

Geo Tracking of Waste, Triggering Alerts and Mapping Areas with High Waste Index

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Abstract— This paper aims to improve the efficiency of the garbage collection process by developing a system for monitoring waste levels in garbage bins using ultrasonic sensors and connecting them to Arduino Uno board for sending the measurements like the amount of waste level to the user. Two smart dustbins were designed for home use and public use which are monitored in real-time using the mobile applications. Notification alerts are also sent when the amount of waste exceeds a certain threshold level. These dustbins are connected wirelessly using Zigbee based transceiver in the form of a mesh network to facilitate the transfer of the amount of waste present in these dustbins to the nearest garbage collection truck and an optimized shortest route to be followed by the garbage collector truck is calculated. The proposed system is user friendly, compact and cost-effective requiring minimum human intervention.

Keywords— Routing system, Smart waste bins, Waste management system, Zigbee standard

I. INTRODUCTION

In India, sixty-two million tons of municipal solid waste is generated in cities and towns every year. Out of these, approximately forty-three million tons of waste is collected properly. Proper waste management is becoming a serious problem in developing countries resulting in deterioration of the environment and poor public health.

Several factors contribute to this improper management of waste collection and processing in India like dependence on the services of small labours or waste pickers for the collection of waste and extraction of any potential value from the waste. Mixed biodegradable and inert waste are often dumped together with e-waste without any segregation. These workers do not utilize any efficient method for processing and disposal of the waste and often practice open burning of the garbage.

Also, municipal corporations have budgets that are insufficient to cover the costs associated with developing the proper waste collection, storage, treatment and disposal. Local bodies spend around Rs. 500–1000 per tonne on solid waste management (SWM) with 70% of this amount spent on collection and 20% spent on transport [1].

In this work, an IoT based waste management system has been proposed for monitoring the waste levels in garbage bins across the city by recording these levels without any human intervention. The status of the dustbins is monitored via user-

friendly applications. The locations and amount of waste present in these dustbins are used to determine the shortest possible route to be followed by the garbage collecting van which would help to reduce the cost of transportation and reduction of fuel consumption. The rest of the paper is organized as follows. The previous initiatives are discussed in Section II. The hardware and software design of the system is discussed in Section III and IV, respectively. System implementation and the related results are presented in Section V. Finally, the paper is concluded in Section VI.

II. LITERATURE SURVEY

A low cost and efficient waste management system has been developed by Balamurugan et. al. Their solution involves developing smart trash cans using Arduino Uno. Ultrasonic and Gas Sensors are used for monitoring the level of trash and the presence of any harmful gas sensors respectively. A GSM module connected with the system is used to send alerts to the administrator when the trash exceeds a threshold level or a decomposition limit [2].

Michael et. al. have designed smart dustbins using ATmega 328P microcontroller interfaced with a GSM module to transfer the bin status to a cloud-based database ThingSpeak. A mobile application is developed using Angular Ionic Framework and Visual Studio Code platforms which can be used by the garbage collectors or van drivers to monitor bin level status and receive SMS alerts. The system also provides an optimized route to the garbage collector for improving the garbage collection process [3]. All these aspects are implemented in the proposed system. Further, a mesh network of dustbins based on Zigbee standard facilitates the transfer of data to the garbage collector. Zigbee based network is simple to use and cheaper as compared to GSM/GPRS standard and devices can be easily added or removed from the Zigbee based mesh network.

Kellow et. al. have developed a system with a load cell for measuring the weight of the dustbin and a temperature and humidity sensor (DHT11) for monitoring the environmental conditions in the vicinity of the dustbin. The proposed system also consists of an IoT middleware platform that is used to connect the IoT devices like the ultrasonic sensor to the designed mobile application. Their solution is geared more towards citizens, who can check the availability of different nearby bins and their locations using their application [4].

Maher et. al. have developed a real-time web-based solid waste management system which uses RFID, GPS and GSM based solution for recording the waste collection process and geo-tracking of the collection vehicle. The data is collected at a central database from where all clients can easily access the same [5].

A lot of product-based solutions are also available in the market like the Reetrix Waste Bin. The main feature of the dustbin is the automatic opening of the lid of the bin which is accomplished by using an infrared sensor and an internal motor mechanism. It can lead to hands-free and effective waste disposal. The bin is made out of plastic that is rust-resistant and durable [6].

Pantech Solutions also provide an IoT based Smart Waste Management System designed using Arduino Uno. These bins are capable of separating wet and dry waste by using IR and moisture sensor. An ESP8266 Wi-Fi module is used to send the amount of waste detected in the dustbin to the ThingSpeak cloud [7].

All of the above-mentioned approaches facilitate the garbage collection either at the citizen's end or administrator's end. In this work, the authors try to unify these two approaches and make a complete waste management system. Two types of dustbins are designed one for home use through which individuals can monitor the level of waste in the bin in real-time and receive alerts if it crosses some threshold level. The other design is for public use where a user can simply scan a QR code to open the dustbin and collect points based on the amount of waste thrown. The data from all of these dustbins are used to determine the shortest path that can be followed by the garbage collecting truck to reduce the cost of transportation and fuel consumption. The proposed system is user-friendly, compact, cost-effective and requires minimum human intervention.

