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Smart Waste Disposal System

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Abstract: *As the world continues to grow technologically, the ripple effect of this is an increase in urbanization. In the same vein, this results in increase in waste generation. Waste management and control becomes necessary to maintain personal hygiene and keep the environment clean. In this project, a smart waste disposal system is designed. This design involves a microcontroller (Arduino UNO), which receives signal about the position of a dustbin user from an ultrasonic sensor, the microcontroller then sends the message to a servomotor to activate the opening of the lid of the dustbin. If the user leaves the range of the ultrasonic sensor, the dustbin lid closes. Additionally, an alarm and a LED are being activated to signify to the user that the dustbin has crossed a FULL threshold level. This provides the opportunity to control the waste level in the bin. Thus, in a simple and cost-effective way, this design work is able to achieve the purpose of preventing environmental pollution, and promoting personal hygiene.*

Keyword: *Arduino; Ultrasonic sensor; Light Emitting Diode; Waste disposal system; Sensor***.**

1. INTRODUCTION

The evolution of technology on almost a daily basis has affected humanity in many ways [1]. One of these ways has been the ability to save human lives and create a better medical treatment for all. A direct result of this has been the increased lifespan and the growth of the population. In year 2022, Nigeria's population was estimated at around 216.7 million individuals. Demographic projections show that the Nigerian population might experience a constant increase in the next decades. By year 2050, it is forecast that the population will double to over 400 million people as compared to year 2019[2]. More people mean an increased demand for food, water, housing, energy, healthcare, transportation and more. Consequently, this creates an increase in waste generation.

In year 2019, the outbreak of the corona virus disease, which has claimed human lives worldwide, and which gets transmitted from one person to another through contact with infected bodies or objects, necessitates the need to maintain a good personal hygiene at all times in the society.

Moreover, it is a common phenomenon to see garbage overflow in waste bins along roads, public places, etc, thereby polluting the environment. Air pollution emanating from an overfull dustbin produces bacteria and virus, which can lead to contact of harmful and infectious diseases for human lives [3],[4],[5]. This begs the question; how do we plan to manage our population growth while preventing the spread of diseases? Surely, one of the engineering approaches towards solving this problem is the usage of a smart waste disposal system. This system solves the problem of environmental pollution and personal hygiene maintenance, or at the very least reduce them to the minimum. This proposed design uses two ultrasonic sensors, microcontroller, servomotor, and a buzzer as its main components. For the maintenance of personal hygiene, the first ultrasonic sensor, servomotor and the microcontroller are all responsible for the automatic open/close system of the dustbin. Also, to avoid environmental pollution due to overfull dustbin, the second ultrasonic sensor, microcontroller, a buzzer, and an LED provide an alerting system to signify to an intending user that the dustbin is full.

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2. LITERATURE REVIEW

A review of literature was performed to have a good understanding of the concepts related to the project. A survey of existing technologies on smart waste disposal system was done to have a good grasp of the technologies that are feasible, cost-effective and environmentally friendly to execute this project. The summaries of some of the reviews that have been made for this design project are discussed in subsequent paragraphs.

Yaohan Fernandes designed a mini smart dustbin using a bucket to store the wastes, and a cardboard as the covering of the bin. In this project, an ultrasonic sensor senses a user, then relays the information to an Arduino UNO microcontroller, which then sends a signal to a servomotor to make a 180 degrees rotation to open the lid of the dustbin. If the user moves away from the bin, the sensor loses its initial signal, and the Arduino UNO withdraws the previous message, which makes the servomotor return back to its initial position by making a 180 degrees counter rotation to close the dustbin. A 9V

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battery was used to power the system. The shortcoming of this system is that there is no mechanism that controls garbage overflow [6].

Navya Teja designed a system that also monitors the fill level of the dustbin, in addition to the basic automatic opening and closing of the dustbin. In this project, an infrared sensor is used to detect the garbage level, and sends the status to a microcontroller. Then, the microcontroller sends the fill status information to a central server (Thingspeak server). The concerned authorities access the information on a GUI through Thingspeak apps. The high cost of hosting a server is a setback to this project [7].

