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IoT-Based Ghost Net Shredder Monitoring System

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Abstract. Abandoned, lost, and discarded fishing gear (ALDFG), commonly known as ghost nets, presents significant environmental and socio-economic challenges by causing marine entanglement, coral reef degradation, and microplastic pollution. One of the initiatives to mitigate this problem is the introduction of the shredder machine at the Eco House, Waste Collection Centre, Pulau Besar, Mersing, Johor. However, the operation requires close monitoring to ensure efficiency and to prevent motor overheating that may result from overuse. Relying on manual monitoring is inefficient, especially in island communities where both manpower and technical resources are limited. This study presents the design and development of an Internet of Things (IoT)-based monitoring system for the ghost net shredders using the ESP32 microcontroller. The system integrated temperature and vibration sensors with an ESP32 microcontroller and relay control. Data were displayed locally on an LCD and transmitted to the Blynk mobile application for real-time remote visualization and notifications. A prototype was deployed and tested at Pulau Besar, demonstrating reliable sensor performance and stable wireless communication without operational interruptions. The system successfully enhanced predictive maintenance and maintained continuous operation even when powered by the photovoltaic (PV) system. The findings confirm the feasibility of combining IoT monitoring with renewable energy to promote safer, more sustainable ghost net recycling, offering a scalable model for coastal and island communities.

Keywords: IoT, ESP32, Motor Shredder, Ghost-net, sustainability

1. INTRODUCTION

Marine debris, particularly abandoned, lost, and discarded fishing gear (ALDFG), represents a significant global environmental challenge with wide-ranging ecological and socio-economic consequences. UNEP estimates that more than 100 million pounds of plastic from industrial fishing gear alone enter the oceans each year [1], contributing to harmful phenomena such as ghost fishing, where marine animals remain ensnared in neglected gear, leading to ecological degradation and economic losses for fisheries. In Malaysia, more than 4,270 kg of derelict fishing nets (DFN) were collected in 2023, with the peak reaching 11,013 kg in 2019 [2]. The environmental impacts are extensive, including entanglements, coral reef damage, and significant declines in fisheries resources. Ghost fishing has been shown to cause injury, starvation, and mortality in seabirds, ultimately reducing their breeding success and survival [3]. Beyond direct harm to wildlife, ALDFG also damages benthic habitats such as coral reefs and undermines ecosystem services [4][3]. Over time, the degradation of synthetic fishing nets further contributes to the generation of microplastics, which pose risks to marine organisms and may enter the human food chain [5].

Efforts to mitigate ghost nets have focused largely on retrieval methods such as diving operations and beach clean-ups, which have successfully removed large quantities of abandoned gear from marine habitats [6]–[8]. For example, community-driven initiatives on Tioman Island, Malaysia, retrieved over 21 tonnes of ghost nets between 2016 and 2022 [7], while large-scale operations in Norway recovered abandoned gillnets and crab pots, yielding valuable ecological insights [6]. However, such initiatives are resource-intensive, requiring high financial investment and extensive manpower [6], [7]. Conventional disposal practices such as landfilling and incineration also carry clear drawbacks, with landfills contributing to microplastic leakage and incineration generating air pollution and greenhouse gas emissions [9], [10]. These limitations underscore the urgency of more sustainable, long-term solutions.

Recycling has emerged as a promising alternative, with both mechanical and chemical methods applied to fishing net waste. Yet, mechanical recycling is often limited by contamination and fibre degradation, while chemical recycling remains technologically complex and costly. In this context, shredder machines play a vital role by reducing ghost nets into smaller, processable fragments suitable for recycling. Specialised marine shredders have been used to improve recycling efficiency and generate high-quality secondary materials [11]. Nevertheless, shredders face persistent operational challenges, including overheating, vibration, and blade wear [12]. Excessive vibration, in particular, can loosen screws and wiring connections, reducing stability and raising maintenance costs. Addressing these challenges requires enhanced monitoring and predictive maintenance strategies to ensure consistent performance and reliability. However, conventional manual checks remain inadequate for effectively managing these issues, particularly in continuous operation in semi-remote island settings.

