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Arduino-Based Waste Detector with Alarm System

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Abstract

This study was deliberately designed to inform and enlighten people about the advantages of proper waste segregation and disposal. The Arduino-based Waste Detector with Alarm System automatically segregates different wastes such as plastic bottles, metals and other waste that is thrown in it with the use of image processing. This fixes problems caused by improper waste disposal due to people being uneducated on how to properly discard trash.

The problem of waste disposal has been ingrained in most people's lives, and discarding trash on roadsides and outside their homes has become routine, despite the fact that it causes enormous environmental damage. According to the World Bank, in 2020, the world was estimated to generate 2.24 billion tons of solid waste, amounting to a footprint of 0.79 kilograms per person per day due to rapid economic growth. And the most significant contributor to this issue is people's poor waste management habits, which is why everyone should take responsibility for their waste management.

The researchers were able to use image processing to recognize different sorts of garbage, including plastic bottles, metal waste and other waste. The camera sensor detects garbage based on its various properties and identifies if it matches the model created by the researchers. The results showed that the prototype was acceptable in terms of the functionalities indicated in the objectives. Having an efficiency rate of 100%, 85% and 100% in the time of waste detection, proper waste segregation and determining if one of the bins is full, respectively.

Keywords: image processing, proper waste segregation, solid waste, waste management, camera sensor

Introduction

The air we breathe, the food we eat, and the water we drink, as well as the numerous items we require in our homes, at work, and for leisure activities, are all provided by our environment. According to Write (2020), the environment is important because it supports the survival of human beings, is the source of natural resources, supports biodiversity and offers remarkable beauty. Moreover, the environment is responsible for air purification and disaster control. Nature, for example, may avoid flooding by storing water, keep our water pure by processing and diluting pollutants, and provide enjoyment, inspiration, and a place to socialize by processing and diluting pollutants.

The environment is frequently controlled in order to extract or develop items that may be sold, but this might come at the expense of other vital benefits. But on the other hand, it is constantly changing today. That is a fact that cannot be denied. With a large number of natural disasters, warming and cooling periods, various weather patterns, and much more.

Humans have the most negative impact on the environment, often unknowingly. However, there are numerous ways in which we may assist the environment. That is, our environmental influence can be positive or negative, necessary but cleaner, or unnecessary and discarded. Life is chemistry, and chemical reactions take place all around us, allowing us to accomplish incredible accomplishments that are necessary for the more convenient times

we live in today. And as we want to become a responsible citizen for our environment, waste disposal is one of the steps to do for a better world.

The problem of waste disposal has been ingrained in most people's lives, and discarding trash on roadsides and outside their homes has become routine, despite the fact that it causes enormous environmental damage. Due to rapid economic growth, urbanization, and population growth, solid waste management has become a global phenomenon. And the most significant contributor to this issue is people's poor waste management habits. Garbage management is critical for the development of sustainable and livable cities, which is why everyone should take responsibility for their waste management. According to Pasha (2021), In developing nations, lack of education leads to improper waste disposal, creating hazardous conditions and leading to environmental degradation if left unchecked. The lack of education in communities around the globe makes it difficult for them to find ways and proper methods on what they can do with trash. Still, there is not always a place nearby where people live.

Improper trash disposal is one of the most serious environmental challenges in the Philippines, causing larger problems that damage not just the environment but also people's health and lives. Ecological solid waste management refers to the systematic administration of activities that provide for segregated transportation, storage, transfer, processing, treatment, and disposal of solid waste, as well as all other waste management activities that do not harm the environment, as defined by Republic Act (RA) 9003 or the Ecological Solid Waste Management Act of 2000.

As a result of the circumstances, the researchers devised an Arduino-based Waste Detector with Alarm System that instructs the user on which bin they should deposit their trash. It will teach the user what type of garbage they are throwing away and how to properly dispose of it in the appropriate bin. It can be made of metal, plastic, or biodegradable materials. An automatic lid has been designed to reduce the need for interaction, especially in this time of pandemic. If the user puts trash in the wrong bin, it will be automatically sorted into the correct one. A notice will flash and a buzzer is built to alert the user that they have thrown their garbage in the wrong bin. It also has a capability to detect the amount of waste in the bins and alerts the utility worker when it is already full. It also aims to raise awareness among the younger generation about proper waste separation, as the system has its own unique features that set it apart from other bins. And when the bin is already full, an alert is included to notify the users and at the same time the lid will not also open which indicates that it is unavailable to receive trash at the moment. Finally, a solar panel is built to serve as the alternative source of power if a shortage or mechanical failure of electricity happens.