Badri Mohapatra designed a model that notifies the users of the fill status of the dustbin, so as to empty the wastes if need be. In this project, an alarm and LED indication system are added to the smart dustbin to alert the user of a FULL garbage level. An ultrasonic sensor placed at the top of the dustbin sends the fill status of the dustbin to a microcontroller, which then activates an alarm when the dustbin is FULL [8].

Dhavel Patel proposed a system that segments the smart dustbin into three layers: dustbin layer, server layer and client layer. The dustbin layer consists of Wi-Fi enabled dustbins. The server layer consists of a server that stores information regarding the fill status of the dustbin. At the client layer, clients make requests of the nearest location of the Wi-Fi enabled dustbin from the server through a mobile application. As requested, the server processes the query, and sends the location of the nearest dustbin to the client with direction on how to access the bin. The limitation to this model is the high cost of a server, and the reliability of the server is not fully guaranteed [9].

Aravind designed an automated self-navigated dustbin dispensary system. In this project, there are multiple dustbins, with each provided with a unique tracking ID. An ultrasonic sensor is also provided for each dustbin to detect the garbage level. The sensor transmits information on the garbage level and ID to a microcontroller when the dustbin level is filled above a preset threshold level. The status of the dustbins is accessed by the concerned authorities through the internet. When a particular dustbin is full, users will be prevented from using it, and the bin will be moved to a navigated place by the authorities. The shortcoming of this system is that there is no mechanism that informs a user to refrain from using the dustbin if full, until the authorities arrive at the scene [10].

Kannapiran Selvaraj designed a monitoring system with the smart dustbin. The system consists of an ultrasonic sensor that measures the dustbin level. An Arduino microcontroller relays the garbage level information to a central LAN server via an Arduino ethernet shield. The LAN sever sends the dustbin level information to workstations connected to the LAN. The high cost of a server is a setback to this project. Also, if the LAN server shuts down due to one reason or the other, then the entire monitoring system will be jeopardized [11].

Akshad Tambekar designed a system that monitors different FULL capacity levels of the smart dustbin. In this project, each of three ultrasonic sensors were used to detect 50% full capacity, 75% full capacity and 95% full capacity respectively. The system is also supplemented by a GSM module, which sends information on the garbage level in the dustbin to relevant authorities via a text message [12].

Telugu Maddileti designed a smart dustbin monitoring system using a Blynk app and Node MCU. The Node MCU is connected to a Wi-Fi hotspot. The level of wastes in the dustbin is detected by an ultrasonic sensor, and the message is been displayed on a Blynk app, which has three widgets, representing different colors of LED. The LEDs are Green LED; which indicates that the waste level inside the bin is very low, and more wastes can be added, Orange LED; which indicates that the waste level inside the dustbin is half-filled, and more wastes can be added, Red LED; which indicates that the dustbin is full, and needs to be emptied. The shortcoming of this system is that seamless connectivity to the Wi-Fi hotspot is not always certain [13].

Priyam Parikh designed an intelligent smart dustbin alerting system which uses an RFID tag and a LCD display. An ultrasonic sensor detects the user of the dustbin through the tag. The sensor then sends the details read from the tag to a microcontroller, which displays the user's name on a serial LCD, situated in front of the dustbin. If the identity of the user is verified, the servomotor gives access to the dustbin for the user. A Red LED glow indicates that the dustbin is full, and a message will be sent to a control room via a GSM Module. The possibility of having a malfunctioning RFID tag is disadvantageous to this project [14].

Anushree designed a smart dustbin monitoring system. In this project, there are two sensor units on the dustbin; IR and dampness sensor. The IR sensor detects the full status of the dustbin, while the dampness sensor isolates wet wastes from dry wastes. An engine connected to the dampness sensor helps to isolate the two sets of wastes. A microntroller transmits the full status information of the dustbin to a remote android application via a Wi-Fi module. The IOT devices used in this project are costly [15].

Upon completion of the literature review, it was discovered that the usage of servers and other IOT systems makes the implementation of the project less affordable to most people. Hence, the system proposed in this design will be affordable to many people, and easy to implement.

