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DESIGN OF AN AUTOMATIC TRASH CAN BASED ON ULTRASONIC SENSORS AND ARDUINO AT LP3I MEDAN POLYTECHNIC

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ABSTRACT

This study aims to design, develop, and test a prototype of an automatic trash bin based on HC-SR04 ultrasonic sensors and Arduino Uno R3 microcontrollers to improve cleanliness, efficiency, and awareness of waste management at the LP3I Polytechnic in Medan. This system is designed to detect the presence of users at a distance of less than 30 cm using an ultrasonic sensor, which then triggers the SG90 servo motor to automatically open the trash can lid and display information on capacity status and full warnings via a 16x2 LCD screen. After a 2-second delay, the lid will close again to prevent the spread of odors and maintain environmental hygiene. The prototype was developed through a research approach that included direct observation in the campus area, literature studies from reliable sources, and system design with hardware and software integration. Testing was conducted at strategic locations such as rest areas and campus corridors for 10 days, involving 100 trials with 10 daily tests per location. The test results showed a system effectiveness rate of 92%.

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1. INTRODUCTION

Waste is a crucial issue in urban environments, including educational institutions such as the LP3I Polytechnic in Medan. The high volume of waste produced every day is often not matched by the level of awareness among the academic community to dispose of waste properly. In addition to the issue of awareness, technical constraints in conventional waste bins are also an obstacle. Manual waste bins require physical contact to open the lid, which raises concerns about hygiene and the risk of disease transmission through direct contact. This situation calls for innovative solutions to improve efficiency and hygiene in waste management on campus.

Several previous studies have attempted to address similar problems with an automation technology approach. Previous research has designed automatic trash bins using the Waterfall method. The use of this method is considered effective in minimizing system errors due to its structured design stages. Technically, the system utilizes an Arduino Uno microcontroller, an HC-SR04 ultrasonic sensor as an object detector, and an SG90 servo motor as a mechanical driver [1]. Another study focusing on Smart Trash Cans also shows that the integration of distance sensors with microcontrollers can create a responsive, touchless waste disposal system [2].

Based on hygiene issues and referring to existing technological developments, this study proposes the design of an Arduino Uno-based automatic trash can that is specifically implemented at the LP3I Polytechnic in Medan. This system is designed with a mechanism where the HC-SR04 sensor detects the presence of an object (user) at a certain distance. The distance data is then processed by the Arduino Uno microcontroller to command the servo motor to open the trash lid automatically. These components were chosen due to their wide availability and ease of programming and maintenance.

This research aims to design and build a device that can make it easier for students and campus staff to dispose of trash without having to touch the trash can lid. By minimizing physical contact, this device is expected to maintain the cleanliness of users' hands, prevent the transmission of bacteria or viruses, and indirectly increase the awareness and comfort of the academic community in maintaining environmental cleanliness. The results of this design are expected to be a practical solution for appropriate technology that can be applied in public facilities on campus.

2. METHOD

This research was conducted at the LP3I Polytechnic in Medan from May to July 2025. The approach used was an experimental method through prototyping with a structured system development model. The research stages began with the identification of problems related to campus waste management, a literature study on microcontroller technology, system design, hardware and software implementation, and testing of the device's functionality. Data was collected through direct observation of manual waste disposal mechanisms and laboratory experiments to test sensor and actuator responses.

The system design in this study is divided into two main segments, namely hardware and software. On the hardware side, the system architecture consists of three main blocks: input block, process block, and output block. The input block uses two HC-SR04 ultrasonic sensors that function to detect the presence of objects (users) and measure the height of the trash volume in the container. The processing block uses an Arduino Uno R3 microcontroller as the main brain that processes the sensor reading data. The output block consists of an SG90 Servo Motor that functions as an actuator to open and close the trash lid and a 16x2 LCD (Liquid Crystal Display) with an I2C module to display the trash capacity status to the user.

