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Smart Bin Design Based on Global System for Mobile Communications Modem and Ultrasonic Sensor Interface using Arduino Uno Board as Platform

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ABSTRACT

The more urbanized and industrialized a country becomes, the more trash it produces. Waste management has been a crucial issue to be considered. In this paper, a smart bin using GSM (Global System for Mobile communications) modem and ultrasonic sensor interface with Arduino Uno board as platform is proposed and prototyped. Technology in arduino, ultrasonic sensor and GSM module are reviewed. The GSM module is an open, digital cellular technology used for transmitting mobile voice, data services and transmission of SMS (Short Message Service). Ultrasonic Ranging Module, HC - SR04, is placed on the cover of the dustbin which will determine the status of the garbage inside. The minimum level of garbage inside the dustbin is 10 cm. Once the garbage reaches the minimum level, HC - SR04 ultrasonic sensor triggers the GSM modem which will continuously alert the required authority until the garbage is removed from the dustbin. Design shows that GSM modem and ultrasonic sensor interfacing using Arduino Uno board as platform can make garbage collection operations smarter, more efficient and less wasteful. To be more energy-efficient, solar power will be incorporated into future designs.

Keywords **—** Engineering processes and systems, Arduino Uno, GSM modem, ultrasonic sensor, experimental method, Philippines

INTRODUCTION

Total waste in the world is enormous. According to Simmons in her article in Los Angeles Time in April 2012, more than half the world's population lacks access to systematic garbage collection. Ede Ijjasz-Vasquez, Senior Director for the World Bank's Social, Urban and Resilience Global Practice, stated that each year, nations generate 1.3 billion tons of waste. That's expected to soar to 4 billion tons by 2100. Leading trash generators are, United States, China, Brazil, Japan and Germany. In 2013, US produced about 254 million tons of waste while China produces about 190 million tons of waste per year.

As a result of population growth, urbanization and rising consumption, the amount of waste will probably double in African and Asian cities, according to United Nations Environment Program. Since 2000, to ensure solid waste disposal, World Bank has allocated about $4.5 billion to support the said project (Los Angeles Time, 2012).

Poor waste management which includes poor handling, collection, transportation, and dumping resulted negative impacts on human health and environment. Improper waste disposal can lead to the accumulation of harmful substances. Uncollected waste can be a breeding ground for bacterial diseases, place where pathogenic parasites can grow resulting to unsanitary conditions especially during the rainy season. Polluted water flowing from waste dumps and disposal sites can cause serious pollution to the surface water and the surrounding environment (Alam & Ahmade, 2013).

In this study, smart bin is being designed using Arduino Uno board as platform to make garbage collection operations smarter, more efficient and less wasteful. Arduino Uno microcontroller is used as the heart of the design since all communications pass through this board. GSM module and ultasonic sensor are being used as interface of the system design. This design will eliminate over-filling of garbage bins and can be remotely monitored. This proposed system reduces cost and optimizes resources .This system indirectly reduces traffic in the city.

FRAMEWORK

Rapid growth in population leads to more waste disposal. Spreading of some deadly diseases can be avoided by proper waste management. Smart bin

is an innovative and environmentally friendly approach to waste management. It is a total waste container management solution that is highly intelligent and user-friendly. Smart bin's Intelligent Monitoring integrates remote, wireless monitoring sensors with web and mobile asset management and route optimisation. Management of 100 bins or more, Smart bin has a solution that will generate significant cost savings.

Monika, Rao, Prapulla and Shobha (2016), presented a design of smart bin built on a microcontroller based platform Aurdino Uno board which is interfaced with GSM modem and Ultrasonic sensor. Ramya, Thaslima, Saranya, Sharli, Christina, Yamuna Jansi (2017), also developed a smart garbage monitoring system using Ultrasonic sensor, Arduino Uno board and Wi-Fi module. This system assures the cleaning of dustbins as soon as the waste level achieves its most extreme. Program interfaced with the Arduino board and the webserver graph shows the level of the garbage.

Dustbins in cities get overfilled many times. Parkash (2016), developed a system to monitor the dustbins' status and location. It uses the web, arduino and the ultrasonic sensor to develop the design. The system provides complete details of the dustbin location. The concerned authority can access the information from anywhere and anytime to get the details on the web.