3. PROPOSED SYSTEM

The following software and hardware were used for the design work;

Software used

i. Arduino IDE
ii. Tinkercad

Hardware used

i. HC-SR04 ultrasonic sensors (2 pieces)
ii. Servomotor (1 piece)
iii. Arduino UNO microcontroller (1 piece)
iv. Buzzer (1 piece)
v. LED (1 piece)
vi. 9V DC battery (1 piece)
vii. DC switch (1 piece)
viii. Jumper wires
ix. Plastic dustbin (1 piece)

3.1.1 Description of Software

i) Arduino IDE

This is an integrated development environment that facilitates communication between components via an algorithm. In this project, the software is used to write the code, and transferred to the microcontroller for implementation.

ii) Tinkercad

This is an online 3D modeling program used for creating circuit diagrams. In this project, the software is used to design the circuit diagram for the automatic dustbin system.

3.1.2 Description of hardware

i) Ultrasonic Sensor

An ultrasonic sensor is an electronic device that calculate the target's distance by emission of ultrasonic sound waves, and convert those waves into electrical signals. The speed of the emitted ultrasonic waves is faster than audible sound. It has mainly two essential elements, which are the transmitter and receiver. Using the piezoelectric crystals, the transmitter generates sound, and from there it travels to the target and gets back to the receiver component. In order to ascertain the distance between the target and the sensor, the sensor calculates the amount of time needed for sound emission to travel from transmitter to receiver. An ultrasonic sensor has four pins; which are Vcc, Trig, Echo and Gnd pins.

Vcc pin - This pin has to be connected to a power supply +5V.

Trig pin - This pin is used to receive controlling signals from the Arduino board. It is the triggering input pin of the sensor.

Echo pin - This pin is used for sending signals to the Arduino board, where the Arduino calculates the pulse duration to know the distance. This pin is the Echo output of the sensor.

Gnd pin – This pin has to be connected to the ground. Ultrasonic sensors are used in robotic sensing for positioning of robotic arms, to avoid collision and for proximity detection.

ii) Servomotor

Servo means an error sensing feedback control which is utilized to connect the performance of a system. A servomotor is a small device that has an output shaft. This shaft can be positioned to specific angular positions by sending the servo a coded signal. As long as the coded signal exists on the input line, the servo will maintain the angular position of the shaft. If the coded signal changes, the angular position of the shaft changes. The power applied to the servomotor is proportional to the distance it needs to travel. So, if the shaft needs to turn a large distance, the motor will run at full speed. If it needs to turn only a small amount, the motor will run at slower speed. This is called 'proportional control'. A servomotor has three wires that connect to the outside world; one is for power (+5V), another one is for ground and the last one is for the control signal. Servos are used radio-controlled airplanes to position control surfaces like the elevators and rudders. They are also used in radio-controlled cars, and in robotics.

iii) Arduino UNO

The Arduino UNO is an open-source microcontroller board based on the Microchip Atmega328P microcontroller. It has 14 digital input/output pins (of which 6 pins can be used as PWM outputs), 6 analog inputs, a 16MHz ceramic resonator, a USB connection, a power jack, an ICSP header and a reset button. It can be powered by an AC-to-DC adapter, battery, or by connecting it to a computer via a USB cable. It can be programmed with an Arduino IDE (Integrated Development Environment). It requires 20mA DC current to control the sensors. Arduino can be used to automate tasks, such as to control lights and devices.

iv) Buzzer

A buzzer is an audio signalling device, which may be of mechanical, electromechanical, magnetic, electromagnetic or piezoelectric type. The main function of a buzzer is to convert the signal from audio to sound. Generally, it is powered through DC voltage and used in timers, household appliances, communication devices, alarm devices, printers, computers, etc. Based on the various designs, it can generate different sounds like alarm, music, bell and siren. The buzzer in this project sounds when the dustbin reaches the FULL state.

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v) LED

A light-emitting diode (LED) is a semiconductor device that emits light when an electric current flows through it. When current passes through an LED, the electrons recombine with holes emitting light in the process. LEDs allow the current to flow in the forward direction and blocks the current in the reverse direction. LEDs are heavily doped p-n junctions. Based on the semiconductor used and the amount of doping, an LED will emit a coloured light at a particular spectral wavelength when forward biased. The LED in this project glows when the dustbin reaches the FULL state.

vi) DC Battery

A DC battery is an external power supply that supplies DC power for low voltage applications. It is used for electronics devices that require low power. The DC battery in this project supplies power to the arduino microcontroller.

