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Smart Recycling Bins Segregation Automatically

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Abstract

Malaysia faces a critical waste management challenge as its landfills are near full capacity which is risking the exhaustion of space for solid waste disposal by 2050. Waste segregation is an effective strategy to reduce waste and boost recyclable numbers. This development introduces smart recycling bins that automatically segregate using an inductive proximity sensor for metal detection and an LDR sensor for identifying plastic and paper. Two servo motors execute the segregation process. The mechanical system consists of servo motors that rotate flaps which allow the trash to fall into the target receptacle. Ultrasonic sensors monitor garbage levels and then notify through Blynk and activate LEDs when bins are full. The system can operate on a 9V 2A external power supply. Results reveal an 80% accuracy for inductive proximity sensors detecting metal and a 50% accuracy for LDR sensors detecting plastic and paper. This system enables real-time monitoring through applications, enhancing management alertness for timely cleaning efforts.

1. Introduction

The topic of rubbish pollution is frequently discussed, even in Malaysia. In 2022, it is reported that 36,699 tons of garbage will be thrown away every day. This means that every Malaysian throws away 1.17kg of solid waste on average. Even if we have many landfills, the remaining space will eventually fill up. A landfill may typically be used for 25 years [1]. So, we need to reduce the disposal of solid waste in the trash and prioritize recycling as long as we can. Waste segregation is an effective way to reduce waste while increasing the number of recyclables. Recycling is turning waste materials into new materials and objects [2]. Some People do throw garbage not according to the proper bins. Proper segregation at source is the first step with these methods. This is implemented to improve the volume of waste recycled and treated. This paper proposes an automated recycle bin segregating system that will be able to classify the type of waste using the material sensors.

2. Methodology

2.1 Block Diagram

The block diagram illustrates the components and connections for a Smart Recycling Bin Segregation Automatically (SRBSA). Fig.1 shows that Arduino Mega is a primary microcontroller for this particular work. Adding ESP8266 is to enable Wi-Fi capabilities on the Arduino board. The proximity sensor serves as the input component of the system. The proximity sensor detects the presence of objects or waste materials in the recycling bin. Proximity sensors will be used here are Inductive Proximity Sensor, LDR Sensor and Ultrasonic Sensor. The servo motors are an output component of the system. It is responsible for controlling the movement of the segregation mechanism in the smart recycling bin. The servo motors can open and close the flap within the recycling bin to segregate different types of waste materials. Blynk is a mobile app that facilitates monitoring the level of each receptacle in smart recycling bins. Once the bins are full, the notification will pop up as an alert to the management to empty the recycle bins. LEDs are output components used to provide visual feedback to the user. Red LEDs indicate the status of detecting the presence of garbage until the end of the segregation process, while Green LEDs can be employed to indicate the status of the bin when the target receptacle is full.

