DEVELOPMENT OF A MOTION AND SOUND SENSOR-BASED SMART TRASH CAN WITH A BUZZER NOTIFICATION SYSTEM

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ABSTRAK

Waste management remains a critical environmental challenge. This research aims to design and implement a prototype of a smart trash bin based on motion and sound sensors with an automatic notification system to improve efficiency and hygiene. The system utilizes an Arduino Uno microcontroller as the central control unit, integrated with two HC-SR04 ultrasonic sensors and a buzzer. The first sensor detects the user's hand movement to automatically open and close the lid via a servo motor, enabling a contactless process. The second sensor measures the waste level inside the bin; when the trash reaches full capacity, the system activates the buzzer as a local notification for cleaning personnel. The prototype was tested in a laboratory setting, and the results confirm that all components functioned optimally according to the design. The system successfully provides an innovative, practical, and efficient solution for smarter waste management, serving as an early implementation of appropriate technology that operates independently without an internet connection.

Kata kunci : *Smart Trash Bin, Ultrasonic Sensor, Arduino Uno, Automation, Notification System.*

1. INTRODUCTION

Waste management remains one of the most critical environmental challenges in many regions. The increasing population and human activities continuously contribute to the growing volume of waste generated each day, whether in households, schools, offices, or public facilities. Improper waste management can lead to various negative impacts such as air and water pollution, unpleasant odors, and the spread of diseases. Therefore, efficient, hygienic, and technology-based waste management has become an urgent necessity in the modern era [1].

The application of automation technology has been proven to improve the effectiveness of sanitation systems. One example of such innovation is the smart trash bin, which utilizes an ultrasonic sensor to detect the presence of objects in front of the bin, allowing it to open and close automatically without physical contact. This system not only enhances user convenience but also reduces the potential spread of germs caused by direct contact with the bin's surface [2].

However, most conventional smart bin systems mainly focus on the automatic open-close feature without considering the monitoring of waste capacity. As a result, cleaning staff often do not realize when the bin is full, leading to waste overflow and reduced environmental hygiene [3]. Therefore, it is necessary to develop a smart bin system capable of detecting the trash level and providing an automatic notification system, so that the waste management process can be carried out more efficiently and responsively.

In this study, an Arduino Uno microcontroller is used as the central control unit connected to two ultrasonic sensors (HC-SR04) and a buzzer as a local notification system. The first sensor functions to detect the motion of the user's hand, while the second measures the level of waste inside the bin [4]. When the waste reaches its maximum capacity, the buzzer will be activated as a signal for the cleaning personnel to empty the bin immediately. The system is designed and tested on a laboratory scale to ensure that each component functions accurately according to the designed logic [5].

Based on this background, this research aims to design and implement a prototype of a smart trash bin based on motion and sound sensors with an automatic notification system. The results of this study are expected to provide an innovative solution for smarter, more efficient, and environmentally friendly waste management, as well as to serve as an early implementation of a simple Internet of Things (IoT) concept in the field of cleanliness and environmental health.

2. LITERATURE REVIEW

2.1. Definition of Smart Trash Bin

A smart trash bin is a waste disposal container designed with sensor-based and microcontroller technology to improve efficiency in waste management processes. In general, a smart bin can automatically detect the presence of a user and measure the trash capacity inside the bin [6].

With this automation system, users do not need to open or close the lid manually, making the process more hygienic and efficient. In this study, the smart trash bin is designed using two HC-SR04 ultrasonic sensors: one sensor detects the user's hand movement to open and close the lid automatically, while the other sensor measures the height or capacity of the trash inside the bin. When the trash reaches the full level, the system provides a local notification in the form of an alarm or buzzer sound, without requiring an internet connection [7].

By implementing this technology, the system is expected to assist users and cleaning staff in monitoring the condition of the trash bin in a practical and real-time manner.

2.2. Framework of Thinking

One of the main problems in waste management is the delay in emptying trash bins due to the absence of an automatic capacity monitoring system. As a result, waste often accumulates, overflows, and causes unpleasant odors [8]. Some existing smart bin systems based on the Internet of Things (IoT) are capable of providing remote notifications, but they rely heavily on internet connectivity, which is not always stable in all locations [9].

