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Smart Waste Bin : Iot-Based Smart Trash Bin Monitoring System

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ABSTRACT

Unmonitored waste accumulation can cause environmental pollution and health risks, especially in campus environments with dense daily activities. This research developed the "Smart Waste Bin," an IoT-based system that monitors trash bin conditions in real time. The system uses an ultrasonic sensor to measure the height of the waste and a NodeMCU ESP32 as the main controller. Data is displayed on an LCD and sent to a monitoring website and Telegram application for notifications. The system classifies waste levels into three statuses: Empty (1–11 cm, green), Nearly Full (12–20 cm, yellow), and Full (21–30 cm, red). It also includes an automatic lid operated by a servo motor. When the bin is full, the lid remains closed to prevent overflow and maintain cleanliness. Testing showed the prototype successfully detected bin status and sent notifications with 90–93% accuracy. However, the system heavily depends on stable internet connectivity. Overall, it effectively enhances waste monitoring using IoT integration.

Keyword : Internet of Things; **Smart Waste Bin**; **Ultrasonic Sensor**; **NodeMCU**.

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1. INTRODUCTION

Waste is the result of human activities, as almost every activity produces some form of residue. It can come from leftover food, damaged items, packaging, or industrial waste, and may be organic or inorganic (Abidin & Marpaung, 2021). At Malikussaleh University, waste is generated from various campus activities such as lectures, student organizations, administration, and services. The types of waste include food scraps, packaging, paper, and plastic. Proper waste management is essential to maintain cleanliness, prevent pollution, and protect human health and the environment.

Waste management involves steps to reduce, process, and dispose of waste to prevent environmental damage. This includes separating organic and inorganic waste, recycling, and reducing single-use items (Putra & Ismaniar, 2020). Proper management helps reduce waste volume, prevent pollution, and support environmental sustainability (Hidayat & Faizal, 2020). However, waste issues remain a challenge, including at Malikussaleh University. Unmonitored waste buildup can make the environment dirty and unhealthy, affecting the comfort and health of the campus community. Waste disposal is often delayed when bins are full. The problem is made worse by monkeys that scatter the trash, requiring staff to clean it up again.

The development of Internet of Things (IoT) technology offers innovative solutions for waste monitoring. By using an IoT-based system, trash bins can be monitored in real time, allowing management to directly track the waste level. The data collected enables more efficient and responsive waste management, as bins can be emptied promptly when needed (Widigdo et al., 2023).

This study aims to develop a *Smart Waste Bin* system that can automatically detect waste capacity using an ultrasonic sensor. The sensor measures the height of the waste to determine whether the bin is full or empty. The system is equipped with Telegram notifications and website-based monitoring. With these features, cleaning staff will receive alerts when the bin is full and can monitor waste conditions in real time. The goal is to make waste management faster, more efficient, and centralize.

2. RESEARCH METHOD

This study uses a qualitative approach to understand the needs, experiences, and perceptions of users toward the Smart Waste Bin, an IoT-based waste bin monitoring system (Musyrifah et al., 2024). Data analysis was conducted by gaining insights through in-depth interviews and field observations to identify the challenges in implementing this technology and its impact on users' waste management habits.

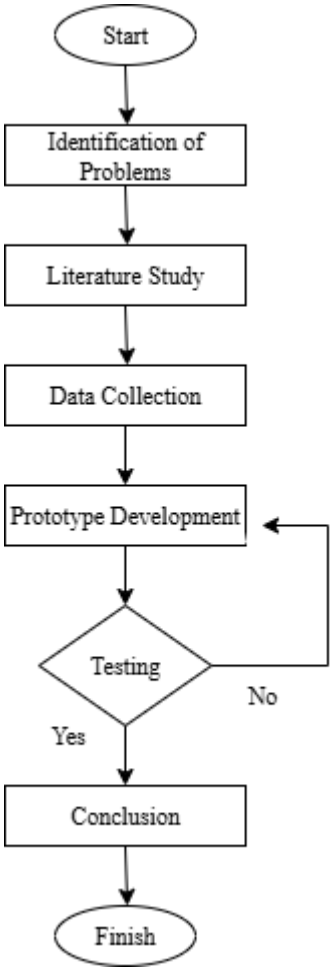

Figure 1. Research Stages

1. Identification of Problems

This stage involves problem-solving and will be followed by finding solutions to the identified issues(Ismail et al., 2021). One approach is to develop a system that addresses the needs of waste disposal management to make it more efficient**.**