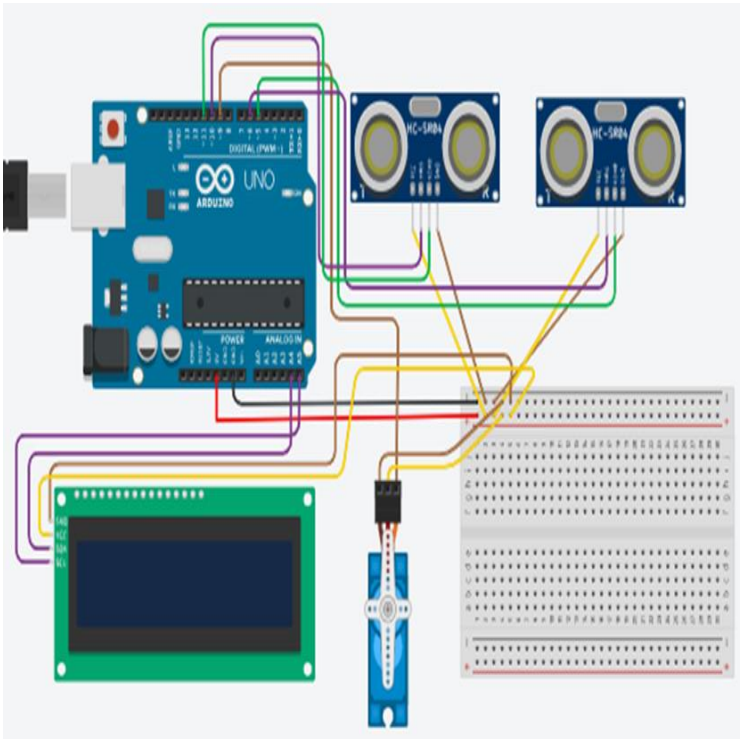

Figure 1. Illustration of system design

To support the design, the specifications of the tools and materials used include a laptop as a workstation, an Arduino Uno microcontroller board, jumper cables (male-to-male and male-to-female) for solderless connections, and a 9V adapter as an external power supply. The electronic schematic design and initial simulation were carried out using Fritzing software, while the program code (sketch) was written and uploaded to the microcontroller using Arduino IDE (Integrated Development Environment).

The system flowchart is designed to operate automatically. When the system is initialized, the first ultrasonic sensor will continuously scan for objects in front of the trash can. If an object is detected within a specified range (e.g., < 30 cm), the microcontroller will send a PWM (Pulse Width Modulation) signal to the servo motor to open the trash can lid. Simultaneously, the second sensor monitors the volume of trash inside the container. If the internal sensor's reflection distance indicates that the trash is nearing the rim of the container, the system will send an instruction to the LCD to display a “Trash Can Full” warning message. Conversely, if the condition is not met, the LCD will display the status ‘Empty’ or “Standby.”