To address this issue, this research designs a smart trash bin prototype based on the Arduino Uno microcontroller, which operates locally without dependence on an internet connection [10]. The system integrates two HC-SR04 ultrasonic sensors with different functions:

a. Ultrasonic Sensor 1: detects the movement of the user's hand in front of the bin, which then triggers the servo motor to open and close the lid automatically.
b. Ultrasonic Sensor 2: measures the distance between the sensor and the trash surface inside the bin. When the detected distance becomes very small or the trash surface is level with the sensor, the system interprets this condition as "full."
c. Local Notification System (Buzzer and LED): is automatically activated when the bin is full, providing an alert for users or cleaning staff to empty the bin without manual inspection.

With this design, the smart trash bin prototype is expected to improve waste management efficiency, provide a more natural user interaction experience, and serve as a practical and independent solution that can be applied in schools, offices, and other public spaces.

2.3. Hypothesis

The prototype of the smart trash bin designed by integrating two HC-SR04 ultrasonic sensors, a servo motor, and a local notification system consisting of a buzzer and LED is expected to deliver optimal performance in supporting modern waste management. The system allows the trash bin lid to open automatically when detecting the presence of a user's hand in front of the first ultrasonic sensor and to close automatically after a few seconds.

In addition, the second ultrasonic sensor functions to detect the height or capacity of the trash inside the bin. When the trash surface reaches the level of this sensor, the system will identify the bin as full and automatically activate the buzzer and LED as a warning notification. Thus, users or cleaning staff can immediately know the appropriate time to empty the bin without needing to check it manually.

This approach is expected to overcome the limitations of conventional systems that still rely on visual monitoring or internet connections, while providing a practical, efficient, and independent solution through the application of sensor-based appropriate technology to support smarter cleanliness and environmental management.

3. RESEARCH METHODS

3.1. Type of Research

This study is a Research and Development (R&D) type of research, as it aims to design, develop, and test the performance of an innovative product in the form of a smart trash bin prototype based on two HC-SR04 ultrasonic sensors. The main focus of this research is to develop an automation system for the trash bin that can open and close automatically and provide an alarm notification when the bin is full.

3.2. Research Location and Time

This research was conducted within the Computer Science Study Program at Universitas Negeri Medan. The research process was planned to take place over a period of four months, covering several stages including system design, prototype development, system programming, and tool testing within a laboratory environment.

3.3. Hardware

a. Microcontroller: Arduino Uno R3 serves as the main controller of the entire system.
b. Ultrasonic Sensors HC-SR04 (2 units):
   - The first sensor is used to detect the user's hand movement, allowing the trash bin lid to open and close automatically.
   - The second sensor is used to detect the height or capacity of the trash inside the bin.
c. Servo Motor: Functions as an actuator to automatically move the trash bin lid.
d. Buzzer: Serves as an audio indicator when the trash bin is full.
e. LED Lights (Red & Green): Serve as visual indicators showing the bin's status (full or empty).
f. Breadboard and Jumper Cables: Used as connectors and assembly media for the electronic circuit components.
g. 5V Adapter or Power Supply: Provides power to the system.

3.4. Software

Arduino IDE Used to write, upload, and test the program that controls the operation of the sensors, servo motor, LEDs, and buzzer.

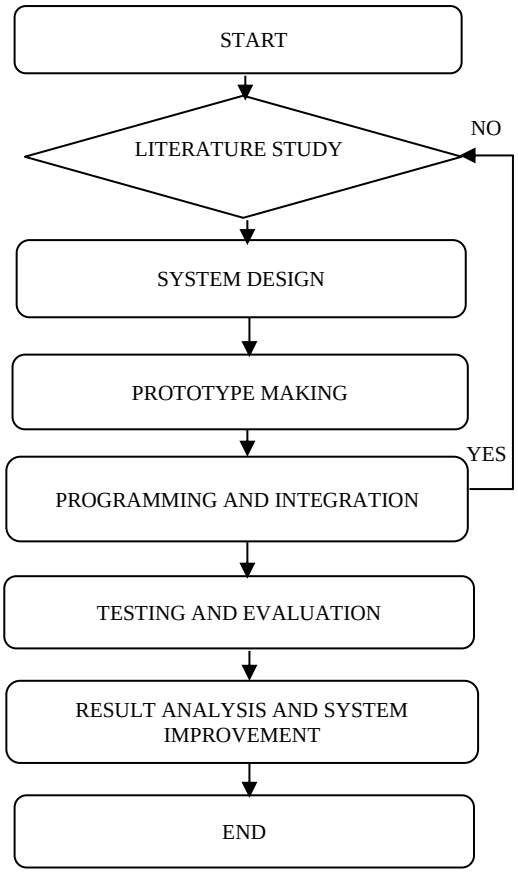

Figure 1. Smart Trash Bin Flowchart

Figure 1 shows the flowchart of the research procedure used in designing the Arduino-based automatic trash bin system. The research begins with the literature study stage, where references related to automation systems, ultrasonic sensor usage, and Arduino microcontroller programming are collected as theoretical foundations.