vii) DC switch

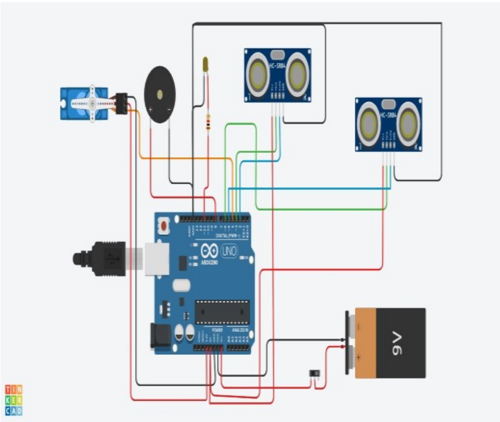
A switch is an electrical component which can make or break electrical circuits automatically or manually. Switch works with ON (closed) and OFF (open) mechanism. Typically, electronic switches use solid state devices such as transistors, though vacuum tubes can be used as well in high voltage applications. Electronic switches also consist of complex configurations that are assisted by physical contact. Physical contact comes from pressing or flipping a switch with one's hand, but other forms of contact like light sensors and magnetic field sensors and magnetic field sensors are used to operate switches. The DC switch in this project controls power flow to the entire system.

3.1.3 Methodology

In this system, an open-source integrated development environment (Arduino UNO board) is used as a microcontroller to facilitate interactions among connected devices. When a dustbin user is at a maximum distance of 30cm away from the bin, an ultrasonic sensor placed at the front of the bin detects the presence of this user, and sends the signal to the microcontroller, which then relays the information to the servomotor, to open the lid of the dustbin by making a 180 degrees rotation. If the user leaves the sensing range of the ultrasonic sensor (distance >30cm), then the initial signal sent to the servomotor by the microcontroller is withdrawn, and as such the servomotor closes the lid of the bin by making a 180 degrees counter rotation. Another ultrasonic sensor placed at the top of the dustbin, continuosly monitors the level of garbage in the bin.

If the garbage level in the dustbin is at a maximum distance of 3cm away from being full, the ultrasonic sensor sends the message to the microcontroller, which then activates an alarm and LED, and automatically closes the dustbin, rather than further opening the dustbin if a user approaches it. This is done to alert the users of the "full status" of the dustbin. The alarm continuously sounds and the LED keeps glowing until the user moves away from the dustbin (i.e user distance >30cm). A DC switch controls power flow to the whole system. Therefore, the switch can be turned OFF to facilitate the manual emptying process of the dustbin. After the dustbin has been emptied, the switch can then be turned back ON to activate the automatic operation of the dustbin. Hence, this system is cost effective and efficient.

3.1.4 Circuit Diagram



The circuit diagram above was generated using the "Tinkercad circuit design" software tool. Two ultrasonic sensors, servomotor, buzzer, LED, resistor, 9V battery, DC switch, and the Arduino UNO microcontroller were used for this project. One of the ultrasonic sensors is attached to the front of the dustbin, and the other is attached to the top of the dustbin. Both sensors have four pins; namely Vcc, Trig, Echo and Ground pins. The Vcc pins of both sensors are jointly connected to the 5V pin on the Arduino UNO. The Trig and Echo pins of the front sensor are connected to digital I/O pins 3 and 2 respectively on the Arduino. The Trig and Echo pins of the top sensor are connected to digital I/O pins 6 and 5 respectively on the Arduino. The Gnd pins of both sensors are connected to the Gnd pin on the Arduino. The servomotor has three pins, namely; power, control and Gnd pins.

The power, control signal, and Gnd pins are connected to the 3.3V pin, digital I/O pin 4, and the Gnd pin respectively on the Arduino. The positive terminals of the buzzer and LED are connected to the digital I/O pins 8 and 11 respectively on the Arduino, while their negative terminals are jointly connected to the Gnd pin on the Arduino. Notably, the resistor is connected along the positive terminal of the LED. The positive and negative terminals of the 9V battery are connected to the Vin and Gnd pins respectively on the Arduino. Lastly, a DC switch is fixed along the positive terminal of the battery, in order to control power flow to the whole system.