Objective of the Study

The general objective of the study is to design an Arduino-based Waste Detector with Alarm System that can automatically detect and properly segregate wastes in the Universities. Distinctively, this study aims to:

1) Determine the design specification needed in the development of Arduino-based Waste Detector with Alarm System for proper identification of the different waste such as metal, plastic bottles, other waste which is essential for the process of automatic segregation.

1.1 Camera Sensor:

1.2 Logitech C270 Webcam 1.1.2 Raspberry PI Microprocessor

1.3 Ultrasonic Sensor:

1.4 Ultrasonic Sensor HC-SR04

2) Test the functionality of the Arduino-based Waste Detector with Alarm System in terms of:

2.1 Waste Detection

2.2 Waste Segregation

2.3 Detecting if the bin is full
2.4 Trigger of Alarm
2.5 Real-time text Notification

Methodology

Research Design

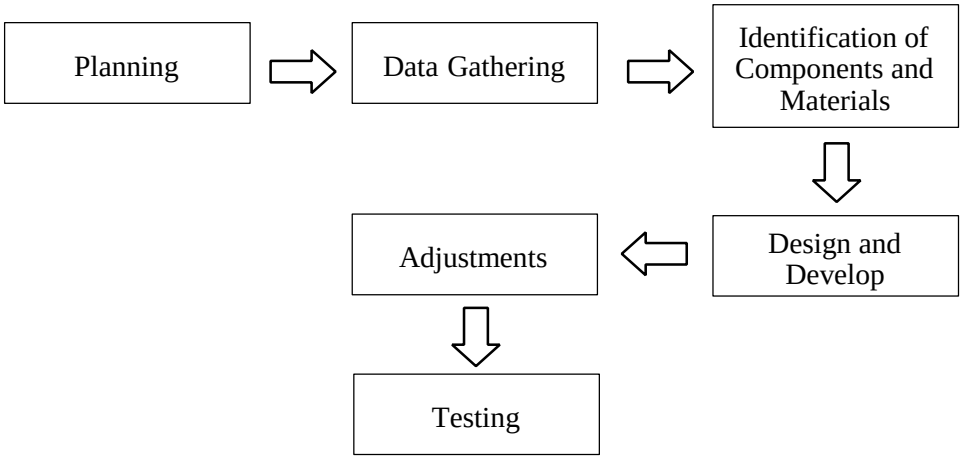
Considering the present study entitled "Arduino-Based Waste Detector with Alarm System" as developmental research, it will be explained in the discussion how the research project will be designed.

Richey as cited by Ibrahim (2016), developmental research is a systematic study of designing, developing and evaluating instructional programs, processes, and products that must meet the criteria of internal consistency and effectiveness. Defined developmental research as "An interactive, cyclic process of development and research in which theoretical ideas of the designer feed the development of products that are tested in classroom tastings, eventually leading to theoretically and empirically founded products, learning process of the developer and (local) instruction theory". For instance, identifies the purpose of developmental research such as initiating both instruction and non-instructional gadgets that run improvement of instruction. Akker recognizes the purpose of his terms of definition as supporting the development of prototypical products which include providing empirical evidence for their effectiveness, and generating methodological decisions for the design and evaluation of the production.

The developmental research design is used in the Arduino-Based Waste Detector with Alarm System. This study focuses on a setting in which the researchers designed, developed, and evaluated educational activities while studying the process.

Data Gathering Procedure

The data collection procedure covers the steps involved in the study's creation, as well as the information and data that will be used to support the research. In order to achieve the project's major goal, the researcher observed and followed a constructive approach.