2. Literature Study

At this stage, a literature review is conducted to explore relevant research. The goal is to study existing solutions, relevant technologies, and the best approaches to address the problem (Syahdi Nasution et al., 2023)

3. Data Collection

At this stage, data collection is conducted to gather the necessary information for designing an appropriate solution. This data includes user requirements, technical analysis, and information from field conditions (Rizky et al., 2020). All data is obtained through interviews with cleaning staff at Malikussaleh University.

4. Prototype Development

The prototype is designed using an ultrasonic sensor, ESP32, and LCD to monitor the condition of the trash bin. The system is connected to a web application and Telegram notifications for real-time

monitoring. The bin is also equipped with an automatic open-close feature controlled by the sensor (Herlina et al., 2022).

5. Testing

The prototype is tested to ensure it meets the requirements and functions as intended (Iqbal et al., 2021).

- If "Yes" (successful), the process continues to the conclusion stage.
- If "No" (unsuccessful), the prototype needs to be revised or adjusted, and the iteration process is repeated

2.2 System Design

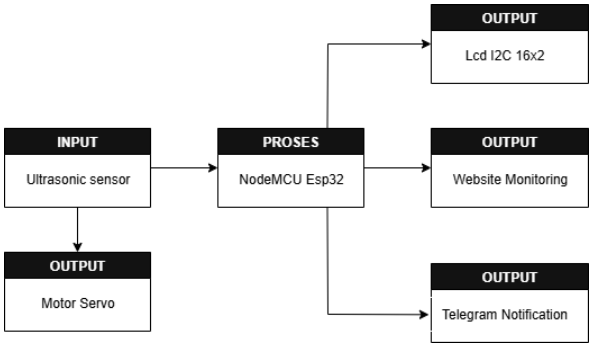

Figure 2. System Desain

1. Ultrasonic Sensor

This sensor functions to measure the distance or the height level of the waste inside the bin. By placing the ultrasonic sensor at the top of the bin, it can detect how full the bin is (Perdana & Wellem, 2023).

2. NodeMCU ESP32

The ESP32 is a microcontroller that controls the entire system and functions as the data processing center. It receives data from the ultrasonic sensor, processes it, and then takes action based on that data(Muliadi et al., 2024).

3. Lcd I2C 16x2

This LCD is used to locally display the status of the trash bin. It shows messages such as "Bin Full" and indicates the percentage of the bin's capacity (Priangga & Simamora, 2025).

4. Servo Motor

In this study, the servo motor is used as the driving component to open and close the lid of the trash bin. It operates based on the input from the ultrasonic sensor, automatically activating when the user's hand is detected near the bin, allowing for a touchless and hygienic waste disposal process (Perdana & Wellem, 2023).

5. Website Monitoring

This website interface displays information about the filled capacity of the trash and its status, allowing users to know when the bin needs to be emptied (Khozin et al., 2022).

6. Telegram Notification

If the trash bin is full, the ESP32 will send a warning message to Telegram, notifying the user or cleaning staff to immediately empty the bin (Emilia Julita Kadja, 2025).

3. RESULTS AND DISCUSSION

This is the front view of the assembled smart trash bin. It features an ultrasonic sensor on the front to detect the user's hand and automatically open or close the lid using a servo motor. A transparent box houses the control unit, including the NodeMCU ESP32 as the main microcontroller and an LCD for real-time status display. Another ultrasonic sensor is mounted under the lid to measure the trash level. When the bin is full, the system sends an alert. The servo motor responds to sensor signals, allowing hands-free operation.