Some studies also developed a smart bin using a microcontroller based system with ultrasonic sensor for monitoring of status of garbage to manage the waste collection system of an entire city by using smart bin (Tapase, Mohite, Kadam & Deshmukh, 2016; Sharma, Singha & Dutta, 2015), Smart Trash System (STS), Local Base Station (LBS), the smart Vehicle System (SVS) and the Smart Monitoring and controlling Hut (SMCH) including RFID and internet (Bashir, Khan & Shafi, 2013) and ARM LPC 2148 with ultra-sonic sensors and pressure sensing resistor (Sruthi & Manjunath, 2016).

OBJECTIVE OF THE STUDY

The study aimed to design a smart bin based on GSM modem and ultrasonic sensor interface using Arduino Uno board as platform.

MATERIALS AND METHODS

Smart bin

Smart bin is equipped with HC-SR04 ultrasonic ranging sensor which measures the level of garbage inside the bin. The garbage bin is divided into

three levels. Every time the garbage reaches each level, GSM module will be triggered and an instant message is sent to the assigned authority. HC-SR04T sensor, measures 2cm to 400cm of non-contact measurement functionality. This module consists of an ultrasonic transmitter, a receiver and a control circuit and has four pins which consist of VCC (Power), Trig (Trigger), Echo (Receive), and GND (Ground).

System Architecture

In this study, designing of smart bin based on GSM modem and ultrasonic sensor interface using Arduino Uno board as platform is presented. This system is composed of hardware interface module and software communication module. Being the heart of the system, all communication and control shall pass through the arduino microcontroller.

The hardware required materials in this design are Arduino Uno and battery (with cable), GSM module SIM900, Ultrasonic Sensor (HC-SR04), ATMEGA328P microcontroller and connecting wires. The following figures show the hardware materials needed in this study. The software requirement is Arduino Integrated Development Environment (IDE).

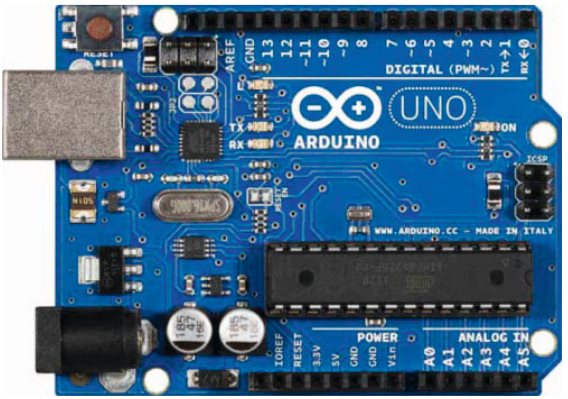

Figure 1. Arduino microcontroller

Arduino Uno as shown in figure 1, is a microcontroller board based on the ATmega328. This microcontroller has 14 digital input/output pins, 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. This microcontroller can be supplied with a battery, a computer and a AC-to-DC adapter to get started.

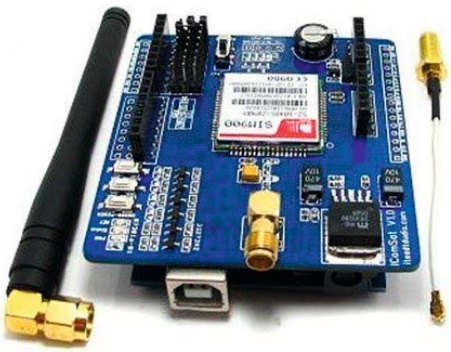

Figure 2. GSM Module SIM900

SIM900 GSM/GPRS module as shown in figure 2, is an ultra-compact and reliable wireless. This is a complete Quad-band GSM/GPRS module in a SMT type and designed with a very powerful single-chip processor integrating AMR926EJ-S core. As an industry-standard interface, the SIM900 delivers GSM/GPRS 850/900/1800/1900MHz performance for voice, SMS, Data, and Fax in a small form factor and with low power consumption. With a measurement of 24mm x 24mm x 3 mm, SIM900 can fit for slim and compact demands of design.

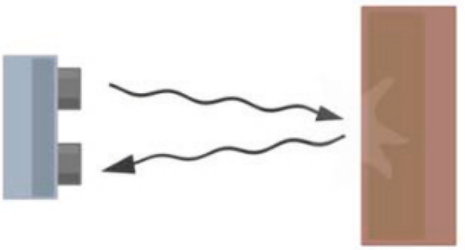

Figure 3. Diagram of the basic ultrasonic sensor operation

Ultrasonic sensor, as shown in figure 3, can measure the distance using sound waves. The distance can be calculated by the elapsed time of sending the sound wave and the time it bounces back.