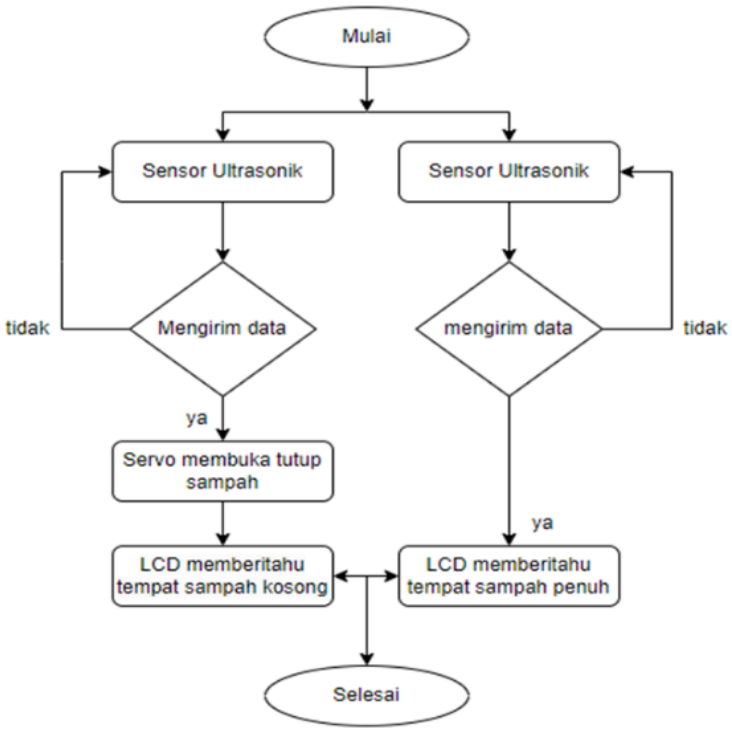

Figure 2. Illustration of system design

The fabrication and integration of components was carried out by placing an HC-SR04 ultrasonic sensor on the front of the casing for accurate user detection, while a servo motor was installed on the main lid hinge to ensure smooth opening and closing mechanics. The Arduino Uno was placed in a separate compartment outside the main container to avoid contact with wet waste or dirt, maintaining the durability of the electronic components. All components are connected according to a simulated circuit diagram to minimize the risk of short circuits or malfunctions during testing.

3. RESULTS AND DISCUSSION

3.1. System Implementation

This research has successfully developed a fully integrated automatic trash can prototype. Physically, the system consists of a modified storage container with an electronic compartment added to the outside to protect the Arduino Uno R3 microcontroller from direct contact with waste. An HC-SR04 ultrasonic sensor is placed on the front of the lid to ensure optimal detection angle for approaching users, while an SG90 servo motor is mechanically mounted on the lid hinge to provide sufficient torque during the opening and closing process. A 16x2 LCD screen is placed on the front panel for easy reading by cleaning staff and users.

Hardware integration is carried out through standard connection lines, where the VCC and GND pins of all components are connected to a 5V power rail. The Trigger and Echo pins on the ultrasonic sensor are connected to the Arduino digital pins for sound wave transmission and reception, while the servo motor signal pins are connected to the PWM (Pulse Width Modulation) pins for precise rotation angle control. Electrical testing shows that the 9V power supply is capable of stabilizing the performance of all components without significant voltage drop when the servo motor is operating.

3.2. Sensor Accuracy Testing

Distance detection accuracy is a key parameter in the success of this system. Testing was conducted by comparing the distance readings by the HC-SR04 sensor to the actual distance measured using a standard measuring stick. Data sampling was carried out at a distance range of 5 cm to 30 cm with a 5 cm increment interval.

Based on the test results, the sensor showed a high level of precision. At a test distance of 15 cm, the sensor was able to read with 100% accuracy (0.0% error). The largest deviation occurred at a very close distance (5 cm) with an error percentage of 4.0%. The overall average error was below 1.5%, indicating that the sensor readings are very suitable for use as a trigger for automation systems. Complete data on the accuracy test results can be seen in Table 1.

Jarak Actual (cm)	Jarak Terdeteksi(cm)	Error (%)
5	5.2	4.0
10	10.1	1.0
15	15.0	0.0
20	20.2	1.0
25	25.1	0.4
30	30.3	1.0

Figure 2. Ultrasonic sensor accuracy testing

3.3. System Performance and Effectiveness

Functionality testing of the entire system was conducted through field testing in the campus rest area over 10 working days. Success was defined as the system being able to open the lid when an object was within 30 cm and close it again automatically after a 2-second delay (delay) according to the programming algorithm. The system algorithm was designed using simple if-else logic: if the sensor reading distance (d) meets the condition d < 30, then the servo rotates 90 degrees; otherwise, the servo returns to the 0-degree position.