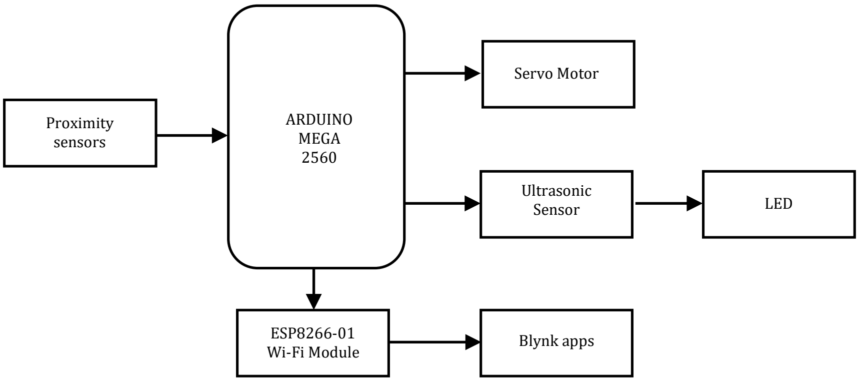

Fig.1 *Block diagram of Smart Recycling Bins Segregation Automatically*

2.2 Flowchart

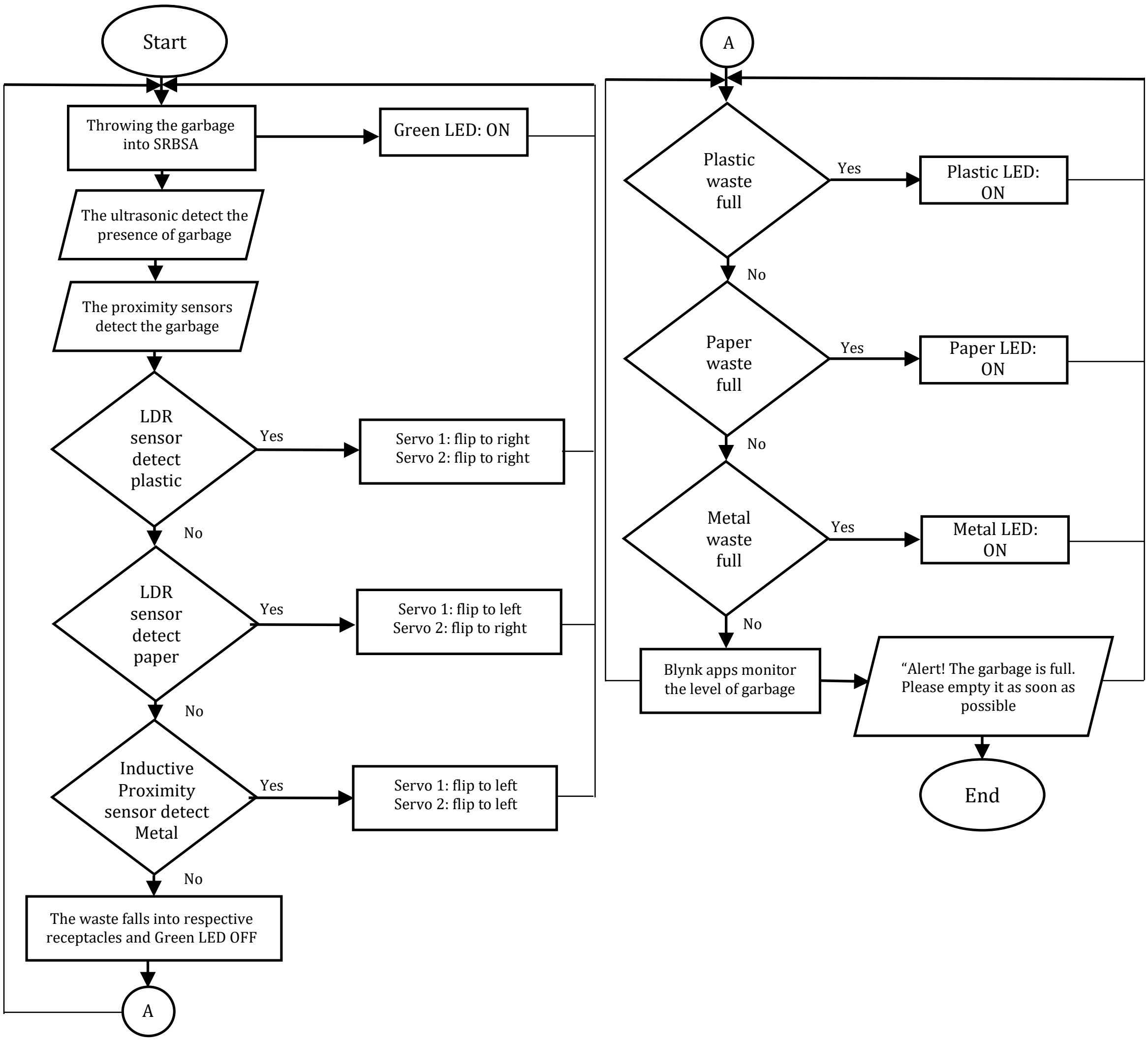

Fig.2 *Flowchart of Smart Recycling Bins Segregation Automatically system*

Fig.2 shows the flowchart of the system process flow. The system starts when the users throw the garbage in the SRBSA. The ultrasonic sensor will detect the presence of incoming waste, and the green LED will light up to indicate that the ultrasonic sensor has detected the presence of waste. Subsequently, 3 sensors will identify each type of garbage. LDR Sensor is for detecting the plastic and paper waste, while inductive proximity sensor is for detecting the metal.

If the LDR sensor detects the plastic, servo 1 will flip the flap to the right, then servo 2 will flip the flap to the right. Next, if the LDR sensor identifies the paper, servo 1 will flip the flap to the left, then servo 2 will flip the flap to the right. Other than that, when the inductive proximity sensor detects the metal, servo 1 will flip the flap to the left, and then servo 2 will flip the flap also to the left.