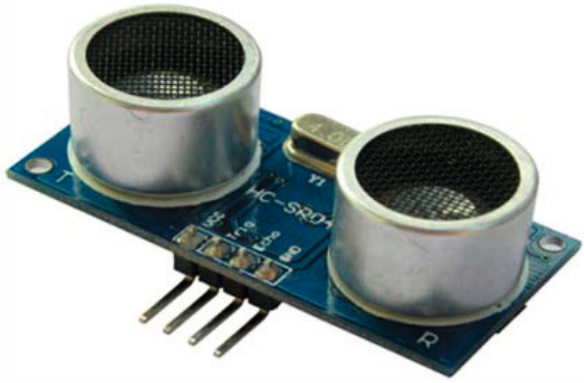

Figure 4. Ultrasonic Ranging Module HC - SR04

Figure 4 shows a HC-SR0, an ultrasonic ranging module, which provides 2cm - 400cm non-contact measurement function. The ranging accuracy of the sensor can reach to 3mm. The ultrasonic sensor module includes ultrasonic transmitters, receiver and control circuit. This module emits an ultrasound wave at the frequency of 40khz. If an object is detected along its way, a sound wave bounces back to the sensor. VCC (Power), Trig (Trigger), Echo (Receive), and GND (Ground) are the four pins of the ultrasonic module.

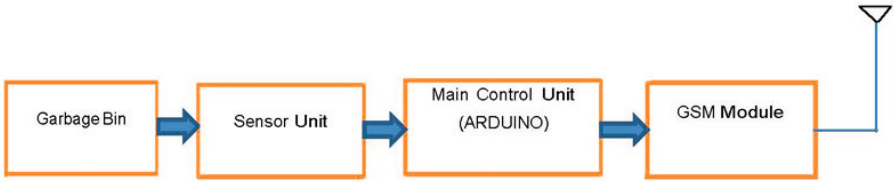

Figure 5. Transmitter Block Diagram

Figure 5 shows the transmitter diagram. The status of garbage is measured by the ultrasonic sensor (HC-SR04) which the signal from the sensor passes through the arduino. The main control unit consists of arduino, signal passes through arduino and reaches the user mobile through GSM as shown in Figure 6. With this project, the arduino is uploaded with a series of program that allows the full function of both ultrasonic and GSM to work. When the ultrasonic sensor reaches the fill level, based on the program, it will trigger the GSM to send a message to the number that is also inputted to the program.

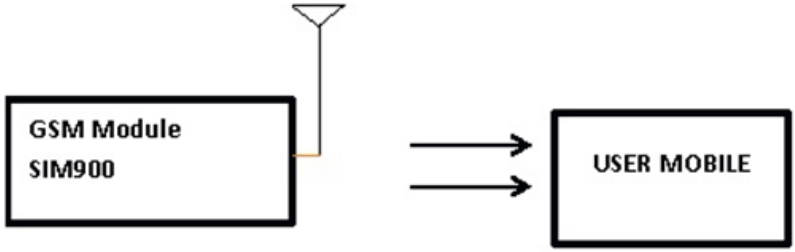

Figure 6. Receiver Block Diagram

The following are the steps in making this design:

Step 1. Setting up the hardware connections

For setting up this system, wiring connections have to be made between GSM Module with arduino, ultrasonic sensor and LEDs. Figure 7 shows the hardware connection of arduino with GSM Module, ultrasonic sensor and the LEDs. Pins 2 to 13 are connected to the corresponding LEDs. The four pins of the ultrasonic sensor are connected to pin 9 for the trigger and pin 10 for the echo. While the 5 V pin and ground are connected to the corresponding supply and ground connections.