To overcome these limitations, Internet of Things (IoT) technologies provide real-time monitoring, remote accessibility, and predictive maintenance [13]. These values are displayed locally on the LCD and transmitted to the any mobile application for remote visualization [14]. Predictive maintenance strategies that integrate IoT-based condition monitoring have been shown to reduce downtime, improve safety, and eliminate the limitations of manual checks, particularly in manufacturing environments with high machine usage demands [15]. By integrating IoT devices into the shredder systems, key parameters such as temperature, vibration, and current can be continuously tracked, allowing early detection of malfunctions and minimising downtime. This study addresses the identified gap by developing an IoT-based safety and monitoring system for shredder machines used in ghost net recycling, powered by a photovoltaic (PV) system. The system employs sensors to monitor motor temperature and vibration in real time, issuing alerts through an LED tower light, buzzer, and LCD. When critical thresholds are reached, the red-light signal prompts users to manually shut down the shredder, thereby preventing damage and ensuring safer operation.

3. Research Methodology

This section presents the design and operation of the IoT-based shredder monitoring system developed to address three key operational risks which are excessive motor temperature, abnormal vibration, and uncontrolled motor stoppages to enable predictive maintenance and controlled shutdowns. The monitoring system integrates sensors, relay control, and alert functions under the ESP32 microcontroller, with both the shredder machine and the IoT unit operating from a shared solar photovoltaic (PV) power supply to ensure sustainability in remote settings.

Figure 1 illustrates the system block diagram, highlighting the integration of temperature and vibration sensors, the ESP32 controller, a relay module, and high-power components such as the shredder motor, tower light indicators, buzzer, and LCD display. The ESP32 also communicates with the Blynk cloud server, enabling real-time monitoring and remote alerts through the mobile application. This architecture ensures operational safety, facilitates predictive maintenance, and provides scalability for remote recycling applications.

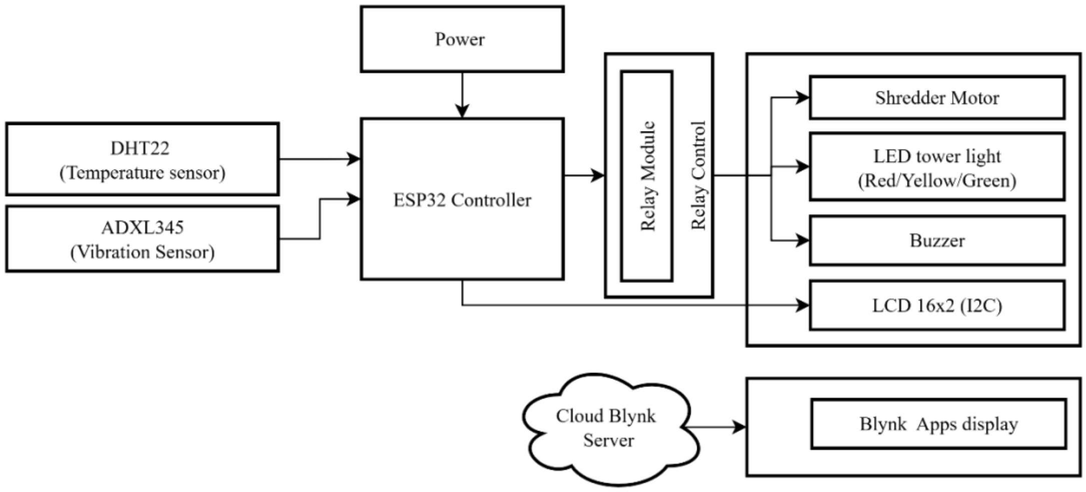

Figure 1. System block diagram of the IoT-based shredder monitoring system integrating sensors, ESP32 controller, relay module, actuators, and Blynk cloud for real-time monitoring and control.

Figure 2 presents the wiring diagram, which details the hardware configuration of the system. The DHT22 sensor monitors motor temperature, while the ADXL345 vibration sensor detects abnormal mechanical oscillations. Their data are processed by the ESP32, which drives the LCD for local display and controls the relay module to switch the motor, tower light indicators, and buzzer. The tower light provides visual status signals (green for safe, yellow for caution, red for critical), while the buzzer delivers audible alerts in hazardous conditions. The relay also enables automatic and controlled motor shutdown, preventing overheating and protecting the blades.