III. HARDWARE DETAILS

This section describes the block diagram, circuit diagram and the hardware components of the home use and public use dustbins.

A. Block Diagram of a Smart Dustbin for Home Use

The block diagram of dustbin for home use is shown in Fig. 1. The design consists of an ESP8266 module interfaced with

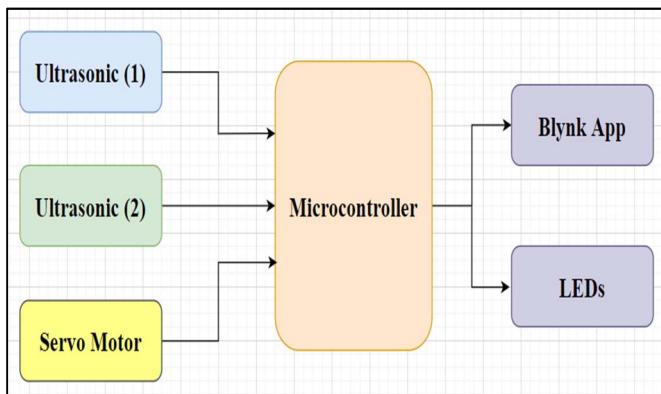


Fig. 1. Block Diagram of a Smart Dustbin for Home Use

two ultrasonic sensors and a servo motor as input devices and four LEDs as output devices. One ultrasonic sensor is used for sensing the presence of an individual near the dustbin and another for measuring the level of waste in the bin, which is displayed using the LEDs. An opening mechanism for the lid of the bin is designed by using a servo motor. It is also used to lock the bin when it becomes 80% full. The ESP8266 sends the data to the designed BLYNK application where the amount of waste present in the dustbin is displayed.

B. Block Diagram of a Smart Dustbin for Public Use

In Fig. 2, the block diagram of a dustbin for 'Public Use' is shown and in Fig. 3 the hardware implementation of the dustbin is given. An Arduino Uno is used as a microcontroller which is connected to an ultrasonic sensor, accelerometer and a servo motor. The ultrasonic sensor measures the amount of waste in the dustbin and the servo motor is used for opening its lid when a user scans the QR code present on it. An accelerometer MPU3250 is used for monitoring the orientation of the dustbin and an SMS alert is generated if there is any tilt in its position. This ensures that the vertical orientation of the dustbin is maintained and no spillage occurs. A Bluetooth module is used for sending the authentication prompt of QR code from the mobile application to the microcontroller in the dustbin. A XBee module is used for transmitting the amount of waste present in the dustbin to the central station. This data transmission is done through a mesh network of such XBee modules from different dustbins.

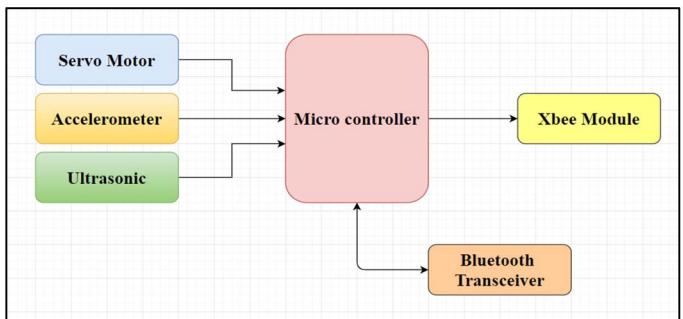


Fig. 2. Block Diagram of a Smart Dustbin for Public Use



Fig. 3. Hardware Implementation of a Smart Dustbin for Public Use

The ESP8266 from Espressif Systems is a low-cost Wi-Fi module with a full TCP/IP stack and microcontroller capability [8]. It is used in the ‘Smart Dustbin for Home Use’ application as a controller and to transmit data through Wi-Fi to the mobile application [9]. The Ultrasonic sensor HC-SR04 provides a measurement range of 2 cm-400 cm with an accuracy of 3 mm [10]. It is used to detect human presence around dustbin and to calculate how much percentage (%) of dustbin is full. Servo motor SG 90 rotates from 0° to 180° [11]. The main purpose of the servo motor is to open and close the dustbin. Accelerometer MPU-3250 is a multi-chip module (MCM) consisting of two dies integrated into a single QFN package and it is used to monitor the position of the dustbin [12]. Its range is less than 100 meters and it supports the baud rate of 9600, 19200, 38400, 57600, 115200, 230400, 460800. The use of Bluetooth module is to transmit details of how much % the dustbin is full to ‘Smart Dustbin’ application and to transmit the data of multiple dustbins to a Data Analysis application running in a central computer station [13]. The XBee module works at the transmission frequency of 2.4 GHz to 2.5 GHz. It is used to transmit the data from one point to another point by creating a mesh network [14].