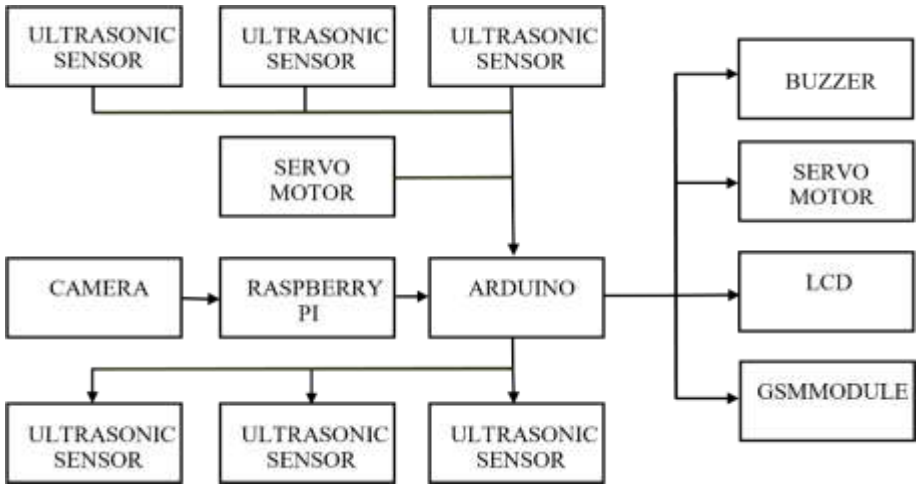
The researchers acknowledge that the Arduino-based Waste Detector with Alarm System necessitates awareness and knowledge of garbage, recycling, and correct waste disposal, thus this research was conducted in order to develop a solution that would benefit the community, particularly in schools. The researchers may be able to assist them in becoming more conscious of and knowledgeable about various wastes. The researchers then gathered information from the relevant people in order to solicit construction proposals for the project. The data gathered

was used to guide the building of the project and the selection of project components and materials, as well as techniques and equipment for design development.

After collecting and analyzing the data, the researchers begin to create a solution that helps in the development of the system's hardware and software requirements. Hardware and software developers explain these systems and illustrate their workflows and procedures using block diagrams as a key tool. Besides when a project involves processes, it is helpful when a clear picture of information is shown.

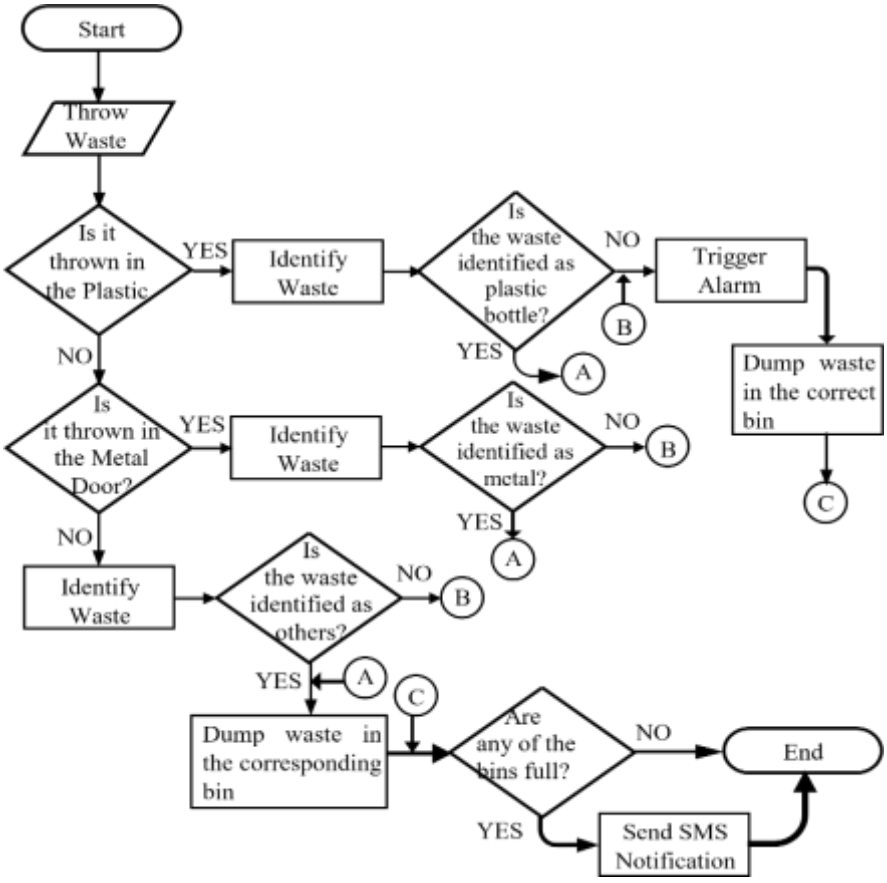
The system block diagram of the Arduino-Based Waste Detector with Alarm System is shown below. It depicts the project's primary components as well as their link to the Arduino microcontroller system. It establishes the system's hardware structures that represent the input and output devices. It also shows the connection of image processing and ultrasonic sensor as input devices to the microcontroller, which then provides data to various output devices.

