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Development of a Microcontroller-Based Waste Sorting System for Metal and Non-Metal Classification Using an Inductive Proximity Sensor

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The increasing volume of waste requires efficient sorting approaches to support recycling and sustainable waste management. Manual waste separation is labor-intensive, time-consuming, and susceptible to classification errors. This study develops a microcontroller-based waste sorting system for distinguishing metal and non-metal waste using an inductive proximity sensor as the primary detection device. Two HC-SR04 ultrasonic sensors are integrated to monitor the fill levels of metal and non-metal waste bins, while a servo motor directs the classified waste to the corresponding containers. An LCD module provides real-time information on waste classification and bin capacity. The system was developed using a Research and Development (R&D) approach and evaluated through functional testing, waste classification accuracy testing, and bin capacity monitoring. The experimental results showed that the system achieved a metal waste classification accuracy of 53.8% and a non-metal waste classification accuracy of 100%, resulting in an overall classification accuracy of 73.9%. The results indicate that the inductive proximity sensor provides reliable detection of non-metal waste classification but has limitations in detecting metal-containing objects, particularly those affected by surface covering, material characteristics, and object positioning within the sensor's effective detection range. These findings demonstrate the feasibility of the proposed prototype for small-scale and educational waste sorting applications while highlighting the need for further improvement in sensor placement and mechanical feeding design to improve metal detection reliability.

Keywords: waste management, waste sorting, inductive proximity sensor, metal, non-metal

1. INTRODUCTION

The problems in the environment caused by the increasing production of waste, it forces us to find solutions for efficient and sustainable waste management [1], [2]. One important process in waste management is separating waste into metal and non-metal categories. Metal waste, like cans and scrap iron, has high recycling value, while non-metal waste, including plastic and paper, can also be effectively reused if sorted properly [3], [4]. Therefore, accurate waste classification plays a very important role in improving recycling efficiency and can help reduce environmental impact.

Waste sorting that is still carried out manually has many limitations because it requires significant human labor, time, and is highly prone to classification errors [5]. These limitations reduce the overall effectiveness of waste management systems, especially in large-scale or continuous operations [6]. Consequently, the development of automated systems based on microcontrollers and sensors is becoming increasingly important to improve sorting accuracy, efficiency, and operational consistency [7], [8].

Among various sensor technologies, inductive proximity sensors are particularly suitable for detecting metal objects without physical contact [9]. These sensors operate based on the principle of electromagnetic induction and are capable of identifying metal objects within a certain detection range. In addition, ultrasonic sensors can be used to monitor the fill level of trash containers, while servo motors function as actuators to control mechanical sorting mechanisms [10], [11]. The integration of these components enables the development of a fully automated and intelligent waste sorting system.

Several previous studies have explored microcontroller-based waste sorting systems by developing an Arduino-based waste sorting system using proximity sensors; however, these systems still operate semi-automatically and are limited to only one type of metal material [12]. In addition, another study designed an automatic trash bin system using an HC-SR04 ultrasonic sensor, inductive and capacitive proximity sensors with a NodeMCU microcontroller, which can be controlled through a smartphone interface [13]. In another study, a system based on the ATmega2560 was implemented, utilizing proximity sensors for metal detection and soil moisture sensors to differentiate between wet and dry waste, enabling simultaneous classification of three types of waste [14], [15].

This study proposes a fully automated waste sorting system capable of directly distinguishing between metal and non-metal waste using an inductive proximity sensor as the main detection component and a servo motor as the sorting actuator. This system is implemented using an Arduino Uno microcontroller and is equipped with an LCD to display information in real time. The use of an ultrasonic sensor serves to monitor the capacity of the waste container. The proposed system is expected to enhance the efficiency and effectiveness of the waste sorting process, particularly in household-scale and educational environment applications, thereby contributing to smarter and more sustainable waste management practices.

2. METHOD

2.1 Research Design

This study adopts a Research and Development (R&D) method combined with an experimental approach to design, implement, and evaluate a waste sorting system based on a microcontroller. The R&D method is selected to systematically develop a functional prototype capable of identifying and separating metal and non-metal waste through iterative testing and performance evaluation. The experimental approach is applied to validate system functionality, sensor accuracy, and overall system reliability under controlled conditions.