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3.1.5 Block Diagram

From the block diagram above, the microcontroller serves as the epicenter of communication among the devices. Two ultrasonic sensors are used for the project; the first sensor is placed at the front of the dustbin, to detect the presence of a user, and the second sensor is placed at the top of the dustbin, to check the level of wastes in the dustbin.

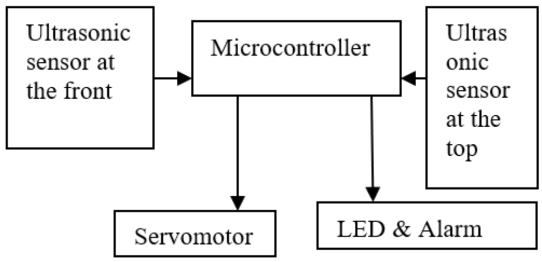

Figure 1: Block diagram of the proposed system

A servomotor is also placed on the cover of the dustbin, to facilitate the opening and closing of the dustbin's cover. From the block diagram above, the two sensors continuously check for objects within their preconfigured range of distances. As for the front sensor, if it detects a user within its range, the signal is sent to the microcontroller, in order for the microcontroller to process the message. This message is then sent from the microcontroller to the servomotor, to open the lid of the dustbin. Similarly, if the user leaves the range of distance, the signal is withdrawn from the microcontroller, and the servomotor goes back to its original state, to close the lid of the dustbin. Additionally, the top sensor detects if the wastes level crosses a preset threshold limit, and sends the message to the microcontroller, in order for it to send output voltage, to activate an alarm and LED.

3.1.6 Flow Chart

Algorithms

Step 1: Check if the dustbin is full.

Step 2: If NO.

- **Step 2.1:** Check the user distance.
- **Step 2.2:** If user distance is less than or equal to 30cm.
- **Step 2.3:** Open the lid of the dustbin.

Step 2: If YES.

- **Step 2.1:** Remain closed.
- **Step 2.2:** If user distance is less than or equal to 30cm.

Step 2.3: Continuously activate an LED and alarm.

Mathematical Equations to Justify the Distance of a User from the Ultrasonic Sensor:

Distance = $speed \times time\ taken$

But, in this case, the time taken is the total time it takes for sound waves to be incident on the user, plus that taken for sound waves to be reflected on the sensor receiver.

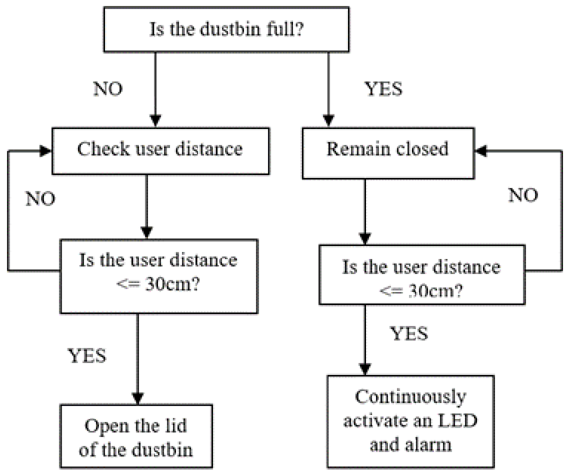

Figure 2: Flow chart of the proposed system

Therefore, user distance = $\frac{speed \times total\ time}{2}$ (1)

speed = speed of sound (340m/s)

total time = ultrasonic sensor's receiver pulse duration

Ultrasonic Sensor at the Front:

The user distance required is <=30cm or <=0.3m

Speed of sound = 340m/s, Ultrasonic sensor's receiver pulse duration required = ?

From eqn i, Total time = $\frac{2 \times user\ distance}{speed}$

Substituting the values above;

Total time = $\frac{2 \times 0.3}{340}$

Total time = 0.6/340

Total time = 0.0018s

Receiver's pulse duration <=0.0018s

Therefore, the front ultrasonic sensor should have a receiver pulse duration of max. 0.0018s

Ultrasonic Sensor at the Top:

The garbage level required is <=3cm or <=0.03m

Speed of sound = 340m/s, Ultrasonic sensor's receiver

pulse duration required = ?