Block Diagram



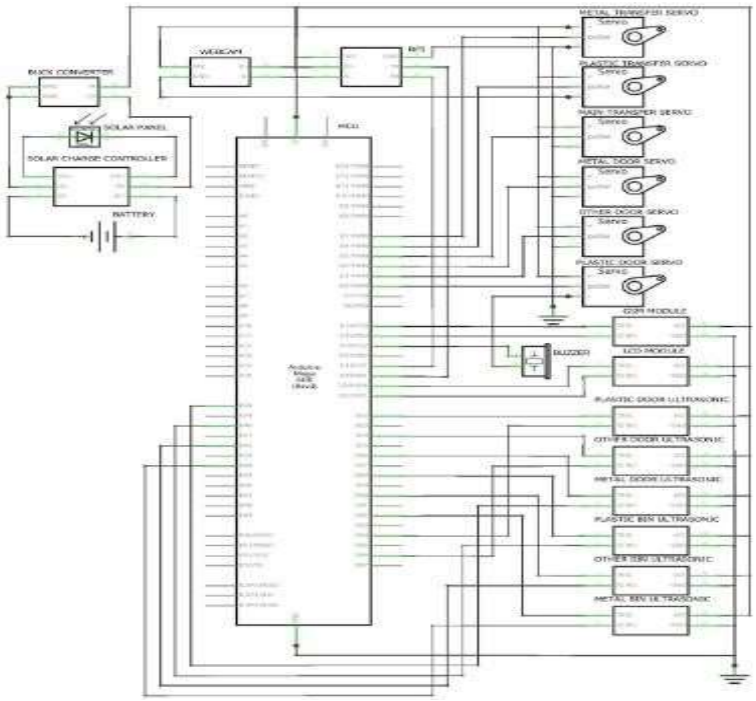
Flow Chart

The Flowchart below shows the process of identification and transferring of waste into their corresponding bin. After the waste has been transfer to its appropriate bin, the level of waste will be monitor to determine if the garbage needs to pulls out and the assigned personnel will receive a notification.



Schematic Diagram

The schematic diagram of the Arduino-Based Waste Detector with Alarm System and shows the connection of the different components to the microcontroller. The Arduino or microcontroller is connected to the servo motors, GSM module, LCD module, buzzer, and raspberry pi. It proves that the Arduino is where all of the processes are taking place.



Results and Discussion

Project Description

The Arduino-based Waste Detector with Alarm System can detect and separate waste such as metal, plastic bottles, and others like biodegradable and non-recyclable waste. The project's goal was to use image processing to detect and separate garbage automatically. When garbage is thrown into its designated bin, the waste detection procedure begins. The webcam is put at the top of the bin and is linked to the Raspberry Pi, it detects garbage. The Raspberry Pi will send the data to the Arduino, which will identify the type of waste. On the other hand, the process of appropriate segregation begins when garbage is thrown in the incorrect bin. When the Arduino identified the waste, the two-servo motor would move in a certain degree respectively to segregate the waste. And the process repeats itself during the whole operating process.

The project includes an alert system to notify the user if they have dumped waste in the wrong bin. The LCD in front of the prototype indicates the kind of trash. It also serves as a signal when it is time to throw out waste. The concept also includes an ultrasonic sensor that can automatically open the various bins. Furthermore, the idea includes a GSM module that helps in maintaining cleanliness and preventing garbage from overflowing. When the ultrasonic was activated, a message was sent to authorized workers advising that the bin had reached its maximum capacity. The user is no longer able to dispose of rubbish since the bins would not open. Finally, the project is powered by a solar panel.