Once the waste has dropped into its corresponding receptacle, an ultrasonic sensor is used to measure the level of the trash in each receptacle and it will be monitored on the Blynk application. When the receptacle is full of garbage, the red LED for that receptacle will ON to signal it is full to the users. The Blynk will send the notification to the management to empty the receptacle as soon as possible. This system facilitates the work of cleaning and segregating the waste.

2.3 Hardware and Software Requirements

2.3.1 Hardware Requirement

Table 1 lists all the components needed in this work. Whilst Fig. 3 shows the circuit diagram of the proposed system.

Table 1 *List of components and their functions*

No.	Components	Function
1	Arduino Mega 2560	Primary microcontroller
2	ESP8266 Wi-Fi Module	Internet connectivity
3	Inductive Proximity Sensor	Metal detection
4	Light Dependent Resistors (LDR) Sensor	Paper and plastic detection
5	Ultrasonic Sensor	For detecting the presence of garbage and monitoring the level of garbage.
6	MG995 Metal Servo Motors	For segregation process
7	Light-Emitting Diode (LED)	Green LED: Indicates the presence of garbage and turns ON until the segregation process is done. White LED: Gives light to the LDR sensor. Red LEDs: Notify when garbage is full.
8	LM2596 DC-DC Adjustable Step-Down Converter	Grounding and providing input voltage from the power supply.
9	Adapter 9V 2A	External power supply

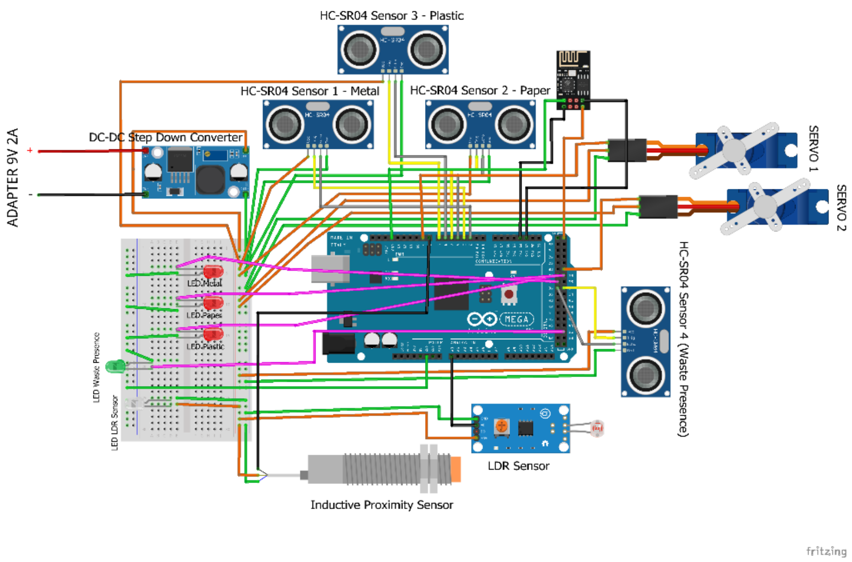

Fig.3 *Circuit diagram of smart recycling bins segregation automatically hardware*

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2.3.2 Software Requirement

The software makes sure that all the hardware components work together smoothly and allows the smart recycling bins system to operate in real time.

1. Arduino IDE : The Arduino IDE is a popular open-source software used for programming Arduino microcontrollers. It serves as the primary software tool for writing and uploading code to the Arduino board.
2. Blynk Platform : An IoT platform that enables the development of custom mobile applications for controlling and monitoring connected devices. Through the Blynk mobile app, users can receive real-time updates on the waste level and get a notification when the waste level is full. It will display the level in percentage, and when it reaches 96% to 100%, it will send a notification and activate the LED on the SRBSA model.

2.4 Hardware Development

This study also develops the model of SRBSA. The model is constructed from 9mm plywood, taking on a rectangular shape with dimensions. The measure is 4 feet x 2 feet x 2 feet. The design is convenient for the segregation process as shown in Fig.4 (a). The model consists of three areas which are the detection area, segregation area, and garbage receptacle area.

In Fig.4 (b), this section includes an ultrasonic sensor that functions to indicate the presence of waste. There is also a white LED next to the right hole for users to dispose of waste through it. On the servo 1 stem, an inductive proximity sensor and an LDR sensor are placed to enhance the effectiveness of waste detection by these sensors.

In the middle section as shown in Fig.4 (c), two servo motors are installed for the segregation process according to the types of waste disposed. Then, the lower part of SRBSA is known as the Garbage Receptacle Area, where ultrasonic sensors have been installed for each receptacle to monitor the waste level. The receptacles have been separated according to the types of waste, which the paper waste at the back left, metal waste at the back right and plastic waste at the front.

