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Development of Home Applied Waste Segregation and Management System

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Abstract

The escalating quantity of waste and irresponsible dumping practices have raised concerns due to their detrimental impact on human health and the environment. Previously, waste in dumping sites was manually sorted, presenting significant challenges such as health risks, high manpower requirements, and excessive funding. Manual waste sorting at home is time-consuming and causes delays in recycling processes. Addressing these issues, an advanced waste segregation system has been developed to enhance recycling efficiency. The home waste segregation system efficiently categorizes waste into three main types: dry waste, wet waste, and metallic waste. Users simply deposit their waste onto a mechanical flap. A rain sensor determines the water content of the waste material, enabling the segregation of wet and dry waste. Additionally, a photoelectric metal sensor prioritizes the detection of metallic waste. An ultrasonic sensor measures the waste level within the waste bins. Detailed information about the waste disposal system is regularly updated on a server and displayed on a Liquid Crystal Display (LCD). When a waste bin reaches its maximum capacity, waste management personnel promptly receive updates through a Wi-Fi module via WhatsApp.

Keywords: Waste Segregation, ESP32, Ultrasonic Sensor, Moisture Sensor, Photoelectric Metal Sensor, LCD.

INTRODUCTION

As society has advanced, people have increasingly sought the comforts and conveniences of life within their homes. Urbanization is now seen as a key indicator of a country's level of development. However, the rapid urbanization and the concentration of people in cities have also given rise to various challenges, including traffic congestion, health issues, and security concerns. One crucial matter that requires careful attention in urban areas is the establishment

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and effective operation of a waste segregation system (Monisha et al., 2021). Unfortunately, it is often observed that this process is either poorly executed or the personnel responsible for its operation lack the necessary efficiency, leading to numerous unwanted health problems. Waste management involves the collection, disposal, and treatment of waste material that is discarded because it has fulfilled its purpose or is no longer useful. Improper Segregation of house waste can create unsanitary conditions, and these conditions in turn can lead to pollution of the environment and to outbreaks of vector-borne disease that is, diseases spread by rodents and insects. Waste management encompasses the tasks and measures necessary to handle waste from its initial generation to its ultimate disposal (Ajinkya et al., 2022). This encompasses activities such as waste collection, transportation, treatment, and disposal, as well as the monitoring and regulation of the entire waste management process. Waste can take the form of solids, liquids, or gases, and each type requires specific methods of disposal and management (Md-Abdullah et al., 2021). The scope of waste management covers various types of waste, including industrial, biological, and household waste. Waste management is intended to reduce the adverse effects of waste on human health, the environment (Elzeiny et al., 2021).

Waste management practices are not uniform among countries of developed and developing nations, it is also not same in regions of urban and rural areas, likewise residential and industrial sectors can all take different approaches. A large portion of waste management practices deals with municipal solid waste (MSW) which is the bulk of the waste that is created by household, industrial, and commercial activity (Awuchi et al., 2020). The Internet of Things (IoT) is a concept in which surrounding objects are connected through wired and wireless networks without user intervention (Abba et al., 2019). In the field of IoT, the objects communicate and exchange information to provide advanced intelligent services for users (Keyur and Sunil. 2016). Owing to the recent advances in mobile devices equipped with various sensors and communication modules, together with communication network technologies such as Wi-Fi and LTE, the IoT has gained considerable academic interests (Akhil, 2017). Sandhya et al., (2018) worked on Automatic Waste Segregation System, they present a system that is able to detect waste autonomously and separate it accurately by using a deep neural network for waste recognition. With waste recognition and automatic navigation functions, the system can efficiently and autonomously clean waste on the ground in places like parks or schools. The hardware architecture of the system includes a module Raspberry Pi, a webcam, PIC microcontrollers (Okomba et al., 2018), EEPROM memory, a DC motor, a pick and place robotic arm, infrared and ultrasound sensors, a gyroscope, and GPS sensors. Ajay et al., (2020) worked on Automatic Waste Segregation and Management system aiming to address the issue of waste mismanagement, particularly the large amount of waste being disposed of in ways that harm the environment. The authors identify industrial and domestic waste as major contributors to the overall waste problem. To achieve this goal, the authors propose a solution in the form of a smart dustbin. The smart dustbin is not only cost-effective but also designed to facilitate efficient waste segregation (Kamlesh et al., 2021).