Project Structure

The Arduino-Based Waste Detector with Alarm System is a technological garbage collector that uses image processing to distinguish different types of waste and later segregate it, allowing the user to be properly engaged for proper disposal with the help of an alarm system and LCD that displays the type of waste being thrown. When a waste bin is full, this project sends an SMS notification to assigned personnel. This approach provides a physical description of various components of each system module. Such is the webcam used to record the waste being thrown, the raspberry pi used to identify the waste, the GSM module used to send real-time text messages, and the various parts used to control the voltage of the machine. Furthermore, to stop all the parts from becoming damaged.

Trials and Revision

Table 1. The system testing

Trials setup	Outcome	Actions taken
1. Testing of the sensors for the detection accuracy	The accuracy of detecting garbage was too low.	Used image recognition in detecting waste.
2. Testing of the camera detection	The area for detection was too dark for the camera that was used for the detection module.	Added lighting inside camera.
3. Testing of the camera detection	The camera was able to properly detect the waste that was thrown.	Waste was detected with a minimal amount of time.
4. Testing the waste detection using collected images from the internet and captured at home	The accuracy of detecting garbage was too low.	No changes needed.

5. Testing the waste detection using the captured images in the prototype	The detection of the garbage was accurate.	Captured the waste in different angles using the webcam that is built in the prototype.
6. Testing the proper segregation	The angles for each door are inaccurate for the doors to fully open.	Adjusted the angles in the program so the door can fully open.
7. Testing the proper segregation	The doors of each bin are able to fully open and are able to segregate the waste properly.	No changes needed.
8. Testing the time of detection of waste		No changes needed.
9. Testing the detection of the level of each bin using ultrasonic sensor	The prototype sends the notification when the bin is almost full.	No changes needed.
10. Testing the alarm sound	The duration of alarm is excessive.	Adjusted the duration of alarm in the program.
11. Testing the alarm sound	The alarm works properly and is no longer excessive.	No changes needed.

Table 1 shows the system testing done by the researchers to test the functionalities of the Arduino-based Waste Detector with Alarm System and acquire the desired outcomes. It shows the situations encountered by the researchers in the development of the prototype and the changes done to be able to achieve the objectives of the study.

Project Evaluation

In the evaluation of the project, the researchers used the criteria which is the Functionality. The functionality testing was conducted by the researchers to know if the project achieved its objectives and to determine its strengths and weaknesses

Presentation, Analysis and Interpretation of Data

Table 2. Testing the functionality of Arduino Based Waste Detector with Alarm System in terms of Waste Detection (Time)

Object as Input	Accuracy (%)	Duration of Detection	Object as Identified	Remarks
1. Pet Bottle	100%	6.54 sec	Plastic Bottle Waste	Correct
2. Canned Sardines	100%	8.76 sec	Metal Waste	Correct
3. Pet Bottle	100%	7.07 sec	Plastic Bottle Waste	Correct
4. Beverage Carton	100%	5.75 sec	Others	Correct
5. Plastic Wrapper	100%	5.99 sec	Others	Correct
6. Soda Can	100%	4.32 sec	Metal Waste	Correct
7. Canned Milk	100%	4.07 sec	Metal Waste	Correct
8. HDPE Bottle	100%	4.00 sec	Plastic Bottle Waste	Correct
9. Plastic Sachet	100%	4.16 sec	Others	Correct
10. Pet Bottle	100%	4.32 sec	Plastic Bottle Waste	Correct
11. Canned Milk	100%	6.87 sec	Metal Waste	Correct
12. Canned Milk	100%	3.63 sec	Metal Waste	Correct
13. Pet Bottle	100%	4.05 sec	Plastic Bottle Waste	Correct

14. Plastic Wrapper	100%	3.86 sec	Others	Correct
15. Paper Bag	100%	3.98 sec	Others	Correct
16. Canned Juice	100%	4.21 sec	Metal Waste	Correct
17.Canned Milk	100%	3.72 sec	Metal Waste	Correct
18. Canned Good	100%	4.11 sec	Metal Waste	Correct
19. Plastic Wrapper	100%	3.92 sec	Others	Correct
	Avg. 100% Avg. 4.87 sec		Rate of Efficiency: 100%	

The table shows the performance of an Arduino-based waste detector with an alarm system in terms of image processing accuracy and detection time. Various types of garbage are thrown into the project to evaluate the detection time and the accuracy of image processing, which is used to identify the type of waste.