2.2 Research Location and Duration

The research was conducted at the Electrical Engineering Laboratory, Universitas Muhammadiyah Parepare, over a period of approximately ten months, from August 2024 to June 2025. This duration includes system design, hardware integration, software development, testing, and performance evaluation.

2.3 Materials and Components

The proposed system is constructed using several electronic components that operate collaboratively to detect, process, and classify waste materials. At the core of the system is an Arduino Uno based on the ATmega328P microcontroller, which functions as the central controller responsible for processing sensor inputs and controlling the actuators. An inductive proximity sensor (LJ12A3-4-Z/BY) is employed as the primary device for detecting metallic objects, with an effective sensing range of ≤4 mm. The short sensing range is an important characteristic of the sensor and requires metallic objects to pass sufficiently close to the sensing surface for detection. This consideration is incorporated into the mechanical design of the sorting mechanism to maintain an appropriate distance between the waste objects and the sensor. An HC-SR04 ultrasonic sensor is utilized to measure the fill level of the waste containers, while a TD 8120MG servo motor directs the classified waste into the corresponding bins based on the sensor readings. An LCD module is integrated to provide real-time system status information, including metal detection, non-metal detection, and bin capacity conditions. A push button is used as a trigger to initiate the detection process. Supporting components, including a breadboard and jumper wires, are used to establish electrical connections, while 5 V and 12 V power supplies are provided to support stable system operation.

2.4 System Design

The proposed system is designed based on a modular architecture consisting of input, processing, and output subsystems that collaboratively perform waste detection and sorting. The system is specifically developed to identify the type of waste material (metal or non-metal) and subsequently activate a servo motor actuator to direct the waste into the appropriate container automatically.

The input subsystem comprises two main detection circuits. First, the waste type detection circuit utilizes an inductive proximity sensor that operates based on electromagnetic induction principles to detect the presence of metallic materials, even when covered by thin non-metal layers such as plastic or paper. Second, the waste capacity detection circuit utilize ultrasonic sensors (HC-SR04) to measure the fill level of both metal and non-metal waste containers and provide alerts when the bins reach their capacity. Additionally, a push button is integrated as an initial trigger to start the detection and sorting process.

The processing unit is centered on an Arduino Uno microcontroller, which functions as the main controller responsible for receiving input data from all sensors, processing the data, and generating appropriate control signals. Arduino interprets whether the detected object is metal or non-metal and determines the corresponding sorting action.

The output subsystem consists of two main circuits. The sorting actuator circuit, driven by a servo motor, mechanically directs the waste into the designated bin based on the classification result. The servo motor operates at specific angular positions, typically rotating to 180° for metal waste and 0° for non-metal waste. The display circuit utilizes an LCD module with an I2C interface to provide real-time visual feedback to the user, displaying system status messages such as “Metal Waste,” “Non-Metal Waste,” and “Bin Full.”

The overall system operation begins when the push button is pressed, triggering the inductive proximity sensor to detect the material type. The sensor data are processed by the Arduino, which then generates a Pulse Width Modulation (PWM) signal to control the servo motor position accordingly. Simultaneously, the ultrasonic sensors continuously monitor the waste level in each bin. When the measured distance falls below a predefined threshold, indicating that the bin is full, the system displays a notification on the LCD.

As illustrated in Figure 1, the system consists of several interconnected modules, including the display unit, microcontroller unit with an integrated step-down module, waste capacity detection circuits for both metal and non-metal bins, waste type detection circuit, sorting actuator mechanism, and separate containers for metal and non-metal waste. This integrated design ensures that the system operates in real time, providing accurate classification, efficient sorting, and continuous monitoring of waste capacity, thereby enhancing the effectiveness of automated waste management.