Sharanaya et al., (2017) worked on Automatic waste segregator, the authors highlight on waste detrimental impact on health and the environment. They propose a practical solution that focuses on waste segregation at the disposal level, emphasizing the cost-efficiency and compactness of their proposed system. The Arduino UNO microcontroller is utilized in the system to ensure smooth and convenient operation, reducing complexity (Aditya et al., 2021). The system incorporates sensors that detect the different types of waste, allowing for their appropriate disposal into assigned bins. Amrutha et al., (2014) worked on Automatic waste segregator. The author studies Rapid increase in volume and types of solid and hazardous waste due to continuous economic growth, urbanization and industrialization. It is estimated

that in 2006 the total amount of municipal solid waste generated globally reached 2.02 billion tones, representing a 7% annual increase since 2003 (Global Waste Management Market Report 2007). They propose a system designed to sort the refuse into metallic waste, wet waste and dry waste. The system employs parallel resonant impedance sensing mechanism to identify metallic items, and capacitive sensors to distinguish between wet and dry waste. Abhishek et al., (2019) worked on Automated Waste Segregation System and its approach towards generation of Ethanol, they proposed a programmed waste segregator that goes for isolating the loss at the transfer level itself, it sorts the loss into 3 noteworthy classes, to be specific metallic, wet and dry, in this manner making waste administration increasingly powerful.

DESIGN METHODOLOGY

The approach employed in this work has steps including materials used, circuit diagram of the system, flowchart of the developed system, software requirement and principle of operation. Figure 1, shows the block diagram of the developed home waste segregation system.

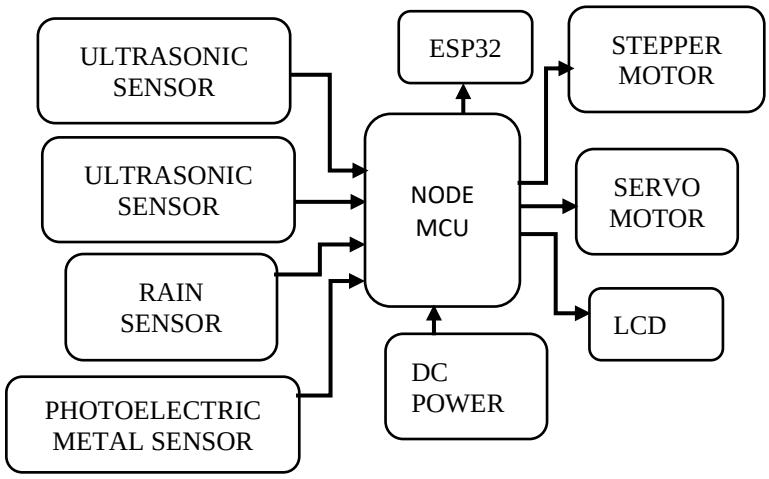

Figure 1: Architecture of Waste Segregation and Management System

There are two Ultrasonic sensors connected to the microcontroller (NODE MCU), the first one detects the approach of users to the system, while the second one detects level of the waste inside the waste bins. Rain sensor is connected to microcontroller, to signal it for the Prescence of waste substance and highlights if the waste material is dry or wet. The Photoelectric metal sensor connected to the microcontroller send a signal to the NODE MCU, after it has reached its activated threshold by detecting metallic waste from the deposited waste. A DC power source is used to power the whole system including the Microcontroller that processes the information from each sensor. Servo motor is responsible for controlling the plate where the waste is deposited. It can be controlled by the microcontroller to rotate at 60 degree or to return to its initial position. Stepper motor is also connected to microcontroller, depending on the signal from the microcontroller, the stepper motor rotates at a precise range/angle moving the specific waste bin as detected by the sensors to receive waste material.

Hardware Implementation

All components to be mounted on the electronic boards were made available, the microcontroller (Node MCU) was programmed to accept inputs from the ultrasonic sensors, Moisture sensor, the servo motor, stepper motor and the Wi-Fi module (ESP32). Each and every component is interfaced to the microcontroller board. The necessary code for controlling the sensors and the motors is coded using embedded C language, in which the inputs and the

output ports can be defined easily. Arduino IDE compiler was used to compile the code and upload it to the board using micro-USB.