The result of the system testing regarding the speed of detection gives the average time of 4.87 seconds. Based on the test conducted, 20 out of 20 wastes has the correct results with the efficiency rate of 100%. The project gives accurate result in identifying different types of waste.

The table shows the performance of an Arduino-based waste detector with an alarm system in terms of proper segregation and the trigger of alarm. Various types of garbage are thrown into the project to evaluate the duration of identifying the waste, duration of transferring, duration of the alarm and the efficiency of segregating the waste into the right bin.

The result of the testing regarding the duration of identifying the waste gives the average time of 4.01 seconds. After identifying the waste, transferring the waste to its designated bin executes the average time of 3.27 seconds. And based on the test conducted, 17 out of 20 has the correct results with the efficiency rate of 85%. The three incorrect findings are caused by the angle at which they were collected, whereas the garbage that was captured is not included in the training model that was developed for detection.

Table 3. Performance Testing on the Effectiveness of Arduino-Based Waste Detector with Alarm System in terms of Detecting if the Bin is Full and Real-Time SMS Notification using Others Bin

Trials	Date	Time	Level of Waste (Inch)	Remarks	Notification	Output
1	05/18/2022	3:05 PM	1 in	Low	×	Correct
2	05/18/2022	3:08 PM	3 in	Low	×	Correct
3	05/18/2022	3:10 PM	5 in	Low	×	Correct
4	05/18/2022	3:13 PM	7 in	Low	×	Correct
5	05/18/2022	3:17 PM	10 in	Medium	×	Correct
6	05/18/2022	3:20 PM	12 in	Medium	×	Correct
7	05/18/2022	3:25 PM	15 in	High	✓	Correct
8	05/18/2022	3:27 PM	17 in	High	✓	Correct
9	05/18/2022	3:31 PM	19 in	High	✓	Correct
10	05/18/2022	3:32 PM	0 in	Low	×	Correct

Legend: ✓ - With Notification; × - Without Notification

Table 3 presents the performance testing in terms of Detecting if the Bin is Full and Real-Time SMS Notification of Others Bin. According to the findings, when the garbage reached a height of 10 inches, the amount of waste was changed from low to medium. When the waste reached 15 inches in height, an SMS was sent to the collector. As a result, the

monitoring can precisely display and transmit notifications for waste overflow prevention with a 100% efficiency rate.

Table 4. Performance Testing on the Effectiveness of Arduino-Based Waste Detector with Alarm System in terms of Detecting if the Bin is Full and Real-Time SMS Notification using Metal Bin

Trials	Date	Time	Level of Waste (Inch)	Remarks	Notification	Output
1	05/18/2022	3:40 PM	1 in	Low	×	Correct
2	05/18/2022	3:43 PM	3 in	Low	×	Correct
3	05/18/2022	3:45 PM	5 in	Low	×	Correct
4	05/18/2022	3:46 PM	7 in	Low	×	Correct
5	05/18/2022	3:50 PM	10 in	Medium	×	Correct
6	05/18/2022	3:51 PM	12 in	Medium	×	Correct
7	05/18/2022	3:53 PM	15 in	High	✓	Correct
8	05/18/2022	3:56 PM	17 in	High	✓	Correct
9	05/18/2022	3:58 PM	19 in	High	✓	Correct
10	05/18/2022	3:59 PM	0 in	Low	×	Correct

Legend: ✓ - With Notification; × - Without Notification

The results of the tests are shown in the table above. The Arduino-Based Waste Detector with Alarm System's efficacy in providing SMS notifications and detecting if the level of waste in Metal Bin is full. With the findings provided, it demonstrates a 100 percent efficiency rate in obtaining the proper consequence of detecting waste level and delivering notification for high levels of trash in the metal bin.