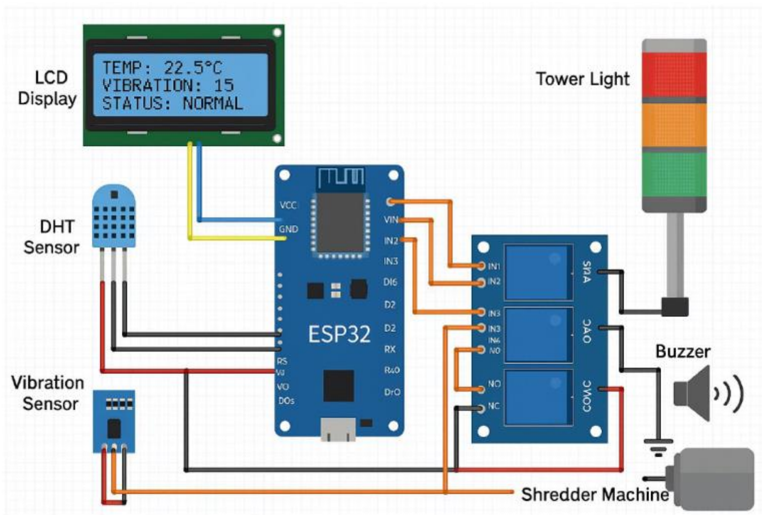

Figure 2. Wiring diagram for the Ghost Net Shredder IoT Monitoring System.

To demonstrate how these components interact in practice, **Figure 3** shows the operation flowchart of the system. After initialization, the ESP32 configures the sensors, LCD, and relay outputs, then continuously reads motor temperature and vibration at two-second intervals. These values are displayed locally on the LCD and transmitted to the Blynk app for remote visualization. The decision-making process evaluates the readings against defined thresholds. If the temperature exceeds 70 °C or vibration surpasses an index of 40, the system enters the 'Critical' state, activating the red light, buzzer, and motor shutdown. If the parameters fall within the 'Warning' range (temperature 60–70 °C or vibration index 20–40), the yellow light is triggered. Otherwise, the system remains in the 'Normal' state, with the green light illuminated. This loop repeats indefinitely, ensuring continuous safety monitoring and enabling both local and remote oversight of the shredder's condition.

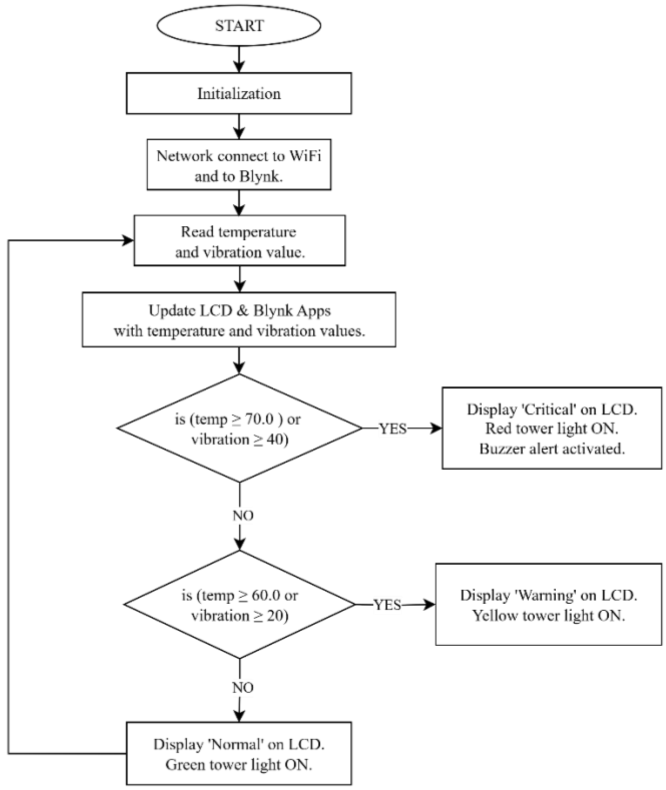

Figure 3. Operation flowchart of the IoT Shredder System.

4. RESULTS AND DISCUSSIONS

The IoT-based shredder monitoring system was assembled and tested at the Eco House, Waste Collection Centre, Pulau Besar, Mersing, Johor, to evaluate its performance in an operational environment. The prototype successfully integrated sensors, relay control, and alert functions while operating from a shared solar photovoltaic (PV) power source that also supplied the shredder motor. The assessment focused on four key aspects, system responsiveness, safety alerts, and visualization through Blynk Application on a mobile phone.

Results demonstrated that the ESP32 microcontroller responded promptly to sensor inputs, the alert mechanisms functioned reliably at defined thresholds, and both local and remote monitoring were achieved without interruption. Furthermore, the shared solar photovoltaic (PV) source successfully powered both the shredder and the monitoring system for continuous operation within the designed usage window. The system reliably triggered safety states based on defined thresholds, and the results are tabulated in Table 1.

Table 1. System behavior and status logic of the IoT-based shredder monitoring system under different operating conditions.