From eqn 1, Total time = $\frac{2 \times user\ distance}{speed}$

Substituting the values above;

Total time = $\frac{2 \times 0.03}{340}$

Total time = 0.06/340

Total time = 0.000412s

Receiver's pulse duration <=0.00018s

Therefore, the top ultrasonic sensor should have a receiver pulse duration of max. 0.00018s

4. TESTING AND RESULTS

1. User distance: 70cm
   Servomotor angle: 0^0
   Top sensor distance: 36cm
   Alarm/LED status: Inactive
   Dustbin status: **CLOSED**

2. User distance: 60cm
   Servomotor angle: 0^0
   Top sensor distance: 36cm
   Alarm/LED status: Inactive
   Dustbin status: **CLOSED**

3. User distance: 45cm
   Servomotor angle: 0^0
   Top sensor distance: 36cm
   Alarm/LED status: Inactive
   Dustbin status: **CLOSED**

4. User distance: 30cm
   Servomotor angle: 180^0
   Top sensor distance: 36cm
   Alarm/LED status: Inactive
   Dustbin status: **OPEN**
5. User distance: 18cm
   Servomotor angle: 180^0
   Top sensor distance: 20cm
   Alarm/LED status: Inactive
   Dustbin status: **OPEN**

6. User distance: 12cm
   Servomotor angle: 180^0
   Top sensor distance: 12cm
   Alarm/LED status: Inactive
   Dustbin status: **OPEN**

7. User distance: 5cm
   Servomotor angle: 0^0
   Top sensor distance: 2cm
   Alarm/LED status: Active
   Dustbin status: **CLOSED**

4.1 Discussion of Results

From the above tests, user distances of 70cm,60cm, and 45cm were tested. Also, the top ultrasonic sensor measures an empty wastes level of 36cm from all three tests in the dustbin. This shows that the dustbin is not full yet, but because the user is out of range of distance that triggers the front sensor to send a message to the microcontroller, then the shaft of the servomotor remains in its initial state, which means a closed dustbin. Also, the alarm and LED were inactive from these tests.

However, when a user stays at a distance of 30cm away from the dustbin, the front sensor detects this as sufficient to trigger a message to the microcontroller. The servomotor's shaft then moves 180^0, which opens the dustbin's cover. The top sensor deects a wastes level of 36cm, which means the FULL condition of the dustbin has not been met, and the dustbin can remain open, untill the user leaves. The same results were achieved for user distances of 18cm and 12 cm, and top sensor distances of 20cm and 12cm.

Figure 3: Image of the dustbin's prototype

Meanwhile, when a user distance of 5cm was tested in front of the dustbin, the dustbin didn't open, because the FULL condition has been met as the wastes level in the bin has reached a distance of 2cm away from being filled up, this condition means no signal would be sent to the microcontroller to activate the servomotor. As such, the servomotor remains in its original state of 0^0, and the dustbin is closed. This condition also activated an alarm and LED to signify to the user why the bin is not opening, despite the user being within range.

In the tests carried out, the front ultrasonic sensor takes a time of 1s to properly process the presence of a user, before carrying out the next action. This was done to ensure that an errant object will not deceive the front sensor as a user. A delay of 1s was also observed before the lid of the dustbin closes, as a result of a user leaving the range.

In summary, from all tests carried out, the top ultrasonic sensor firstly processes the wastes level in the dustbin. If the level is not the FULL condition, then further action is taken by the microcontroller to decide whether or not to activate the servomotor, based on the signal it received from the front sensor, as regards the user distance, which ultimately facilitates the opening and closing process of the bin.

5. CONCLUSION

Waste management is very important to keep the environment clean, and reduce the spread of diseases. A smart waste disposal system presents a new paradigm that is applicable to a smart city, and ensures that wastes are being managed properly.

In this project, a smart dustbin was designed. This dustbin uses ultrasonic sensors to check for user distance and wastes level in the bin. It also uses a servomotor to open or close the bin. When the dustbin is full, the system was designed in such a way that prevents users from accessing the bin, by remaining closed and activating an alerting system to the users. Therefore, this system improves personal hygiene, and reduces environmental pollution.

In conclusion, the smart waste disposal system makes wastes collection more efficient, and keeps the surroundings clean.

6. RECOMMENDATIONS FOR FUTURE WORK

For future work, this project can be further improved by incorporating a system that segregates wet wastes from dry wastes, and also an IOT system that can give status report of the wastes level in the dustbin.

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