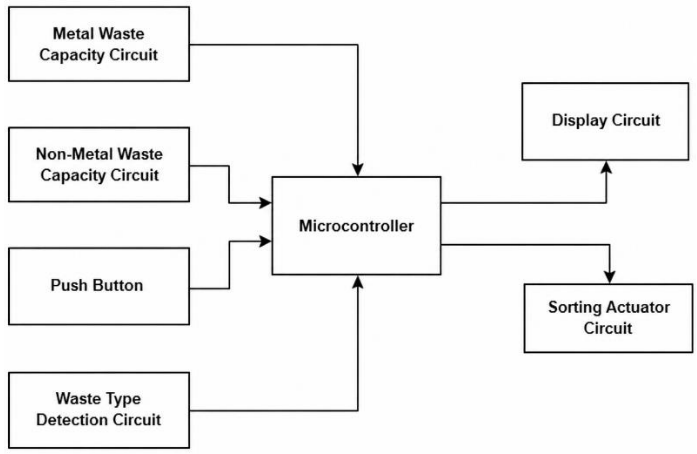

Figure 1. Block Diagram of the Automatic Waste Sorting System

Figure 2. Design of the Waste Sorting System

As illustrated in Figure 2, the proposed waste sorting system consists of several interconnected modules that collectively perform waste detection, classification, sorting, and capacity monitoring. Each module has a specific function that contributes to the overall operation of the system, as described below.

1. Display and Control Unit : This module consists of an LCD display and a microcontroller enclosure containing the Arduino Uno and a step-down voltage regulator. The LCD provides real-time information regarding the system status, including the classification of detected waste as either metal waste or non-metal waste, as well as notifications indicating when a waste bin has reached its maximum capacity. Meanwhile, the Arduino Uno

functions as the central controller that processes sensor inputs and coordinates all system operations, while the step-down module ensures a stable voltage supply for reliable system performance.

2. Metal Waste Bin Capacity Detection Unit : This module employs an HC-SR04 ultrasonic sensor to continuously monitor the fill level of the metal waste container. The sensor measures the distance between the sensor surface and the accumulated waste, allowing the system to determine whether the container has reached its predefined capacity threshold and requires emptying.
3. Non-Metal Waste Bin Capacity Detection Unit : Similar to the metal waste monitoring module, this unit utilizes an HC-SR04 ultrasonic sensor to measure the fill level of the non-metal waste container. Continuous distance measurements enable real-time monitoring of the container capacity and provide timely notifications when the bin is full.
4. Waste Type Detection Unit : The waste type detection module utilizes an inductive proximity sensor to distinguish between metallic and non-metallic objects based on the principle of electromagnetic induction. The sensor detects the presence of metal without physical contact and remains effective even when the metallic object is covered by thin layers of non-metallic materials, such as plastic or paper, provided that the covering thickness does not exceed approximately 0.5 cm. The detection result is transmitted to the Arduino Uno for subsequent waste classification and sorting.
5. Waste Sorting Actuation Unit : This module consists of a servo motor that functions as the mechanical actuator of the sorting mechanism. Based on the classification result provided by the inductive proximity sensor, the servo motor rotates to 180° to direct metal waste into the designated metal waste bin and returns to 0° to direct non-metal waste into the corresponding container. This automated movement enables accurate and efficient waste separation without manual intervention.
6. Metal Waste Bin : This container is specifically designated for collecting waste classified as metallic material. After detection and classification, the servo-driven sorting mechanism directs metal waste into this bin, where its capacity is continuously monitored by the ultrasonic sensor.
7. Non-Metal Waste Bin : This container is used to collect waste classified as non-metallic material. Once the waste is identified as non-metal, the sorting mechanism directs it into this bin, while the ultrasonic sensor continuously monitors the fill level to ensure effective waste capacity management.

2.5 Research Procedure

To provide a clear understanding of the operational workflow, the research procedures of the proposed system are depicted in the form of a flowchart. This flowchart explains the sequential process of system operations, starting from initialization, input detection, decision making, to the execution of sorting mechanisms and system monitoring.

As illustrated in the flowchart, the system begins with the initialization of all components, including the microcontroller, sensors, servo motors, and display module. This process starts when the push button is pressed, prompting the inductive proximity sensor to detect whether the object is metallic or non-metallic. Based on the detection results, the microcontroller processes the input signals and sends control signals to the servo motor to direct the waste to the appropriate bin. Simultaneously, the system updates the LCD to display the classification results.

