that weather information becomes more useful when it is timely, tailored to decisions, and delivered in a form that users can understand and apply [6]. This issue is particularly important for small-scale

fishing communities whose operational decisions can be affected by sudden changes in wind and rainfall.

IoT-based monitoring offers an alternative by enabling local environmental observations through low-cost sensors and networked microcontrollers. Research on low-cost automatic weather stations has demonstrated the feasibility of real-time measurement, web-based access, and remote data transmission [7]–[10]. Other studies have also shown that IoT platforms can support environmental monitoring through low-cost sensor networks and open-source hardware, provided that sensor calibration and field validation are considered [11]. The present study focuses on a different operational objective: not only displaying weather measurements, but converting local sensor observations into simple risk categories that can be accessed before a fishing trip. The developed system combines ESP32-based sensing, threshold and scoring classification, a PHP/MySQL web dashboard, and Telegram Bot notifications. The contribution is therefore the integration of local real-time observation and simple early warning in a single system oriented toward traditional fishermen.



2. RELATED WORK

2.1. Previous Studies

Previous research can be grouped into three main directions. The first concerns low-cost weather-station development. Bernardes et al. developed a low-cost automatic weather station for disaster monitoring and showed that calibrated sensors could produce measurements without statistically significant differences from a reference professional station [8]. Rivera et al. developed a local weather station to improve access to environmental measurements for small-scale users [7]. Ioannou et al. reviewed low-cost automatic weather stations in the IoT era and highlighted real-time observation, edge computing, and low-power communication as important directions [9].

The second direction concerns intelligent or networked weather monitoring. Mestre et al. developed an intelligent weather station integrating sensing, communication, and data processing [10]. Huang et al. combined mobile weather sensing with machine learning to obtain real-time observations and prediction [12]. Fahim et al. proposed an IoT-smart weather monitoring station using MQTT and fuzzy inference for environmental assessment [13]. Narayana et al. demonstrated a real-time IoT environmental monitoring architecture using sensors, Wi-Fi, HTTP, and a web interface [14]. Alves et al. further demonstrated an IoT cloud-based wind station with high-temporal-resolution processing and web visualization [15].

The third direction concerns fishing safety and climate information. Rezaee et al. reported relationships between extreme weather and fishing incidents in Atlantic Canada [2], while their subsequent work addressed the effects of extreme weather on fishing activity and vessel incidents [3]. A related review emphasized that weather forecasts, communication, safety information, and decision support are important elements of fishing safety [4]. Vincent et al. argued that climate services should be decision-driven, time-managed, inclusive, and usable by end users [6]. In Indonesia, Rahman et al. examined climate adaptation among fishers, while Ningsih et al. analyzed extreme wave occurrence and its implications for maritime safety [5], [16], [17].

2.2. Research Gap

The reviewed studies demonstrate that real-time IoT weather monitoring is technically feasible and that weather conditions are relevant to fishing safety. However, many monitoring systems emphasize measurement, visualization, or forecasting, while fishing-safety studies frequently focus on statistical risk relationships, policy, or climate adaptation. The gap addressed in this study is the integration of local sensor measurement, simple threshold-based risk classification, web visualization, and automatic messaging specifically for pre-departure weather awareness among traditional fishermen. Unlike prediction-

oriented systems, the proposed system is intended as a practical monitoring and early-warning aid rather than a long-term weather forecasting model.

3. RESULTS AND DISCUSSIONS

3.1. Research Workflow

The research uses an engineering research approach with design and development activities. The workflow consists of problem identification, literature study, requirements analysis, system design, implementation, testing, and evaluation. The sequence follows the workflow documented in the final report and is shown in Figure 1.

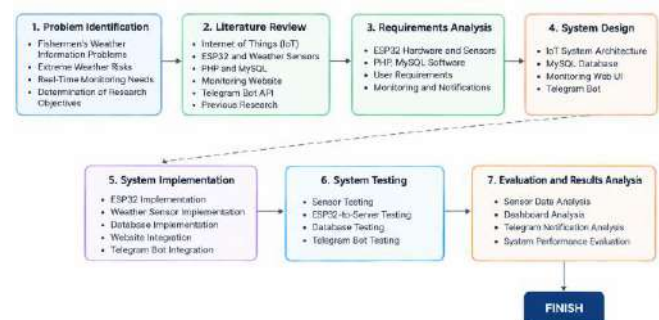


Fig. 1. Research workflow used to develop the monitoring and early warning system.