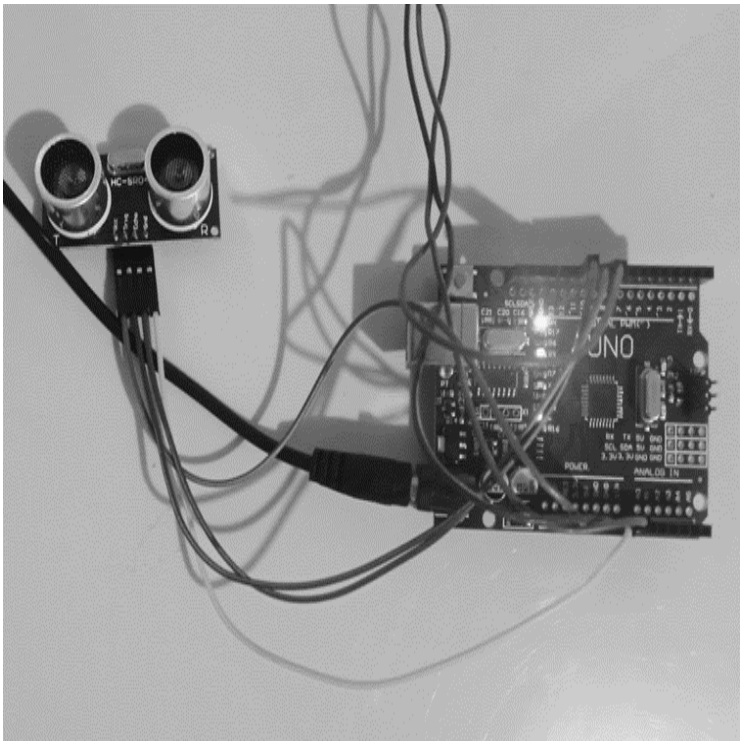

Figure 3. Tests of the HC-RS04 ultrasonic sensor

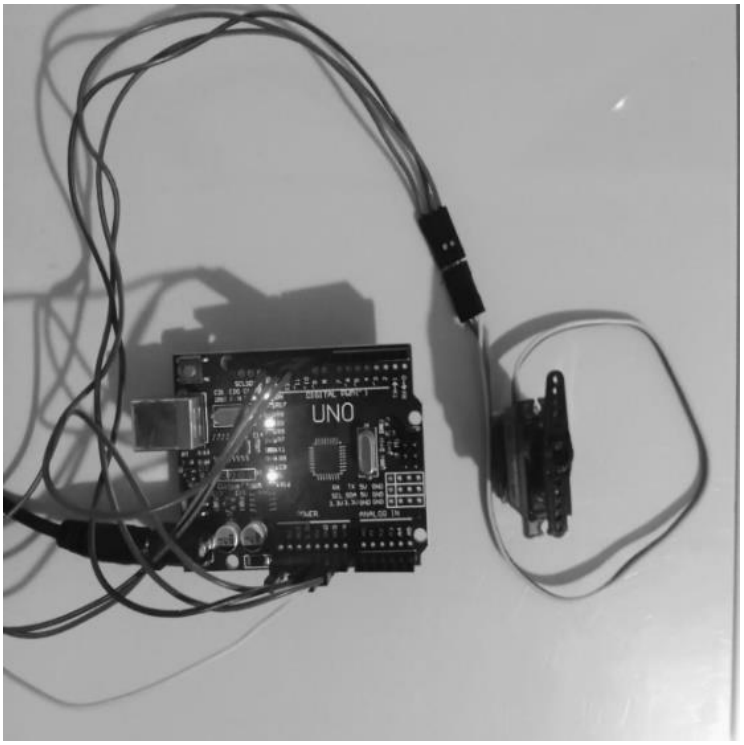

Figure 4. Tests of motor servo

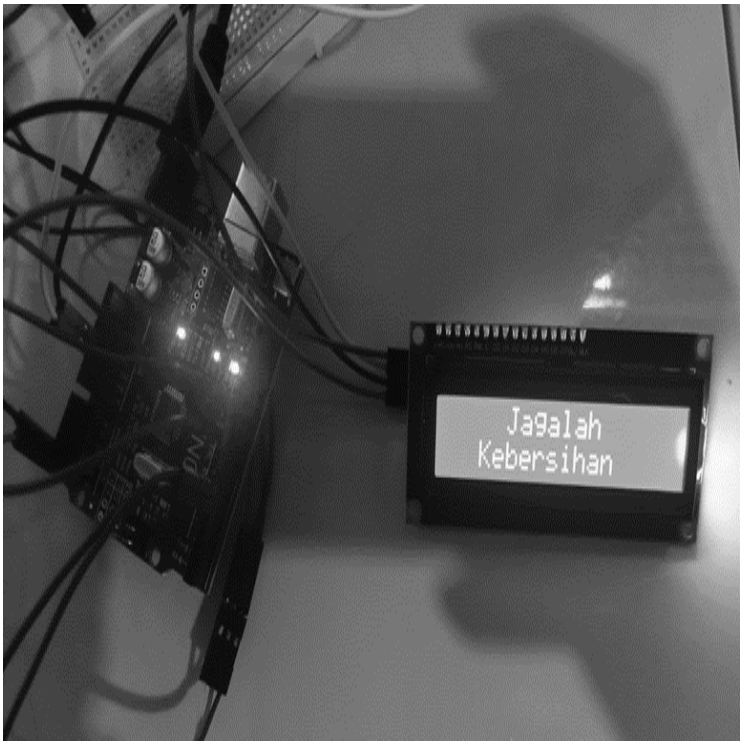

Figure 5. Tests of LCD

Out of a total of 100 triggering attempts (10 attempts per day), the system responded correctly 92 times, resulting in a success rate of 92%. The 8% failure rate was generally caused by objects moving too quickly in front of the sensor (transient objects), preventing the ultrasonic waves from reflecting back to the receiver perfectly. In addition, the LCD notification system functioned as designed, displaying the status "Full" when the internal sensor detected that the volume of waste was approaching the rim of the container, and "Standby" when conditions were normal.

Overall, these results show that the designed prototype can improve user hygiene by eliminating physical contact. Minor obstacles related to sensor response to fast-moving objects can be improved in future research by increasing the sampling rate in the program code or using sensors with industrial specifications.

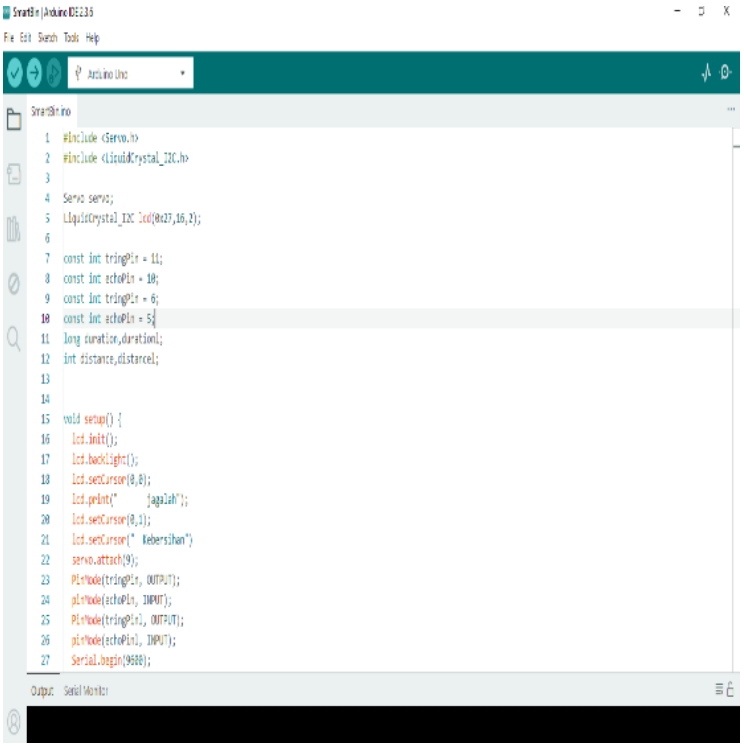

Figure 6. Tests of LCD Source Code Arduino


Figure 7. Final Testing of Equipment (a)

Figure 8. Final Testing of Equipment (b)

4. CONCLUSION

Based on the test results and analysis, this study concludes that the design of an automatic trash bin using an Arduino Uno R3 microcontroller and HC-SR04 ultrasonic sensor has been successfully implemented as an appropriate technology solution at the LP3I Polytechnic in Medan. The system is able to operate responsively by detecting users at an effective distance of less than 30 cm and has a functional test success rate of 92%, as well as sensor reading accuracy with a low average error of 1.52%. The implementation of this prototype has proven to make a real contribution to improving user hygiene by minimizing direct physical contact with public facilities. For further research development, it is recommended to optimize the signal filter to reduce environmental interference, use actuators with industrial specifications for higher mechanical durability, and explore the potential integration with Internet of Things (IoT) technology to enable real-time and remote monitoring of waste capacity.

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