(a) (b) (c)

Fig.4 *SRBSA Model overview (a) SRBSA Model; (b) Upper section; (c) Middle and lower section*

2.5 Working Principle of SRBSA

Fig. 5 to 7 demonstrate the real system of the SRBSA process being executed to segregate different types of waste which are plastic, paper, and metal.

Fig. 5 *Paper Segregation Process*

Fig. 6 *Plastic Segregation Process*

Fig. 7 *Metal Segregation Process*

The movement of the two servo motors is according to the positions they are installed in. Table 2 summarized the segregated working principle.

Table 2 *Segregated working principle*

Type of waste	Proximity sensor	Segregate movement	Waste receptacle
Paper	LDR Sensor	Servo 1: Left Servo 2: Right Value: > 3V	Back and left
Plastic	LDR Sensor	Servo 1: Right Servo 2: Right Value: <3V	Front
Metal	Inductive Sensor	Servo 1: Left Servo 2: Left Value: 0 (Detection) 1 (No detection)	Back and right

3. Result and Discussion

3.1 Result

This work focuses on three types of waste which are plastic, paper, and metal. The segregation process on the servo motor is programmed for three different movements so that each type of waste with different materials goes into the designated receptacle according to its waste type. Fig. 8 shows that each type of waste is placed in its designated receptacle due to the segregation process executed by the servo motor according to the type of waste. With this segregation in place, the recycling process becomes more straightforward as the waste is no longer mixed.

Fig.8 *The types of waste are separated according to their respective receptacles*

3.2 Analysis of Proximity Sensor Accuracy During Waste Segregation Process

An analysis is conducted to study the waste detection accuracy through the utilization of proximity sensors. The focus of this investigation is to evaluate the precision of these sensors in discerning various types of waste materials, including metal, paper, and plastic. Through a comprehensive examination, each waste category undergoes 10 tests to the effectiveness of the proximity sensor in accurately identifying and distinguishing the unique characteristics of the materials.

3.2.1 Analysis of Inductive Proximity Sensor Accuracy

Metal has a high accuracy, where when a metal object touches the inductive proximity sensor, the first servo will immediately flip the flap for the segregation process without any delay. It needs to ensure that metal waste comes into direct contact with the inductive proximity sensor. Ten types of metal objects were used for testing to determine the accuracy of metal waste.

Table 3 shows the result of testing with these 10 types of metal, in which it was found that only 80% could be detected by the inductive proximity sensor, while 20% could not be detected. Due to the limited range of accuracy of this inductive proximity sensor, it has some errors in its effectiveness.

Table 3 *The results of the effectiveness of the inductive proximity sensor*

No.	Waste	Time taken (s)	Result (0/1)
1	Beverage can 1	4s	0
2	Beverage can 2	7s	0
3	Screw	3s	0
4	Scissor	5s	0
5	Spoon	4s	0
6	Crushed beverage can	2s	0
7	Sauce travel packet	11s	0
8	Tyeso tumbler	11s	1
9	Smartwatch frame	11s	1
10	Stapler	7s	0

From the result in Table 3, 0 is a metal detection and 1 is no detection. These are the readings from the programming that appeared on the serial monitor in Arduino IDE. It can be seen that the crushed beverage can have high accuracy, taking only 2 seconds for the sensor to detect the can. This is because the crushed beverage can is more static in its position compared to a normal beverage can that can easily roll for the sensor to detect the object. Even though the Tyeso tumbler is a metal tumbler, the inductive sensor cannot detect it because the body material of the tumbler is stainless steel. Similarly, the strap of a smartwatch has a metal frame, but the inductive sensor cannot detect it due to the distance between the smartwatch and the sensor.

3.2.2 Analysis of LDR Sensor Accuracy

This analysis focuses on the examination of a specialized LDR sensor designed for the detection of paper and plastic waste. The program logic defines that a voltage reading greater than 3V signifies the detection of paper, while a voltage reading below 3V indicates the identification of plastic. Through a systematic evaluation involving controlled experiments, this research aims to assess the LDR sensor's efficacy in accurately distinguishing between paper and plastic materials within a waste context.

For the paper and plastic detection, there is a limitation in this work with the LDR sensor. The time taken by the first servo motor to read the signal from the LDR sensor is 10 seconds after the ultrasonic sensor detects the presence of waste. Therefore, other types of waste may potentially be detected as paper or plastic based on the light received by the LDR sensor.