Next is the system design stage, which involves creating block diagrams, circuit schematics, and system workflows to ensure that all components are properly connected according to their functions. After the design is completed, a prototype is developed by assembling components such as the microcontroller, two ultrasonic sensors, a servo motor, an LED, and a buzzer, followed by testing the wiring connections on a breadboard.

The following stage is system programming and integration, which includes writing code in the Arduino IDE so that the first sensor can detect a hand to automatically open and close the trash lid, while the second sensor activates the LED and buzzer when the bin is full.

Subsequently, testing and evaluation are carried out to ensure that all components function properly. This includes testing automatic lid movement, full-bin notification, and system durability. After testing, analysis and system improvement are performed if deficiencies are found, ensuring that the device operates optimally.

4. RESULT AND DISCUSSION

4.1. System Implementation Results

The prototype of the smart trash bin developed in this research is the result of implementing technology based on the HC-SR04 ultrasonic sensor, servo motor, and buzzer controlled by the Arduino Uno microcontroller. This system is designed to operate automatically and contactlessly, with the aim of improving convenience and hygiene in the waste disposal process.

The system operates using two ultrasonic sensors with different functions. The first sensor is placed on the outer part of the bin and functions to detect the presence of a hand or object in front of the trash bin. When the sensor detects hand movement within a certain distance (around 10–20 centimeters), the servo motor is activated to open the lid automatically. After a few seconds, when no object is detected, the system instructs the motor to slowly close the lid again. Meanwhile, the second ultrasonic sensor is installed inside the bin and serves to detect the height of the accumulated trash. When the trash level reaches the preset distance limit (indicating that the bin is full), the system triggers the buzzer to sound as a local warning notification. This allows users or cleaning staff to know when the bin is full without having to check it manually.

The electronic circuit of this system consists of an Arduino Uno, two HC-SR04 ultrasonic sensors, a Tower Pro SG90 servo motor, and a buzzer as the output component. All components are connected using a breadboard and jumper wires, with power supplied through a 5V USB port from an adapter or computer.

The device programming is carried out using the Arduino IDE with the C/C++ programming language. The main program logic controls the system's response based on the distance detected by each sensor using an if–else structure. When the distance between the object and the front sensor is smaller than the threshold, the system activates the motor to open the lid. Conversely, when the distance increases again, the system automatically closes the lid. On the other hand, when the internal sensor detects that the distance between the sensor and the trash surface becomes very small (indicating the bin is full), the system activates the buzzer as a warning signal.

4.2. Device Testing Results

The prototype was tested to ensure that all functions operated according to the design. Testing was conducted in a laboratory environment under various scenarios to observe the system's response to changes in distance and bin conditions.

Figure 2 shows the implementation result of the Arduino-based smart trash bin prototype that was successfully designed and tested in this research. The figure illustrates the device design, which consists of several main components such as

the Arduino Uno microcontroller as the central controller, two HC-SR04 ultrasonic sensors, a servo motor, and a buzzer as the sound notification system.

Figure 2. Trash Bin Prototype Tested with Arduino

The first ultrasonic sensor is positioned on the outer side of the bin and functions to detect the user's hand movement when disposing of waste. When the hand is detected within approximately 5–10 cm of the sensor, the system automatically sends a signal to the servo motor to open the bin lid. After a few seconds, when no object is detected, the servo motor slowly closes the lid again, allowing for a touchless waste disposal process.

Meanwhile, the second ultrasonic sensor is placed inside the trash bin to detect the height of the accumulated waste. When the trash surface reaches a very close distance to the sensor (indicating that the bin is full), the system automatically triggers the buzzer to sound as a warning notification to the user or cleaning staff.