In addition, an ultrasonic sensor is used to monitor the fill level of the trash container. If the measured distance indicates that the trash bin has reached its capacity threshold, the system will send a notification that will be displayed on the LCD indicating that the trash bin is full. This process operates in a continuous loop to ensure that detection, sorting, and monitoring processes are carried out in real-time, thereby enhancing the efficiency and reliability of the waste management system.

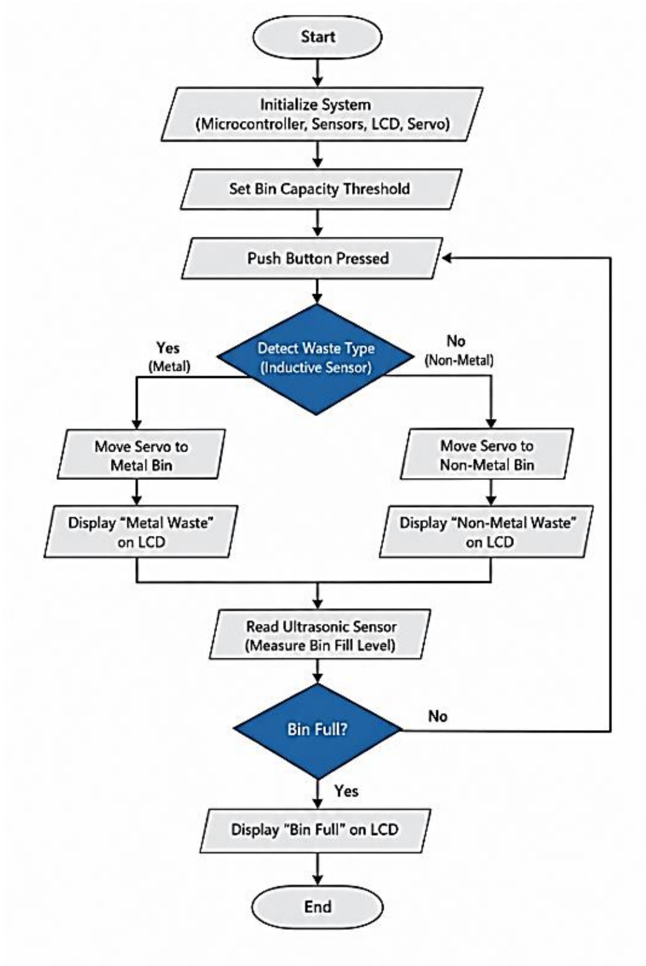

Figure 3. Flowchart of Waste Sorting System

2.5 Testing and Data Acquisition

System testing in this study was conducted to evaluate the accuracy and overall performance of the proposed waste sorting mechanism. The testing process began with functional testing, in which each component, including sensors, the servo motor, and the LCD, was examined both individually and as part of an integrated system to ensure proper operation. Furthermore, detection accuracy testing was performed by introducing various samples of metal and non-metal waste into the system to assess the capability of the inductive proximity sensor in correctly classifying materials. In addition, response time measurement was carried out by recording the time interval between object detection and actuator movement to evaluate system responsiveness. Capacity monitoring testing was also conducted by gradually filling the waste container to verify the accuracy of the ultrasonic sensor in detecting full-capacity conditions.

Data were collected in several forms, including sensor detection results (metal versus non-metal), servo motor response behavior in terms of angle and timing, distance measurements obtained from the ultrasonic sensor, and system status outputs displayed on the LCD. The collected data were subsequently analyzed to determine the reliability of the system, the accuracy of waste classification, and the overall effectiveness of the proposed system in supporting automated and efficient waste management.

3. RESULTS AND DISCUSSION

3.1. Inductive Proximity Sensor Test

The inductive proximity sensor operates based on the principle of electromagnetic field disturbance caused by the presence of conductive metal objects. To evaluate its detection capability and output characteristics, a series of experiments were conducted using various metal and non-metal objects, including a nail, tea box, beverage can, paper, water cup, plastic bottle, and cigarette pack. Each object was positioned in front of the sensing surface, and its distance from the sensor was gradually varied from 5 mm to 1 mm to evaluate the sensor response at different sensing distances. The sensor output voltage and LED indicator status were recorded at each distance interval. The test was conducted under the same sensor operating conditions for all tested objects to provide a consistent basis for comparison between metallic and non-metallic materials. The results of the inductive proximity sensor testing are presented in Table 1.