Ultrasonic Sensor was used to measure the distance of objects/person approaching the waste segregator machine and the Level of the Waste in bin., it works on 5v DC and has 4 ports which are the voltage source (V+), ground pin (GND), echo pin (E) and the trigger pin (T). The first Ultrasonic Sensor trigger port is connected to pin 18, and echo pin is connected to pin 16 on the ESP32. The second Ultrasonic Sensor trigger port is connected to pin 17, and echo pin is connected to pin 19 on the ESP32. Moisture Sensor was used to determine the level of moisture of the waste being disposed. It has 3 port which are the voltage source (V+), ground (GND) and digital pin (G0). It also works on 5v DC, the (G0) port is connected to pin 7 on the ESP32.

ESP32 Wi-Fi Module was used as a means of connecting the waste segregator machine to the internet world. It works on 3.3v DC. Servo Motor Module was used to rotate the flap to 180 and it works on 5v DC. It has 3 ports which are the voltage source (V+), ground (GND) and digital port (G0) which is connected to pin 32 on the ESP32. The stepper motor moves in discrete steps by energizing each phase in sequence and rotate one step at a time. it has a stepper motor driver which convert and regulate AC to DC and regulate the voltage to 12v Dc. It also has 4 ports which are digital port (G0), digital port (G1), digital port (G2) and digital port (G3). The (G0) port is connected to pin 13, 14, 10 and 11 pins. The display crystal shows the alphabet and figure from the waste input to the system, it has 16 pins that are connected through a I2C module to the controller using input pins A0, A1, A2, A3 which are bridge for input voltage source (V+), Serial Clock (SCL) and Serial Data (SDA). It works on 5V DC, and the SCL pin is connected to pin 21 while the SDA pin is connected to pin 22 of the controller. Figure 2 shows the circuit diagram of the home waste segregation and management system using the internet of things.

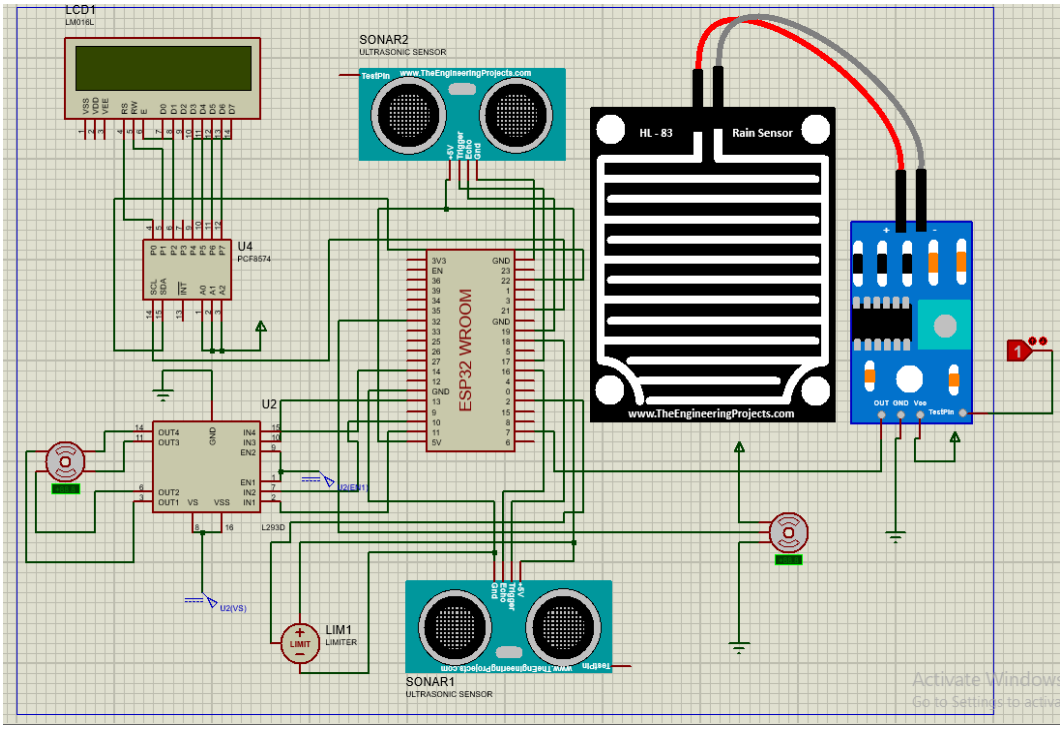

Figure 2: Circuit diagram of the developed system.