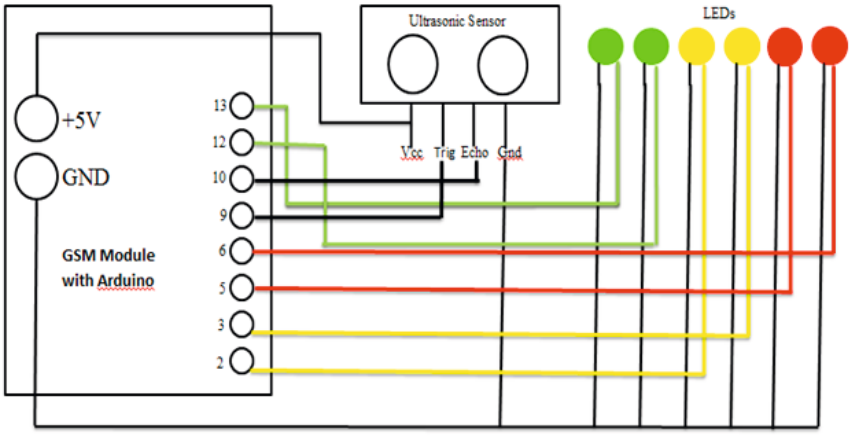

Figure 7. GSM Module with Arduino Ultrasonic Hardware Connection

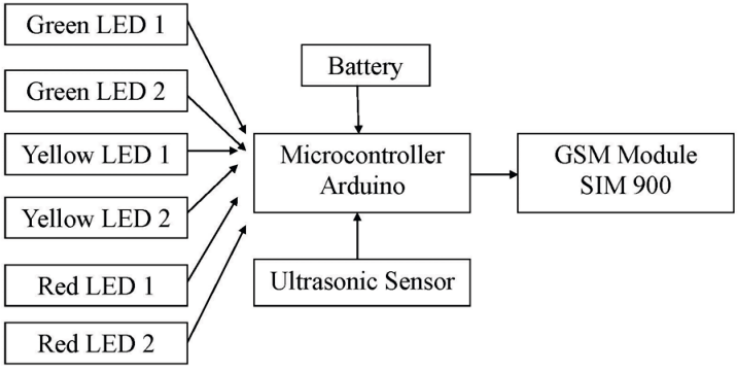

Figure 8. System Block Diagram

Figure 8 shows the system block diagram of smart bin. Ultrasonic sensor determines the status of garbage which is indicated through the LED display. All communications pass through the arduino

Step 2. Loading the Arduino Software

Arduino Integrated Development Environment can be downloaded from Arduino. The open source Arduino Software (IDE) makes it easy to write code and compile it to the board. It runs on Windows, MAC OS and Linux. The environment is written in java based on processing and other open source software. The software can be used with any Arduino development board. The code checks the garbage status and triggers the GSM module to be able to send message of the current status to the garbage collector or corresponding authority.

The Bluetooth module should be removed from the arduino board and connected once the upload is complete.