Table 5. Performance Testing on the Effectiveness of Arduino-Based Waste Detector with Alarm System in terms of Detecting if the Bin is Full and Real-Time SMS Notification using Plastic Bottle Bin

Trials	Date	Time	Level of Waste (Inch)	Remarks	Notification	Output
1	05/18/2022	4:12 PM	1 in	Low	×	Correct
2	05/18/2022	4:17 PM	3 in	Low	×	Correct
3	05/18/2022	4:19 PM	5 in	Low	×	Correct
4	05/18/2022	4:20 PM	7 in	Low	×	Correct
5	05/18/2022	4:23 PM	10 in	Medium	×	Correct
6	05/18/2022	4:24 PM	12 in	Medium	×	Correct
7	05/18/2022	4:25 PM	15 in	High	✓	Correct
8	05/18/2022	4:27 PM	17 in	High	✓	Correct
9	05/18/2022	4:30 PM	19 in	High	✓	Correct
10	05/18/2022	4:31 PM	0 in	Low	×	Correct

Legend: ✓ - With Notification; × - Without Notification

Table 5 presents the performance testing when detecting if the bin is full and real-time SMS Notification of Plastic Bottle Bin. The waste height was provided to assess the trash level in the bin. According to the results, the prototype has a 100 percent efficiency rate, the capacity to send a notice to the collector when the amount of trash is high, and the ability to show an exact level of waste for detection if the bin is full.

Findings

1. Arduino-Based Waste Detector with Alarm System is developed using Logitech C270 Webcam and Raspberry PI Microprocessor which serves as the camera sensor. It is the main component used to provide the proper waste disposal that would detect and segregate Plastic bottles, Metal Waste and other waste such as biodegradable and non-recyclable waste.

2. The level of performance of the prototype was evaluated based on the functionality of Arduino-based Waste Detector with Alarm System in terms of Detection of Waste, Proper Segregation of Waste, Monitoring the level of waste in the bin, Trigger of Alarm and Real-time text Notification.

4. The Arduino-Based Waste Detector with Alarm System can segregate different types of waste effectively with an efficiency rate of 85%.

5. By using the Ultrasonic sensor, the level of waste in the bin had been observed and detected. The waste height was provided to assess the trash level in the bin.

6. According to the results, the prototype has a 100 percent efficiency rate, when a user throws garbage in the wrong bin, the alarm will trigger for 3 seconds. With the Real-time text notification, a message is automatically sent with the efficiency rate of 100% using GSM module whenever a bin would get full and a message was received by the researchers during the testing.

Conclusion

The researchers were able to provide proper waste disposal by the use of the Arduino-Based Waste Detector with Alarm System. Based on the previous findings and result, the researchers hereby formulated that the objectives were met with the following conclusions:

The researchers were able to use image processing to recognize different sorts of garbage, including plastic bottles, metal waste and other waste. The camera sensor detects garbage based on its various properties and identifies if it matches the model created by the researchers.

The researchers had tested the efficiency of the Arduino-Based Waste Detector with Alarm System.

The characteristic features of the garbage affects the efficiency of detecting the waste.

Capturing the garbage in its different angles helps to increase the accuracy of detecting and segregating the waste properly.

In creating a model, capturing the different angles of the garbage in the detection area of the bin helps to identify and segregate the waste more efficiently because of its distance area where the waste is captured, the lighting and its background.

The service provider's signal affects the real-time text that notifies the user if the garbage reaches the highest level of the bin.

The Ultrasonic sensor had been tested and observed and it detects the level of each bin. The signal of the sensor affects the sending of notification and the reboot of the Arduino-Based Waste Detector with Alarm System.

When the garbage is thrown in the wrong bin, the alarm triggers and segregate the waste on its designated bin.

Recommendations

1. Based on the finding there were identified for further improvement on the capabilities of the Arduino-Based Waste Detector with Alarm System.

2. To maximize the space in the bin, use a compressor or garbage compactor.

3. The project may be improved by maximizing the solar panels to fully support the project's power, allo4wing it to operate continuously.

4. Expand the project to accommodate vast garbage.

5. Add On/Off Switch to easily activate the project.

6. Improve the design of the prototype for it to withstand getting wet.

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