Software Implementation

The software implementation is sub divided into two sections, the programing of the microcontroller (NODE MCU) and mobile application, the detailed step-by-step procedure for implementing the software on the microcontroller is specified. The high-level language used for this software implementation is the C programing Language. The system was programmed on Arduino IDE software. Figure 3, shows a snippet of the C program getting signal from sensors.

```
#define EEPROM_SIZE 64

void setup() {
  pinMode(trigPin, OUTPUT);    // Sets the trigPin as an Output
  pinMode(echoPin, INPUT);     // Sets the echoPin as an Input
  pinMode(trigWaste, OUTPUT);  // Sets the trigPin as an Output
  pinMode(echoWaste, INPUT);   // Sets the echoPin as an Input
  pinMode(wetsensor, INPUT);
  pinMode(metalSensor, INPUT);
  pinMode(STEP, OUTPUT);
  pinMode(DIR, OUTPUT);
  lcd.init();
  lcd.backlight();
  lcd.print("SMART WASTE");
  lcd.setCursor(0, 1);
  lcd.print("SYSTEM");
  myservo.attach(32);  // attaches the servo on pin 9 to the servo object
  // Debug console
  Serial.begin(115200);
  delay(10);

```

Figure 3: Snippet of C program

The home waste segregation system starts by initializing all sensors in the system and all components to their default conditions. The photoelectric metal sensor has highest priority to detect metallic waste. If activated, the stepper motor rotates at 360 degrees. The stepper motor rotates by 90 degrees, if it detects wet waste substance and rotates by 180 degrees if it detects dry waste substance. The servo motor rotates by 60 degrees to pour waste into the waste bin. Ultrasonic sensor triggers a signal to the microcontroller to activate WhatsApp API bot to send a message to the registered authority number. Figure 4 shows the flowchart diagram of the developed system.