The code in this design is shown below:

```
#include <SoftwareSerial.h>
SoftwareSerial SIM900(7, 8);
const int trigPin=9;
const int echoPin=10;
const int red2Pin=5;
const int red1Pin=6;
const int yel2Pin=2;
const int yel1Pin=3;
```

```
const int gre2Pin=12;
const int gre1Pin=13;

int duration;
int distance;

void setup() {
 // put your setup code here, to run once:
Serial.begin(19200);
pinMode(echoPin, INPUT);
pinMode(trigPin, OUTPUT);
pinMode(red1Pin, OUTPUT);
pinMode(red2Pin, OUTPUT);
pinMode(yel1Pin, OUTPUT);
pinMode(yel2Pin, OUTPUT);
pinMode(gre1Pin, OUTPUT);
pinMode(gre2Pin, OUTPUT);
digitalWrite(red1Pin, LOW);
digitalWrite(red2Pin, LOW);
digitalWrite(yel1Pin, LOW);
digitalWrite(yel2Pin, LOW);
digitalWrite(gre1Pin, LOW);
digitalWrite(gre2Pin, HIGH);
SIM900.begin(19200);
delay(100);

}

void sendSMS()
{
 SIM900.print("AT+CMGF=1\r"); // AT command to SMS mode to text
 delay(100);
 SIM900.println("AT + CMGS = \"+639356100821\""); // Change this to your
desired recipient mobile

 delay(100);
 SIM900.println("The Bin is Full and ready to be Collected"); // Message
```

```
 delay(100);
 SIM900.println((char)26); // End AT command with a ^Z, ASCII code 26
 delay(100);
 SIM900.println();
 delay(7000); // give module time to send SMS
}

void sendSMSW()
{
 SIM900.print("AT+CMGF=1\r"); // AT command to SMS mode to text
 delay(100);
 SIM900.println("AT + CMGS = \"+639356100821\""); // Change this to your
desired recipient mobile

 delay(100);
 SIM900.println("Wait for the notification if the Bin is really Full"); // Message

 delay(100);
 SIM900.println((char)26); // End AT command with a ^Z, ASCII code 26
 delay(100);
 SIM900.println();
 delay(7000); // give module time to send SMS
}

void loop() {
 // put your main code here, to run repeatedly:
digitalWrite(trigPin, LOW);
delayMicroseconds(2);
digitalWrite(trigPin, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin, LOW);

duration= pulseIn(echoPin, HIGH);
distance= duration*0.034/2;

Serial.print("Distance: ");
Serial.println(distance);
```

```
if ((distance >= 1) && (distance <=4)) //
{
 digitalWrite(red1Pin, HIGH);
 digitalWrite(red2Pin, HIGH);
 digitalWrite(yel1Pin, HIGH);
 digitalWrite(yel2Pin, HIGH);
 digitalWrite(gre1Pin, HIGH);
 digitalWrite(gre2Pin, HIGH);
 delay(100);
}
if ((distance >= 5) && (distance <=15)) // Critical Level Indicator First Reading
{
 digitalWrite(red1Pin, HIGH);
 digitalWrite(red2Pin, HIGH);
 digitalWrite(yel1Pin, HIGH);
 digitalWrite(yel2Pin, HIGH);
 digitalWrite(gre1Pin, HIGH);
 digitalWrite(gre2Pin, HIGH);
 delay(100);
 sendSMSW(); // Warning Notification Message
 delay(10000);

 digitalWrite(trigPin, LOW);
delayMicroseconds(2);
digitalWrite(trigPin, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin, LOW);

duration= pulseIn(echoPin, HIGH);
distance= duration*0.034/2;

Serial.print("Distance: ");
Serial.println(distance);

if ((distance >= 9) && (distance <=15)) // Critical Level Indicator Second
Reading
{
 digitalWrite(red1Pin, HIGH);
```

```
 digitalWrite(red2Pin, HIGH);
 digitalWrite(yel1Pin, HIGH);
 digitalWrite(yel2Pin, HIGH);
 digitalWrite(gre1Pin, HIGH);
 digitalWrite(gre2Pin, HIGH);
 delay(100);
 sendSMS(); // Actual Message
 delay(5000);

}
if ((distance >= 16) && (distance <= 25)) // Warning Level Indicator
{
 digitalWrite(red1Pin, LOW);
 digitalWrite(red2Pin, HIGH);
 digitalWrite(yel1Pin, HIGH);
 digitalWrite(yel2Pin, HIGH);
 digitalWrite(gre1Pin, HIGH);
 digitalWrite(gre2Pin, HIGH);
 delay(100);
}
if ((distance >= 26) && (distance <= 30)) // High Mid Level Indicator
{
 digitalWrite(red1Pin, LOW);
 digitalWrite(red2Pin, LOW);
 digitalWrite(yel1Pin, HIGH);
 digitalWrite(yel2Pin, HIGH);
 digitalWrite(gre1Pin, HIGH);
 digitalWrite(gre2Pin, HIGH);
 delay(100);
}
if ((distance >= 31) && (distance <= 40)) // Low Mid Level Indicator
{
 digitalWrite(red1Pin, LOW);
 digitalWrite(red2Pin, LOW);
 digitalWrite(yel1Pin, LOW);
 digitalWrite(yel2Pin, HIGH);
 digitalWrite(gre1Pin, HIGH);
 digitalWrite(gre2Pin, HIGH);
```

```
 delay(100);
}
if ((distance >=41) && (distance <= 55)) // Low Level Indicator
{
 digitalWrite(red1Pin, LOW);
 digitalWrite(red2Pin, LOW);
 digitalWrite(yel1Pin, LOW);
 digitalWrite(yel2Pin, LOW);
 digitalWrite(gre1Pin, HIGH);
 digitalWrite(gre2Pin, HIGH);
 delay(100);
}
if ((distance >= 56)) // Very Low Level Indicator
{
 digitalWrite(red1Pin, LOW);
 digitalWrite(red2Pin, LOW);
 digitalWrite(yel1Pin, LOW);
 digitalWrite(yel2Pin, LOW);
 digitalWrite(gre1Pin, LOW);
 digitalWrite(gre2Pin, HIGH);
 delay(100);
}
}
if ((distance >= 16) && (distance <= 25)) // Warning Level Indicator
{
 digitalWrite(red1Pin, LOW);
 digitalWrite(red2Pin, HIGH);
 digitalWrite(yel1Pin, HIGH);
 digitalWrite(yel2Pin, HIGH);
 digitalWrite(gre1Pin, HIGH);
 digitalWrite(gre2Pin, HIGH);
 delay(100);
}
if ((distance >= 26) && (distance <= 30)) // High Mid Level Indicator
{
 digitalWrite(red1Pin, LOW);
 digitalWrite(red2Pin, LOW);
```

```
 digitalWrite(yel1Pin, HIGH);
 digitalWrite(yel2Pin, HIGH);
 digitalWrite(gre1Pin, HIGH);
 digitalWrite(gre2Pin, HIGH);
 delay(100);
}
if ((distance >= 31) && (distance <= 40)) // Low Mid Level Indicator
{
 digitalWrite(red1Pin, LOW);
 digitalWrite(red2Pin, LOW);
 digitalWrite(yel1Pin, LOW);
 digitalWrite(yel2Pin, HIGH);
 digitalWrite(gre1Pin, HIGH);
 digitalWrite(gre2Pin, HIGH);
 delay(100);
}
if ((distance >=41) && (distance <= 55)) // Low Level Indicator
{
 digitalWrite(red1Pin, LOW);
 digitalWrite(red2Pin, LOW);
 digitalWrite(yel1Pin, LOW);
 digitalWrite(yel2Pin, LOW);
 digitalWrite(gre1Pin, HIGH);
 digitalWrite(gre2Pin, HIGH);
 delay(100);
}
if ((distance >= 56)) // Very Low Level Indicator
{
 digitalWrite(red1Pin, LOW);
 digitalWrite(red2Pin, LOW);
 digitalWrite(yel1Pin, LOW);
 digitalWrite(yel2Pin, LOW);
 digitalWrite(gre1Pin, LOW);
 digitalWrite(gre2Pin, HIGH);
 delay(100);
}
}
```