Table 1. Inductive Proximity Sensor Test Result

No	Object Type	Distance (mm)	Output Voltage (V)	LED
1	Nail	5	0	Off
		4	12.05	On
		3	12.05	On
		2	12.05	On
		1	12.05	On
2	Tea Box	5	0	Off
		4	12.05	On
		3	12.05	On
		2	12.05	On
		1	12.05	On
3	Beverage Can	5	0	Off
		4	12.05	On
		3	12.05	On
		2	12.05	On
		1	12.05	On
4	Paper	5	0	Off
		4	0	Off
		3	0	Off
		2	0	Off
		1	0	Off
5	Water Cup	5	0	Off
		4	0	Off
		3	0	Off
		2	0	Off
		1	0	Off
6	Plastic Bottle	5	0	Off
		4	0	Off
		3	0	Off
		2	0	Off
		1	0	Off
7	Cigarette Pack	5	0	Off
		4	12.05	On
		3	12.05	On
		2	12.05	On
		1	12.05	On

The test results presented in Table 1 indicate that the inductive proximity sensor begins to produce an output voltage of 12.05 V and activates the LED indicator when a metallic object is placed within 4 mm or less from the sensor surface. At a distance of 5 mm, no response from the sensor was observed (output voltage = 0 V), which indicates that the effective detection threshold of the sensor is approximately 4 mm.

Specifically, the sensor demonstrated complete selectivity toward metallic materials. Non-metallic objects, including paper, plastic water glasses, and plastic bottles, did not elicit a sensor response across the tested distance range (1–5 mm), confirming the sensor's inherent resistance to non-conductive materials. An important observation is that cigarette wrappers, which contain a thin inner layer of metal foil (aluminum-based), were successfully detected at distances ≤4 mm. These test results indicate that the sensor remains sensitive in its readings even to thin metal layers. This feature is a crucial characteristic for real-world waste classification scenarios involving composite packaging materials.

Overall, the inductive proximity sensor demonstrated a high detection success rate for all metal objects tested within its effective range. These results confirm that the sensor is highly suitable for integration into automated waste sorting systems designed to distinguish between metal and non-metal waste.

3.2. Ultrasonic Sensor Test

The HC-SR04 ultrasonic sensor was evaluated to assess its accuracy and reliability in measuring object distances for waste-bin fill-level monitoring. The testing methodology involved comparing the ultrasonic sensor readings with manual measurements obtained using a ruler as a reference. Objects were positioned at predetermined distances ranging from 5 cm to 30 cm above a flat surface, and the corresponding sensor readings were recorded for comparison with the reference measurements. The measured distance was defined as the distance between the ultrasonic sensor and the upper surface of the target object. The sensor readings and reference measurements are presented in Table 2.

Table 2. Ultrasonic Sensor Test Result

No	Ruler Measurement (cm)	Ultrasonic Reading (cm)
1	5	5.1
2	10	10.2
3	15	15.3
4	20	20.4
5	25	25.5
6	30	30.6

The test results, as shown in Table 2, demonstrate that the distance measurements using the HC-SR04 ultrasonic sensor, when compared to the actual distance, have a small margin within the tested distance range. The average deviation between the sensor readings and manual measurements is approximately ±0.1 to ±0.6 cm. This systematic positive bias is caused by several physical factors, including the behavior of acoustic wave reflections, environmental temperature fluctuations, and the incidence angle between the sensor and the target surface. Ambient acoustic noise and minor wave interference may also affect this deviation.

Although there are some minor discrepancies, the measurable errors remain within an acceptable tolerance range for waste level monitoring applications, where centimeter-level precision is generally sufficient. The consistency of readings across all six distance points further confirms that the sensor operates stably and reproducibly. Based on these results, the HC-SR04 sensor is considered reliable and accurate for use as a container capacity monitoring component in an automated waste management system.