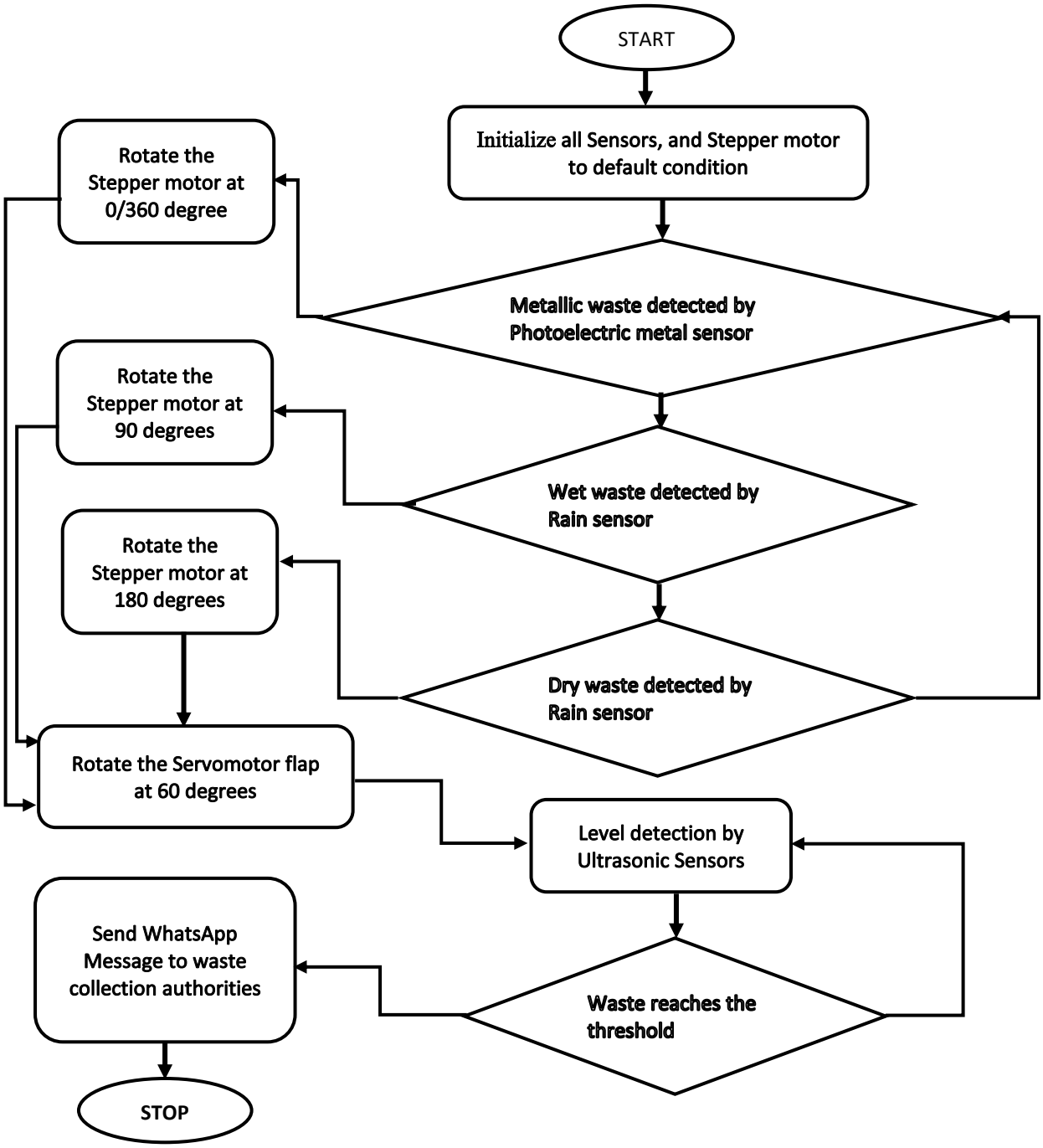

Figure 4 Flowchart Diagram of the Developed System

WhatsApp chat bot uses artificial intelligence or pre-programmed rules to engage audience on the WhatsApp platform. Receiving messages from ESP32 directly to WhatsApp was achieved WhatsApp bot API sends notifications to WhatsApp using ESP32. The ESP32 has a generic 433Mhz receiver attached for detecting the triggers from the ultrasonic sensor wirelessly. Once ESP32 gets a trigger from the attached sensors, it will activate WhatsApp bot to send a preprogram message for appropriate action. Figure 5 shows a snippet for WhatsApp configuration with registered number.

```
21  String api_key = "2687776";
22  String phone_no = "+2347035934830";
23  String url;
24
25  //Ultrasonic Sensors
26  const int trigPin = 18;
27  const int echoPin = 16;
28  const int trigWaste = 5;
29  const int echoWaste = 23;
```

Figure 5: Programing configuration of WhatsApp

The device has been constructed with a 12v DC power adapter which converts the Alternating Current (AC) from the power outlet to 12v Direct Current (DC) which is suitable for the operation of the device. Once the system is on, all the sensors used fix themselves to default settings to meet the normal operating conditions of the system. The ESP32 Wi-Fi module was programmed to connect to specific Internet credentials with SSID (Wi-Fi name) as **SmartWasteIoT** and PASSWORD as **segregation1234**. The constructed device will connect to any Internet access medium with these stated credentials. After a successful connection the connected Wi-Fi signal (or Mobile hotspot) has internet access, and the device will then be connected to the WhatsApp chatbot which will be notified on the mobile application designed for the device.

The developed system detects the presence of an object within a distance of 40cm and below. Any object detected within this range of distance will prompt the device to get ready to accept waste with a display of **APPROACH DETECTED** on the LCD. The constructed device has carrier flap mechanism where the waste can be placed. After the waste is placed, the carrier flap will wait for about 8 seconds before, it rotates 60 degrees in order to pour the waste appropriately. During the 8 seconds, the sensors will detect whether the waste is metal, dry or wet waste. The waste containers have a height of 6cm each which is calculated by the proximity sensors that are on the lid of the containers and the maximum programmed level the waste can reach is 5.5cm**.** Once the waste reaches the maximum level, the device will send a mobile notification to the administrator of the waste bin for the immediate evacuation of the waste. Figure 6 and 7 shows the developed system implementation unit and the package.