Based on the observation of the results in Table 4, the LDR sensor does not detect paper waste only because it operates based on darkness. Since paper has a dark characteristic, the LDR sensor easily detects paper waste. The test results for 10 objects obtained values of 3V and above, as programmed. However, the possibility of detecting other types of waste is also high, as long as the waste has a dark material, including dark plastic. In this test, the candy wrapper, which has plastic material, was also detected as paper because of its dark colour which blocks the light to the LDR. Similarly, the plastic casing of the calculator was detected as paper because it showed a reading of 3.91 V, which is the reading for paper waste. This is an error for the LDR sensor, which should ideally focus only on paper and plastic materials.

Table 4 *The results of the effectiveness of the LDR sensor for paper detection*

No.	Waste	Voltage reading (V)	Identification
1	Crumpled paper	4.69 V	Paper type
2	A4 paper	4.47 V	Paper type
3	Beverage cup	4.24 V	Paper type
4	Cardboard	4.59 V	Paper type
5	Candy wrapper	3.76 V	Non-Paper type
6	Piece of box	4.83 V	Paper type
7	Paper bag	4.37 V	Paper type
8	Casing calculator	3.91 V	Non-Paper type
9	Gift wrapper	3.13 V	Paper type
10	Fabric	3.42 V	Non-Paper type

In Table 5, the results for the effectiveness of the LDR sensor for plastic detection show readings less than 3V except for the candy wrapper, which is above 3V. For reading plastic, anything that the ultrasonic sensor detects as a presence will be identified as plastic. This is because plastic is programmed to detect brightness. Transparent plastic has a higher possibility of being detected as plastic compared to coloured plastic. The accuracy of the LDR sensor in detecting only paper and plastic for the segregation process is 50% because the rest may not be detected based on material due to the influence of light. However, the effectiveness of the accuracy of the LDR sensor in detecting light and darkness is 97%. For paper and plastic waste, improvements can be made by using more suitable sensors, such as capacitive proximity sensors. Achieving effectiveness is crucial to realizing technology in recycling objectives.

Table 5 *The results of the effectiveness of the LDR sensor for plastic detection*

No.	Waste	Voltage reading (V)	Identification
1	Transparent beverage lid 1	0.41 V	Plastic type
2	Transparent beverage lid 2	0.41 V	Plastic type
3	Dark beverage lid	1.92 V	Plastic type
4	Transparent plastic bag	0.40 V	Plastic type
5	Red plastic bag	0.89 V	Plastic type
6	Candy wrapper	4.83 V	Plastic type
7	Plastic container lid	1.90 V	Plastic type
8	Crushed mineral water bottle	1.91 V	Plastic type
9	Empty mineral water bottle	1.91 V	Plastic type
10	Straw	0.42 V	Plastic type

3.2.3 Calculation

The LDR sensor is connected to a circuit, and the voltage output from the sensor (V) is related to the resistance of the LDR. The relationship between resistance (R) and voltage (V) can be described using Ohm's Law. It has a constant current (I) and the LDR resistance decreases when exposed to light and increases when in the dark. The current (I) is kept constant at 1 mA. The formula becomes:

$$Voltage\ (V) = 0.1\ mA\ x\ Resistance\ (R) \tag{1}$$

Based on equation (1), assume in bright light conditions, the LDR resistance is 2 kΩ yields the result below than V, therefore, it resulting the plastic is detected.

$$V = 0.1\ mA\ x\ 2\ k\Omega$$
$$= 2\ V$$

In low light conditions, the LDR resistance increases to 5 kΩ yields the result of equation (1) greater than 5V which indicate the paper is detected.

$$V = 0.1\ mA\ x\ 5\ k\Omega$$
$$= 5\ V$$

3.3 Waste Level Monitoring

This section is for monitoring the waste level so that authorities can be alerted to empty the Smart Recycling Bins with Automatic Segregation when they are full. With the convenience of modern technology, authorities can empty the bins more frequently, reducing waste buildup. At the same time, users can also be noticed when the bin is full, prompting them to dispose of their waste in another bin. Waste level monitoring is divided into two aspects, catering to both authorities and users.