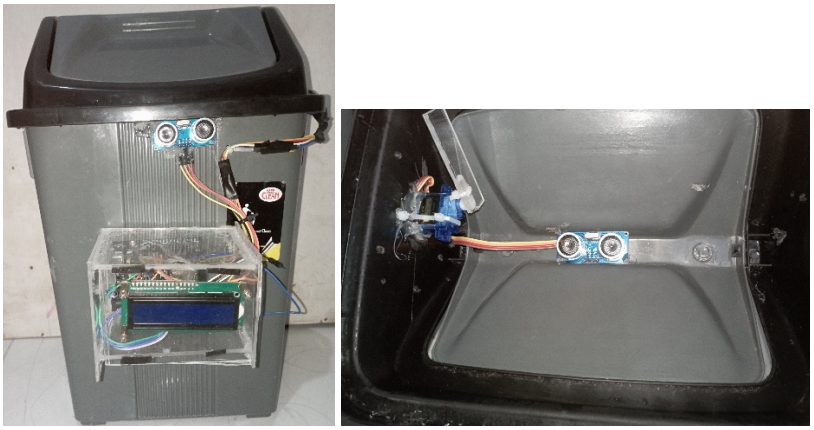

Figure 3. Device Prototype

The SmartBin monitoring website functions to track the condition of trash bins in real-time. Through this interface, users can view the current trash height, bin status (empty, nearly full, full), and the last update time. The website also provides a history of monitoring data and sends automatic notifications to cleaning staff.

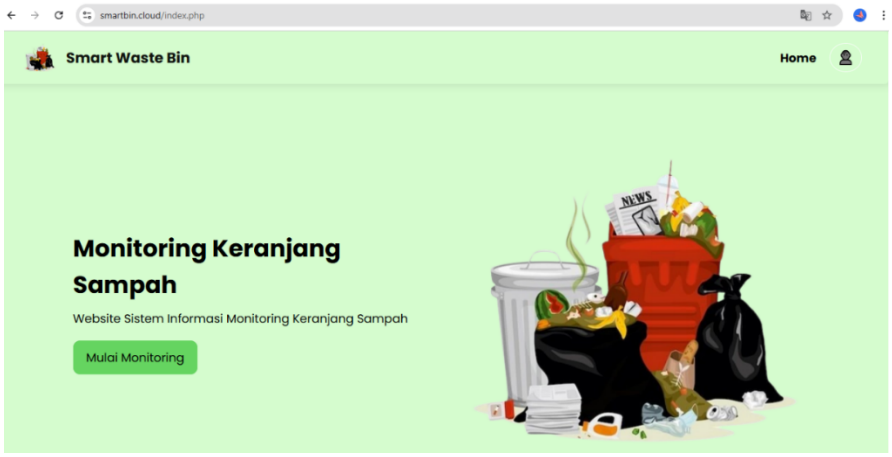

Figure 4. Smartbin.cloud Homepage Display

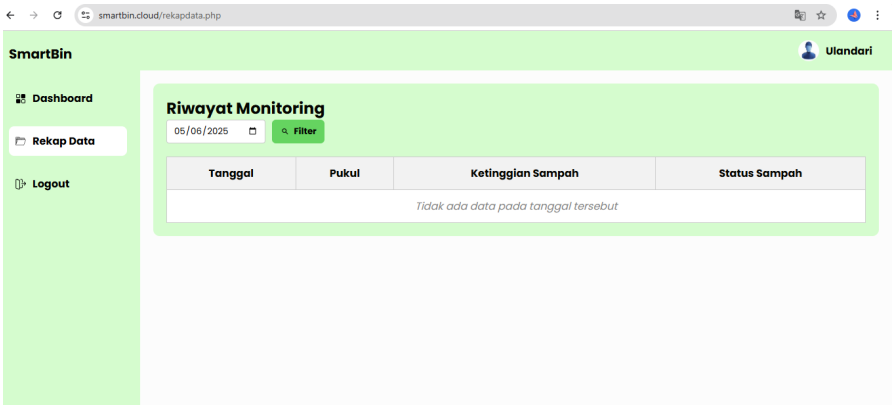

Figure 5. Data Recap

3.2 Testing

Figure 4. Servo Motor Testing

The testing process involves the servo motor and the ultrasonic sensor installed at the front. The ultrasonic sensor functions to detect objects in front of it. When someone approaches to throw away trash, the sensor detects the object, and the servo motor automatically opens the trash bin lid.