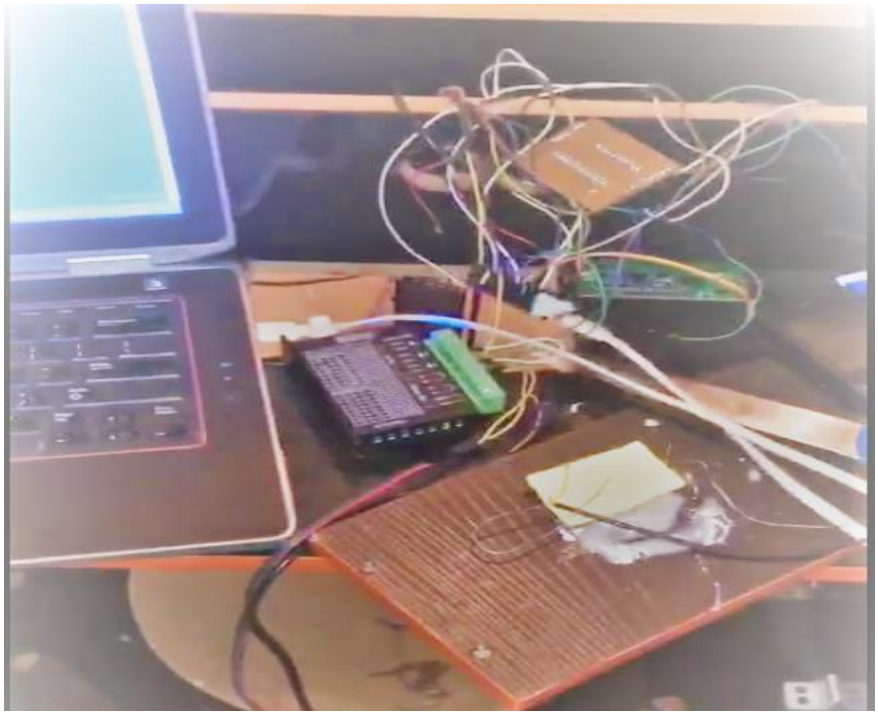

Figure 6: System Implementation Unit.

Figure 7: Package of the Developed System

RESULTS AND DISCUSSION

This section points to the testing of the developed system and discussion of the realized results. The circuit diagram of the system as specified in figure 2 guides the mounting of the components and was tested on a breadboard, then patterned and etched on a circuit board. The result of the system was specified in Table 1, showing the time of testing the system, active

status of the waste bin, height of waste in the bin, stepper motor operation, and the system instant status.

Table 1: System Experimental Performance Result

	Waste Bin Active Status			Distance of Waste in Bin Ultrasonic(cm)				
Time	**Wet Bin**	**Dry Bin**	**Metal Bin**	**UR Wet**	**UR Dry**	**UR Metal**	**Motor Acton**	**System Status**
9am	0	1	0	0	2.2	0	Rotate 180^0	Wait for waste
10am	0	1	0	0	3.5	0	Rotate 180^0	Wait for waste
11am	1	0	0	2.1	3.5	0	Rotate 90^0	Wait for waste
12noon	0	0	1	2.1	3.5	2.4	Rotate 360^0	Wait for waste
1pm	1	0	0	4.3	3.5	2.4	Rotate 90^0	Wait for waste
1pm	0	0	1	4.3	3.5	4.7	Rotate 360^0	Wait for waste
3pm	0	1	0	4.3	5.8	4.7	Rotate 180^0	Send message to waste team

The system was tested by dumping wet, dry, and metal waste materials in the bin at different time intervals. The waste bin active status shows the type of waste material deposited in the bin as detected by the sensor at a time interval and activate the applicable bin for the particular waste. The stepper motor action is determined by the type of deposited waste in the bin, it moves at a precise angle of either 180^0, 90^0, or 360^0 to get the activated bin to position and returns back to initial state. The Distance of Waste in the Bin is realized with the aid of the Ultrasonic (UR) sensor and it determines the system status to the waste management authority. From 9am to 1pm, the waste bin has received various materials and still awaits more waste to reach the set 5.5cm distance measure in the bin. By 3pm, the dry waste bin was able to get fill above the set 5.5 benchmark, and the system sends a message to the waste management for pickup

CONCLUSION

A waste segregator using the Internet of Things (IoT) has been designed and constructed. The waste segregator was designed to be able to segregate metal, dry and wet waste to their respective bins. The waste segregator could receive a message via a mobile application. The waste segregator and the mobile application is connected to the WhatsApp API platform for synchronization and instant messages to alert user. In the design and construction of a home waste segregator using the Internet of Things (IoT), the system can be improved upon by making sure that the waste segregator can separate more than three types of wastes, and also increasing the volume/capacity of the bins.