3.3.1 Blynk Monitoring

Designing a Blynk application dashboard for a smart recycling bin segregation involves creating an interface that allows users to monitor the bin's functionalities. It displays real-time information about the recycling bin's status and ultrasonic sensor readings for the level of waste. Clear visual cues such as a value display bar and LED bar to represent these measurements. As shown in Fig.9, the value display bar will display the percentage of volume in the target receptacle. The LED bar refers to the physical red LED at the model hardware when the garbage is full. Notifications and alerts are implementing a notification system to inform the authorities when the recycling bin reaches its maximum capacity or when specific waste types are full. These notifications can be sent as push notifications, or within the dashboard itself. This allows users to monitor and control the recycling bin from anywhere.

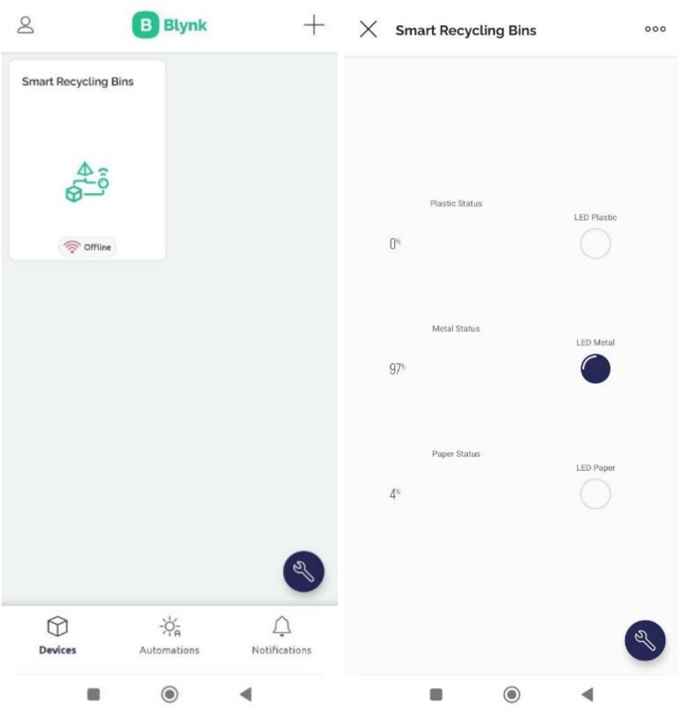

Fig.9 *Blynk dashboard on mobile application*

3.3.2 LED Notification

Fig.10 shows that the red LEDs serve as a notification for a full waste level to inform users. The ultrasonic sensor plays the role of monitoring the waste level and sends data to the red LED when the waste reaches full capacity. The red LED will remain ON until the waste level decreases or until the authorities collect the waste. These LEDs are installed so that users are aware when the recycling bins for specific types of waste are full, prompting them to dispose of their waste in other bins. This system helps prevent waste overflow and promotes a more efficient waste management process.

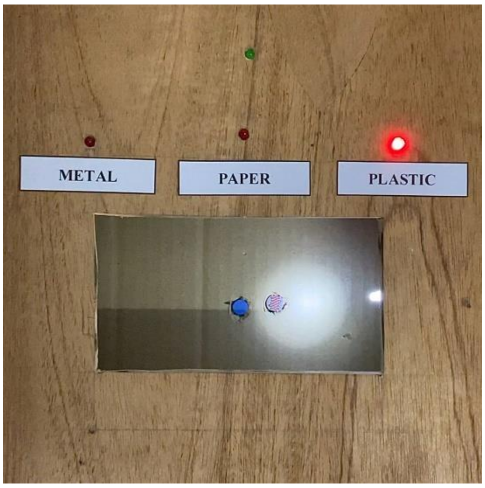

Fig.10 *Paper LED is ON when the paper receptacle is full*

4. Conclusion

To sum up, this work has accomplished a great deal in reaching its stated goals. The goal of the first objective was to create a waste segregation mechanism that could use trained optical and material sensors to sort waste into receptacles made for plastic, paper, and metal waste. Within the detection area, proximity sensors efficiently determine the different types of waste and send this information to servo motors for accurate segregation. After the waste has been separated, it is directed to areas designated for receptacles. This work faced difficulties in achieving its second goal, which was to monitor waste levels using mobile apps. Regretfully, efforts to use the Blynk application for waste level monitoring were not successful. However, despite the setback of unsuccessful monitoring implementation, the LED notification is functioning to notify the waste fullness. This work successfully executed the waste segregation process, effectively utilizing optical and material sensors along with servo motors. The success achieved in waste segregation underscores the robustness of the control system, highlighting the need for further refinement in the IoT aspect for future implementations.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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