3.2. Data Acquisition and System Architecture

The hardware consists of an ESP32 S3 as the main microcontroller, a DHT22 for temperature and humidity, a rain sensor for rainfall detection, and an anemometer for wind-speed measurement. Supporting components include an ESP32 S3 expansion board, jumper wires, and a waterproof panel box. The software environment includes Arduino IDE, Visual Studio Code, Native PHP, MySQL, a web browser, and Telegram Bot.

The ESP32 reads the sensors every ten seconds. The resulting temperature, humidity, rainfall, and wind-speed values are processed locally. The classified status is transmitted to the PHP server using HTTP. The server receives the data through the data endpoint, stores the values in MySQL, and provides data for the web dashboard. Telegram Bot is used for scheduled daily information and danger notifications.

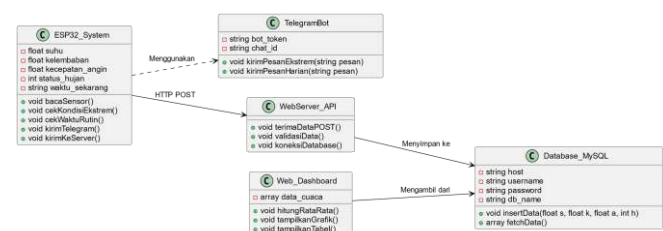


Fig. 2. System architecture represented through the implemented class structure.



3.3. Threshold and Scoring Method

Weather status is determined by comparing each sensor parameter with predefined warning and danger thresholds. The report assigns larger weights to rainfall and wind speed because these parameters are treated as more directly relevant to fishing safety before departure. The total score determines the final weather category.

TABLE 1. Threshold and scoring parameters used in the system

Parameter	Warning (score)	Danger (score)
Temperature	$\geq 33^{\circ}\text{C}$ (1)	$\geq 35^{\circ}\text{C}$ (2)
Humidity	$\geq 80\%$ (1)	$\geq 90\%$ (2)
Rainfall	$\geq 25\%$ (2)	$\geq 30\%$ (4)
Wind speed	$\geq 21\text{ m/s}$ (2)	$\geq 25\text{ m/s}$ (4)

The classification rule is: a total score of 0–2 is classified as Safe, 3–5 as Warning, and ≥ 6 as Danger. The classification is executed automatically after sensor acquisition and the resulting status is transmitted with the sensor data.

3.4. Web and Telegram Implementation

The web application provides a landing page, administrator login, administrator dashboard, sensor data, Telegram Bot status, monitoring graphs, export functions, user dashboard, and real-time sensor data. The user dashboard is simplified to emphasize current weather information. Telegram Bot provides two message modes: scheduled weather information at 06:00 WIB and 17:00 WIB, and automatic warning messages when the system detects a danger condition.

3.5. Testing

Black-box testing was used to verify the functional behavior of the main web features. Perfetto UI was additionally used to measure response time for login, dashboard, sensor data, monitoring graph, data export, and logout. The report also documents functional checks for sensor transmission, database storage, dashboard display, Telegram notifications, and weather classification.

4. RESULTS AND DISCUSSIONS

4.1. System Implementation

The implemented system successfully connects the sensing layer, server, database, web interface, and Telegram notification layer. Sensor data are received and stored for monitoring and historical access. The web interface presents the current temperature, humidity, rainfall condition, wind speed, and weather status. This architecture provides a direct path from local observation to user-facing information.



Fig. 3. Implemented user monitoring dashboard showing real-time sensor information and weather status.

The notification layer provides an additional access channel so that users do not need to keep the dashboard open. The implementation documented in the report shows daily weather reports and warning messages delivered through Telegram Bot. This supports the pre-departure objective by placing weather information in a communication channel that can be checked directly by the user.

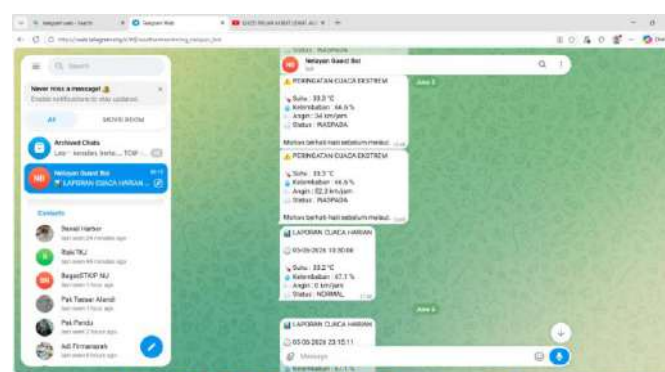


Fig. 4. Implemented Telegram Bot notifications for daily weather information and warning messages.