REFERENCES

Abba, S., Wadumi, N. J., Lee, J. A., and Liz, C. M. (2019). Design and Performance Evaluation of a Low-Cost Autonomous Sensor Interface for a Smart IoT-Based Irrigation Monitoring and Control System, *Multidisciplinary Digital Publishing Institute (MDPI) Sensors*, 19(17), 1-25.

Abhishek, M., Minal, P., and Prabhakar, D. K. (2019). Automated Waste Segregation System and its approach towards generation of Ethanol, Conference: *2019 5th International Conference on Advanced Computing & Communication Systems (ICACCS)* DOI:10.1109/ICACCS.2019.8728358

Aditya, S. K., Omkar, K., and Sagar, B. (2021). Automatic Waste Separation. *Journal of Advance Research in Mobile Computing,* 3(1), 1-4.

Ajay, V. P., Bradeep, K. M., Kishanth, A., Vaishnavi, K. R., Santhiya, D., and Amirtharajan, R. K. (2020). Automatic Waste Segregation and Management. *2020 International Conference on Computer Communication and Informatics (ICCCI -2020)*, Jan. 22 – 24, 2020, Coimbatore, INDIA

Ajinkya, V., Lokesh, J., Suraj, V., and Tanmay, S. (2022). Automatic Waste Segregator. *International Journal of Advance Research and Innovative Ideas in Education (IJARIIE),* 8(3), 1840-1842.

Akhil, R. N., and Valarmathie, P. N. (2017). IoT Based Waste Management System for Smart Cities. *International. Journal. Advance. Research. Ideas Innovation. Technology*, 3(3), 1276-1280.

Amrutha, C., Joyal, M., Nikhil, R. S., Nikhil, U. B., Nitin, K. K., and Suma, M. S. (2014). Automated Waste Segregator, *2014 Texas Instruments India Educators' Conference (TIIEC)*, Bangalore, India, DOI: 10.1109/TIIEC.2014.009

Awuchi, C. G., Awuchi, C. G., Amagwula, I. O., and Igwe, V. S. (2020). Industrial and community waste management. *Global perspective American Journal of Physical Sciences*, 1(1), 1–16.
https://doi.org/10.1371/journal.pone.0266173

Elzeiny, M. E., and Mohamed, B. Z. (2021). Thermal analysis in recycling and waste management. *Thermal Analysis: Introductory Fundamentals to Advanced Applications Elsevier,* 247-300.
*https://*doi.*org/*10.1016/b978-0-323-90191-8.00002-6

Kamlesh, K. J., Harsh, S., and Prajjwal, C. (2021). Automatic Waste Segregation System. *International Journal of Research in Engineering and Science* (IJRES), 9(1), 13-16. https://doi.org/10.1164/rccm.200511-1780OC

Keyur, K. P., and Sunil, M. P. (2016). Internet of Things-IOT: Definition, Characteristics, Architecture, Enabling Technologies, Application & Future Challenges. *International Journal of Engineering Science and Computing (IJESC)*, 6(5), 6122-6131. DOI 10.4010/2016.1482

Md-Abdullah, A. R., Md-Sohel, R., Md-Moklesur, R., and Fysol, I. A. (2021). Dry and Wet Waste Segregation and Management System. *European Journal of Engineering Research and Science (EJERS),* 6(5), 129-133.

Monisha, B. R., Niharika, S. A., and Sunil, K. G. (2021). Automatic Waste Segregator System. International Journal of Research Publication and Reviews, 2(7), 1794-1802.

Okomba N. S., Adebimpe, E., Omodunbi, B., Nwobodo, L., Nduanya, U., and Oyediji (2018). Development of A Door Lock Security System Based on Automatic Speech Recognition. *FULafia Journal of Science & Technology*, 4(2), 21-27

Sandhya, R. S., Vijaykumar, V. R., and Muthumeena, M. (2018). Waste Segregation using Deep Learning Algorithm. *International Journal of Innovative Technology and Exploring Engineering (IJITEE)*, 8(2S), 401-403.

Sharanya, A., Harika, U., Sriya, N., and Sreeja, Kochuvila. (2017). Automatic waste segregator, *2017 International Conference on Advances in Computing, Communications and Informatics (ICACCI)*. 13-16 September 2017, Udupi, India. DOI:10.1109/ICACCI.2017.8126023