Condition	Red LED	Yellow LED	Green LED	Buzzer	Display on LCD
Normal operation	OFF	OFF	ON	OFF	‘Normal’
Warning (temp > 60°C or mild vibration)	OFF	ON	OFF	OFF	‘Warning’
Critical (temp > 70°C or high vibration)	ON	OFF	OFF	ON	‘Critical’

During normal operation, the green LED remained active, the buzzer was off, and the shredder motor ran continuously. When the system detected warning conditions (temperature between 60–70 °C or mild vibration above threshold 20), the yellow LED was triggered while the motor continued running, serving as a precautionary alert without interrupting operation. Under critical conditions (temperature exceeding 70 °C or vibration above index 40), the red LED and buzzer were activated to draw the operator's immediate attention. At this stage, the system did not automatically stop the motor; instead, the alerts indicated that the shredder should be manually switched off to prevent overheating or mechanical damage. These findings confirm that the monitoring logic functioned effectively, enabling real-time fault detection, operator awareness, and safe manual intervention in line with the design objectives. The approach also aligns with predictive maintenance strategies reported in similar IoT-based monitoring studies [15]. In addition, powering the system with solar energy demonstrates its resilience and sustainability, underscoring its suitability for remote or off-grid recycling sites.

Real-time operational status was displayed on the local LCD for immediate on-site monitoring. Simultaneously, the ESP32 transmitted sensor values and system states to the Blynk mobile application through cloud connectivity. Push notifications were successfully delivered during warning and critical events, and remote functions such as alarm acknowledgment, motor stop, and system reset were executed reliably. This dual interface strengthened both local and remote supervisory control, reducing reliance on manual inspection and enhancing operator responsiveness. These results are consistent with prior IoT-enabled monitoring frameworks where remote visualization significantly improved system reliability and user decision-making [14]. The combined results emphasize the system's role in advancing safe and sustainable recycling practices, directly supporting Malaysia's sustainability and digitalization goals.

Figure 4 illustrates the IoT monitoring dashboard developed using the Blynk mobile application. The interface displays the shredder's operational parameters in real time, including motor temperature (25.5 °C) and vibration scale (40), alongside a live temperature chart for trend analysis.

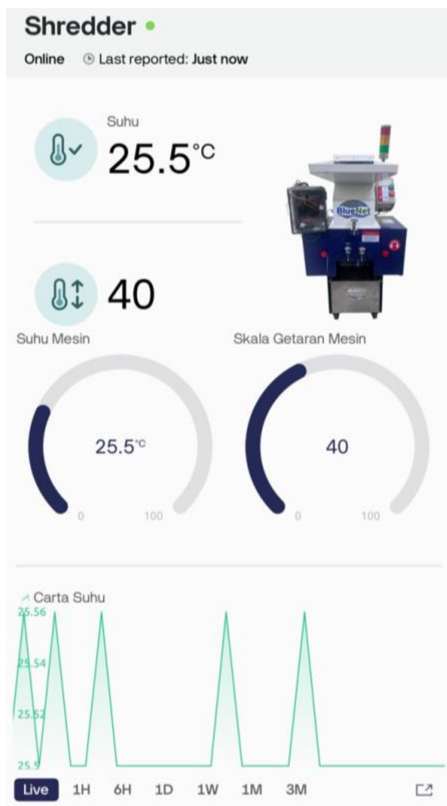

Figure 4. Blynk mobile application interface showing real-time monitoring of shredder motor temperature, vibration scale, and status visualization.

The system provides instantaneous updates of sensor readings, with data represented both numerically and through gauge indicators. The green status indicator confirms that the device is online, while the application also supports remote notifications and control functions. This dual visualization, numerical and graphical, facilitates user-friendly monitoring and enhances situational awareness for operators, especially in remote deployment scenarios.

Overall, the results validate the system's ability to provide reliable, real-time monitoring and safety alerts, reinforcing its potential as a scalable solution for sustainable recycling operations.

6. CONCLUSION

This study developed and evaluated an IoT-based monitoring system for shredder machines in ghost net recycling, integrating temperature and vibration sensors with an ESP32 microcontroller, relay control, and visual–audible alerts. Powered by a shared solar photovoltaic source, the system enabled reliable operation in a semi-remote island setting. Field testing at Pulau Besar confirmed that the system effectively detected abnormal conditions, issued timely alerts, and supported manual intervention to prevent equipment damage. Real-time monitoring through both local LCD display and the Blynk mobile application enhanced operator awareness and remote control. By combining IoT monitoring with renewable energy, the system advances operational safety, predictive maintenance, and sustainability in recycling. The approach not only supports circular economy goals and marine debris reduction but also provides a scalable model for coastal and island contexts, offering practical impact for sustainable waste management.

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