4.2. Functional and Performance Testing

The black-box results show that the tested functions operated according to the expected behavior. The response-time measurements recorded using Perfetto UI ranged from 0.56 to 1.34 seconds. The average of the six measured features was 0.945 seconds, rounded to 0.95 seconds in the report.

TABLE 2. Web feature response-time results from the reported Perfetto UI measurements

Feature	Response time	Status
Login	1.18 s	Pass
Dashboard	0.73 s	Pass
Sensor data	0.89 s	Pass
Monitoring graph	1.34 s	Pass
Export data	0.97 s	Pass
Logout	0.56 s	Pass

All six web functions were reported as Pass, resulting in a 100% functional success rate for the tested features. The fastest measured function was logout at 0.56 seconds, while the monitoring graph required 1.34 seconds. These



measurements indicate that the implemented web interface was responsive within the limited test environment.

4.3. Comparison with Previous Studies

Compared with previous low-cost weather-station studies, the present system adopts the same general principle of local sensing and networked data transmission, but adds a user-oriented classification and notification layer. Bernardes et al. emphasized sensor reliability and calibration for disaster monitoring [8], while Rivera et al. focused on accessible local environmental monitoring [7]. The present system similarly prioritizes local data accessibility, but its output is deliberately simplified into Safe, Warning, and Danger categories for practical pre-departure awareness.

Compared with intelligent or predictive systems, the current implementation is intentionally simpler. Huang et al. used machine learning for weather prediction [12], and Fahim et al. applied fuzzy inference for weather assessment [13]. The present study instead uses threshold and scoring rules. This is appropriate for a lightweight applied system because the objective is immediate classification of observed conditions rather than forecasting future weather. The trade-off is that the system does not provide probabilistic or long-horizon predictions.

In relation to fishing-safety studies, Rezaee et al. established that environmental conditions are linked to fishing incidents and emphasized the importance of weather information and decision support [2]–[4]. Vincent et al. also showed that climate information is more useful when it is tailored to user decisions [6]. The present study translates those principles into an implemented technical workflow: local sensor acquisition, simple risk classification, web presentation, and automatic Telegram delivery. The system therefore occupies the practical interface between environmental observation and user-facing early warning.

For Indonesia specifically, Ningsih et al. highlighted the relationship between wind, waves, tropical cyclones, and maritime safety [5]. The current system does not measure wave height or perform cyclone prediction, so it should not be interpreted as a replacement for official marine forecasts. Its role is narrower: provide local observed conditions and an additional warning channel before fishing activity.

4.4. Discussion and Limitations

The main strength of the system is integration: the same local observation is converted into a simple status, stored for historical monitoring, visualized on the web, and distributed through Telegram. This reduces the number of steps a user must perform to obtain an understandable warning. The reported response-time measurements also show that the web layer is lightweight in the tested environment.

Several limitations remain. The system is designed for local monitoring and does not forecast future weather. The classification depends on predefined thresholds and therefore cannot automatically adapt to changes in local risk patterns. The report also describes a limited-scale test rather than a deployment across multiple fishing locations. Future work should validate sensor readings against standardized meteorological instruments, expand the observed environmental parameters such as wave height and pressure, and evaluate the thresholds using longer historical datasets and broader field trials.

5. CONCLUSIONS

A web-based extreme weather monitoring and early warning system for traditional fishermen was successfully implemented using ESP32, DHT22, a rain sensor, anemometer, MySQL, Native PHP, and Telegram Bot. The system acquires weather data at ten-second intervals, applies threshold and scoring rules, stores the results, and presents them through a web dashboard. Telegram provides scheduled weather information at 06:00 WIB and 17:00 WIB as well as event-triggered warnings for danger conditions. The reported black-box tests achieved a 100% success rate for the tested web features, with response times from 0.56 to 1.34 seconds and an average of 0.95 seconds. The system is therefore suitable as a local monitoring and early-warning aid before traditional fishermen depart, while official weather information remains necessary for broader marine forecasting and decision-making.

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