3.3. Servo Motor Test

The performance evaluation of the servo motor is carried out to provide a correlation between the PWM pulse width input and the rotational angle produced by the TD 8120MG servo motor, which serves to validate the consistency of the control signals generated by the Arduino. This testing is conducted by providing PWM signals with pulse widths ranging from 1000 µs to 2000 µs and measuring the corresponding physical rotational angles using a protractor. An oscilloscope is used simultaneously to ensure signal integrity and timing accuracy. The theoretical rotational angle for each pulse width is calculated using the following linear conversion formula:

$$\text{Angle } (^\circ) = (\text{Pulse Width} - 1000) \times 180 / 1000$$
$$\text{Pulse Width } (\mu s) = (\text{Angle} \times 1000 / 180) + 1000$$

Table 3 presents the complete test results, illustrating the correspondence between applied pulse widths, calculated theoretical angles, and the observed servo positions.

Table 3. Servo Motor Test Result

No	Pulse Width (µs)	Calculated Angle (°)	Description
1	1000	0°	Initial Angle
2	1200	36°	Position 1
3	1350	63°	Position 2
4	1500	90°	Center Angle
5	1700	126°	Position 3
6	1850	153°	Position 4
7	2000	180°	Maximum Angle

The test results indicate that the TD 8120MG servo motor can respond accurately to all tested PWM pulse widths, producing rotation angles very close to the theoretical values using the conversion formula. Measurements with an oscilloscope were used to validate that the PWM signals generated by the Arduino microcontroller correspond to the pulse widths set using microsecond time units. No significant lag, oscillation, or mechanical backlash was observed during transitions between angular positions.

The servo demonstrated reliable bidirectional motion across the full 0° to 180° range, which is essential for the waste sorting mechanism where rotation to 0° directs waste toward the non-metallic bin and rotation to 180° directs waste toward the metallic bin. The combination of software-based PWM generation verified by oscilloscope measurements establishes a high level of confidence in the electromechanical performance of the servo actuation subsystem.

3.4. Metal Waste Classification Test

The next testing was conducted to evaluate the performance of the automated waste sorting system that has been integrated to direct and identify metal objects to the appropriate trash bins. In this experimental phase, a total of 13 trials were carried out using objects with varying metal compositions, shapes, and surface conditions. A proximity sensor was used to determine the metal content, while a servo motor directed the waste to the metal bin (left rotation, 180°) or the non-metal bin (right rotation, 0°) as required. The classification results were displayed on a 16×2 LCD screen. The test results are presented in Table 4.

Table 4. Metal Waste Classification Test Result

No	Object Type	Sensor Detection	LCD Display	Servo Rotation
1	Tea Box	Detected	Waste Detected — Metal Waste	Left (180°)
2	Bear Brand Milk	Detected	Waste Detected — Metal Waste	Left (180°)
3	Can A	Detected	Waste Detected — Metal Waste	Left (180°)
4	Cigarette Pack A	Detected	Waste Detected — Metal Waste	Left (180°)
5	Battery A	Not Detected	Waste Detected — Non-Metal Waste	Right (0°)
6	Ultra Milk	Detected	Waste Detected — Metal Waste	Left (180°)
7	Cigarette Pack B	Not Detected	Waste Detected — Non-Metal Waste	Right (0°)
8	Aluminum A	Detected	Waste Detected — Metal Waste	Left (180°)
9	Iron	Detected	Waste Detected — Metal Waste	Left (180°)
10	Can B	Not Detected	Waste Detected — Non-Metal Waste	Right (0°)
11	Battery B	Not Detected	Waste Detected — Non-Metal Waste	Right (0°)
12	Cigarette Pack C	Not Detected	Waste Detected — Non-Metal Waste	Right (0°)
13	Aluminum B	Not Detected	Waste Detected — Non-Metal Waste	Right (0°)