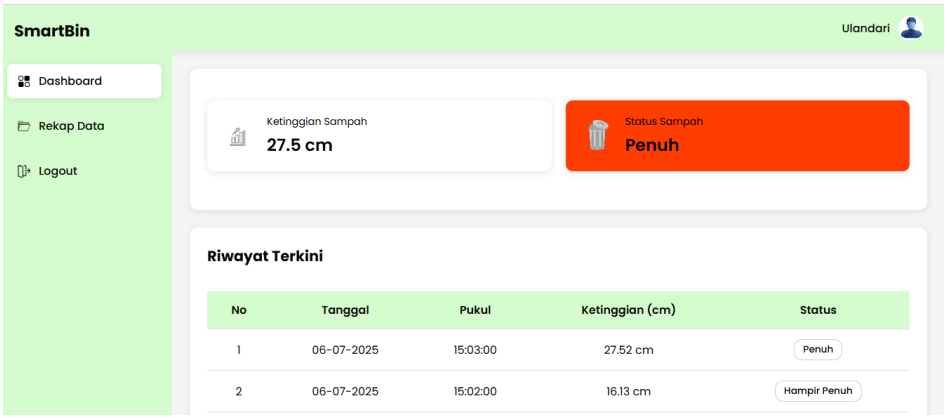

Figure 5. Dashboard Smartbin

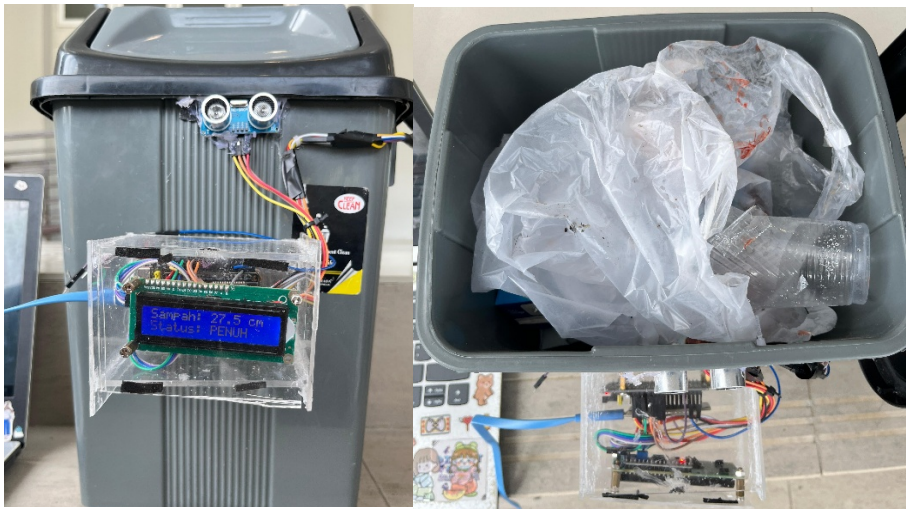

Figure 6. Full bin

As shown in Figures 5 and 6, the trash bin is at full capacity, with a trash height of 27.5 cm based on ultrasonic sensor readings. This information is displayed in real time on both the LCD and the SmartBin dashboard, with a "FULL" status and a red indicator. The monitoring history shows consistent readings, indicating that the system functions effectively in automatically detecting and displaying the waste status.

Figure 7. Telegram Notification

The cleaning staff will receive two types of notifications. The first is a warning alert indicating that the trash bin is almost full, triggered when the trash height reaches between 12 and 20 cm. The second is a command notification to empty the bin when the trash height reaches 21 to 30 cm. This notification will continue to send messages every 3 minutes until the bin is completely emptied

4. CONCLUSION

The IoT-based smart trash bin monitoring system was successfully designed and implemented. The HC-SR04 ultrasonic sensor accurately detects the height of the trash and sends real-time data to the LCD display, website dashboard, and Telegram notifications. The servo motor was also successfully integrated to automatically open and close the trash bin lid when a hand is detected. Testing results show that all components work in an integrated, responsive, and consistent manner, making the system effective in helping cleaning staff monitor and manage waste efficiently. System also supports periodic monitoring with automatically recorded data history, allowing for analysis of waste disposal patterns. The website interface is simple and informative, making it easy for users to understand the bin's condition. The notification feature, which sends alerts every 3 minutes when the bin is full, ensures timely response. The integration between hardware and software remained stable throughout testing. Overall, this system is feasible for implementation in campus environments or other public facilities.

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