This figure clearly illustrates the integration between all components within a coordinated automatic system and demonstrates that the device has been successfully implemented according to the design developed during the design stage. The test results show that the device functions properly and responds quickly to received stimuli. The testing data are summarized in Table 1 below:

Table 1. Trash Bin Testing Results

No.	Component / Function Tested	Test Condition	Result Obtained	Remarks
1	Ultrasonic Sensor 1 (hand detection)	Hand placed 5–10 cm from sensor	Lid opens automatically	Functions properly
2	Servo Motor	No hand movement	Lid closes automatically after ±3 seconds	Stable and responsive
3	Ultrasonic Sensor 2 (trash level detection)	Trash reaches sensor distance	Buzzer is activated	Notification works well
4	Buzzer	Activated when trash reaches sensor	Sound is active	Functions properly

Based on the test results shown in Table 1, the smart trash bin system developed in this study operated optimally according to the design. The first ultrasonic sensor successfully detected the user's hand at a distance of approximately 5–10 cm with high accuracy, allowing the servo motor to automatically open the bin lid. When no hand movement was detected for a few seconds, the lid closed again smoothly and responsively. In addition, the second ultrasonic sensor placed inside the bin effectively detected the height of the accumulated trash. When the trash surface reached the level of the sensor, the system immediately triggered the buzzer to sound as a notification that the bin was full and needed to be emptied.

These results demonstrate that all system components-including sensors, the microcontroller, and actuators-worked in good coordination without requiring manual control. From these findings, it can be concluded that the designed device supports a hygienic, automatic, and efficient waste management process by minimizing direct contact between users and the bin lid.

The test results are consistent with several previous studies conducted by Indonesian researchers in the field of Arduino-based automation. [3] reported that the use of ultrasonic sensors and servo motors in an Arduino Uno-based smart trash bin system successfully enabled automatic lid opening and closing within a detection range of 0-20 cm, along with sound feedback to the user. Similar results were obtained by [4] in their journal Smart Green Box Trash Design Based on HC-SR04 Sensor Arduino Uno Integrated, which successfully designed a system using two ultrasonic sensors to measure trash volume in real-time with very high accuracy and a very small average error of only 0.09% and 0.03%. These successes reinforce the reliability of ultrasonic sensor technology in distance and volume detection, making it highly suitable for automation systems like the one developed in this study.

Furthermore, a local study conducted at Nusa Nipa University, titled Development of an Automatic Trash Bin Using Ultrasonic Sensor HC-SR04 in the Faculty of Teacher Training and Education Environment, also demonstrated that an automatic trash bin system can function properly, with the lid

opening automatically when a hand approaches and closing again after approximately three seconds. This study confirms that the use of the Arduino Uno microcontroller with ultrasonic sensors can produce a system that responds effectively to user movement-highly relevant to the system developed in this research.

Similarly, [5] in their journal Application of Smart Trash Bin with Notification Using Telegram successfully developed an IoT-based smart bin system that sends notifications to the Telegram application when the bin is full. However, that system depends on an internet connection, which may not always be stable in all locations. In contrast, the system in this study uses a local notification approach with a buzzer that does not require an internet connection, making it more energy-efficient and easier to implement in various environments.

Therefore, the findings of this research strengthen previous Indonesian studies that demonstrate the effectiveness of integrating the HC-SR04 ultrasonic sensor, servo motor, and Arduino Uno microcontroller in developing automated trash bin systems. Nevertheless, this study presents a distinct advantage-its locally based notification system that operates entirely offline, making it more power-efficient and practical for use in various settings such as schools, households, and public facilities.

The combination of empirical test results and alignment with prior studies indicates that the developed device is not only technically valid but also highly applicable in promoting environmental cleanliness and the implementation of appropriate technology. With further development, this system has the potential to be integrated with visual indicators such as LEDs or LCDs to display fullness status more informatively and to serve as a practical example of smart environment implementation in modern waste management in Indonesia.

5. CONCLUSION

Based on the research, it can be concluded that the prototype of a smart trash bin based on ultrasonic sensors and a buzzer notification system has been successfully designed and functions as intended. The system effectively detects the presence of a hand or object to open and close the lid automatically, and uses a second sensor to detect when the bin is full, triggering a buzzer. This system, which operates without an internet connection, is efficient, energy-saving, and suitable for various public settings, enhancing hygiene and user convenience.

For future development, it is suggested to add visual displays like an LCD or LED indicators, integrate wireless communication modules (e.g., WiFi/Bluetooth) for remote notifications, consider alternative power sources such as solar panels, and improve the physical design for greater durability. With these refinements, this smart bin has the potential to be an effective, appropriate technology that supports environmental cleanliness and the development of sustainable smart cities.

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