Out of a total of 13 metal waste trials, the system successfully detected and correctly classified 7 objects, resulting in a metal waste classification accuracy of 53.8%, while 6 objects were not detected and were consequently classified as non-metal waste. The detection results varied among the tested objects, including batteries, cans, cigarette packs, and aluminum materials. This variation indicates that the inductive proximity sensor did not respond consistently to all metal-containing objects under the tested conditions. An important distinction should be made between metal-containing objects and directly exposed metallic targets when interpreting these results. An inductive proximity sensor responds to the electromagnetic characteristics of the material present within its sensing area rather than simply determining whether an object contains a metallic component. Therefore, an object may be categorized as metal-containing waste but may not produce a sufficient sensor response when the metallic component is covered by a non-metallic material, has a limited exposed metallic surface, or is not positioned sufficiently close to the sensing area. In contrast, a directly exposed metallic target located within the effective sensing range is more likely to produce a detectable response. This distinction may explain the inconsistent detection observed among objects with similar general classifications, such as the different can, cigarette pack, and aluminum samples listed in Table 4. The results indicate that the metal classification performance of the proposed system is dependent on the physical characteristics of the target objects and their interaction with the sensing area. However, the present experiment did not independently control or quantitatively evaluate variables such as sensor-to-object distance, object orientation, exposed metallic surface area, material composition, or covering thickness. Therefore, the individual contribution of these factors to the six detection failures cannot be conclusively determined from the current dataset. The 53.8% metal classification accuracy should consequently be interpreted as an indication of the limitations of the current sensor configuration under the tested waste-sorting conditions, rather than as a definitive measure of the sensor's performance for all types of metal-containing waste.

3.5. Non-Metal Waste Classfication Test

The non-metal waste classification test was designed to assess the specificity of the short-range inductive sensor with non-conductive materials. In this setup, if the waste is not detected, it will send a command to the servo motor to rotate to 0° (right) and the LCD will display "Non-Metal Waste Detected." A total of 10 trials were conducted using various non-metal materials including plastic bottles, glass, tissue, paper, food wrappers, and drink pouches. Table 5 summarizes the results of these experiments.

Table 5. Non-Metal Waste Classification Test Result

No	Object Type	Proximity Sensor	LCD Display	Servo Rotation
1	Bottle	Not Detected	Waste Detected — Non-Metal Waste	Right 0°
2	Plastic	Not Detected	Waste Detected — Non-Metal Waste	Right 0°
3	Water Cup	Not Detected	Waste Detected — Non-Metal Waste	Right 0°
4	Glass	Not Detected	Waste Detected — Non-Metal Waste	Right 0°
5	Tissue	Not Detected	Waste Detected — Non-Metal Waste	Right 0°
6	Paper	Not Detected	Waste Detected — Non-Metal Waste	Right 0°
7	Food Wrapper	Not Detected	Waste Detected — Non-Metal Waste	Right 0°
8	Beverage Sachet	Not Detected	Waste Detected — Non-Metal Waste	Right 0°
9	Drink Bottle	Not Detected	Waste Detected — Non-Metal Waste	Right 0°
10	Plastic	Not Detected	Waste Detected — Non-Metal Waste	Right 0°

As shown in Table 6, the system achieved a classification accuracy of 100% across all 10 non-metal waste trials. The inductive proximity sensor did not produce false positive responses to the non-conductive materials tested, indicating complete specificity to metallic substances. These results confirm the inherent selectivity of electromagnetic induction-based sensor technology, which is physically incapable of generating eddy currents in non-conductive materials.

4. CONCLUSION

This study developed a prototype waste sorting system based on an Arduino Uno, inductive proximity sensor, HC-SR04 ultrasonic sensors, and a servo motor for distinguishing metal-containing and non-metal waste. The experimental results showed that the system achieved a metal waste classification accuracy of 53.8% and a non-metal waste classification accuracy of 100%, resulting in an overall classification accuracy of 73.9%. The relatively low metal detection accuracy indicates that the current configuration has limitations in reliably detecting metal-containing objects under the tested waste-sorting conditions. In particular, the inductive proximity sensor responds to the electromagnetic characteristics of the material present within its sensing area, meaning that the presence of metal within an object does not necessarily guarantee detection when the metallic component is not sufficiently exposed or positioned within the effective sensing range. Therefore, the proposed system should be regarded as a functional prototype rather than a fully reliable solution for general-purpose waste sorting. Future development should focus on improving the mechanical feeding channel to maintain a more consistent distance and orientation between waste objects and the inductive sensor. The use of complementary sensing technologies may also be investigated to improve the detection of metal-containing objects that are difficult to identify using inductive sensing alone. Further experiments are required to quantitatively evaluate the effects of sensor-to-object distance, object orientation, exposed metallic surface area, material composition, and non-metallic covering on metal detection performance.

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