RESULTS AND DISCUSSION

In this paper, a design of smart bin based on GSM modem (SIM 900A) and ultrasonic sensor (HC-SR04) interface using Arduino Uno board as platform is built. The working unit of the proposed system has been successfully developed. GSM 900A modem is used to send the messages. It consists of a GSM/GPRS modem with standard communication interfaces like RS-232 (Serial Port) and USB. The ultrasonic sensor is used to find the height of garbage filled at different intervals of time. Figure 9 shows the smart bin with ultrasonic sensor equipped at surface level.

Arduino Uno board is used as microcontroller platform. Interfacing is done between GSM modem and Arduino board by connecting RX pin of modem to TX pin of board and vice-versa. ECHO and TRIGGER pins of ultrasonic sensor is connected to digital pins 5 and 13 of Arduino board. Arduino board works at 5V power supply and GSM modem requires 2A to power on. In this design, threshold stature is set at 10 cm. Threshold distance is the difference in height at which sensor is placed and the level of garbage fill. During garbage accumulation, whenever the difference falls below threshold value, GSM modem is activated to send an alert signal to the concerned authority through an SMS.

Figure 9. Smart Bin with ultrasonic sensor equipped at surface level

CONCLUSION

A design of smart bin using GSM modem (SIM 900A), ultrasonic sensor (HC-SR04) and Arduino Uno is successfully developed. A working design has been built to monitor the status of the garbage bin through SMS. This smart dustbin can contribute a lot towards clean and hygienic environment. GSM modem and ultrasonic sensor, proved to be very efficient in designing a smart bin with arduino as platform. It is concluded that the design of smart bin using gsm module, ultrasonic sensor and arduino effectively eliminate over-filling of garbage bins and offer remote smart monitoring. This smart dustbin can contribute a lot towards clean and hygienic environment.

RECOMMENDATION

Implementation is done only for a single bin. Integration of many bins, each with a unique ID can be monitored by creating database for each bin which can be maintained by using SQL technology. With integration of smart bins, collection can be smarter, more efficient, and less wasteful.

TRANSLATIONAL RESEARCH

The circuit design can be introduced at the garbage collection section of the city making garbage collection operations smarter, more efficient and less wasteful. The design concept can also be evaluated by stakeholders alike for acceptability and impact.

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