The major hardware components, their operating voltage and current are shown in Table I. It can be seen that the operating voltage of all the hardware components is in between 3-5 Volts making them power efficient.

TABLE I. OPERATING VOLTAGE AND CURRENT DETAILS OF THE HARDWARE

Sr. No.	Component	Operating Voltage	Operating Current
1.	Arduino	5 V	20 mA
2.	ESP 8266	3 V-3.6 V	15 mA
3.	HC-SR04	3 V-3.6 V	0.3 mA
4.	SG 90	5 V	15 mA
5.	MPU 3250	3.3 V-5 V	15 mA
6.	HC-05	3.3 V-5 V	15 mA
7.	S2C XBee Module	2.1 V-3.6 V	100 nA

IV. SOFTWARE DETAILS

A. Home Use Dustbin

The amount of waste present in the dustbin which is measured by the ultrasonic sensor can be monitored on an android device by the user using the BLYNK application designed [15]. The GUI of the application includes a display gauge which represents the quantity of waste present in the dustbin. An email notification can also be sent to the user via the application. When the dustbin gets 80% full the user is sent an email alert. The flow chart for the same is shown in Fig. 4.

B. Public Use Dustbin

For the public use dustbin, a Smart Dustbin application is designed using MIT App Inventor through which users can open the dustbin and collect points based on the amount of waste thrown by them. MIT App inventor is a cloud-based integrated development environment (IDE) used for developing mobile applications online [16].

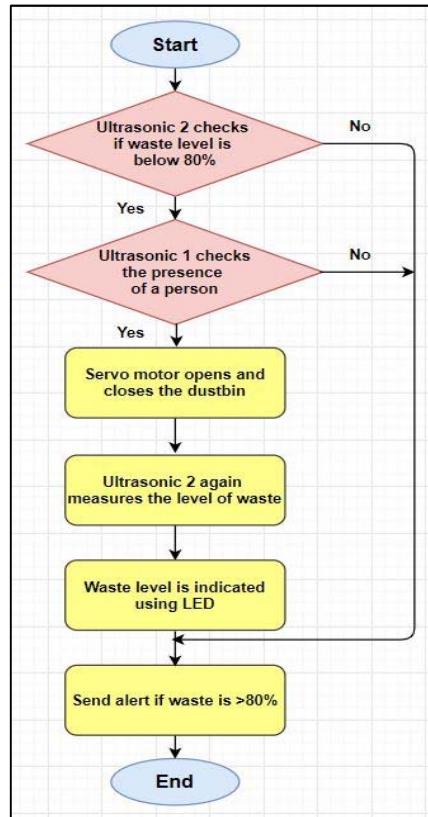


Fig. 4. Flow Chart of a Home Use Dustbin

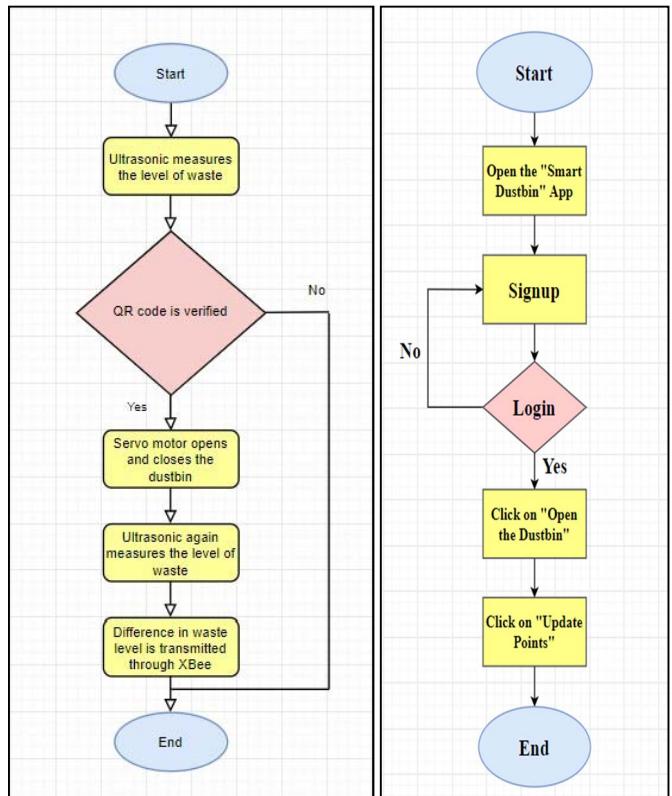


Fig. 5. (a) Flow Chart of Public Use Dustbin (b) Flow Chart of Smart Dustbin Application

A user needs to login in the designed application to use the dustbin. Once a user is successfully logged in, he/she needs to scan the QR code present on the bin using their mobile phone. After the code is verified the lid of the dustbin is opened via the prompt sent to the Arduino using the Bluetooth module. The lid remains open for 20 seconds and then 2nd time ultrasonic sensor will check the garbage level. Further, based on the change in the garbage level detected, points are awarded to the user. The user can update points after using the dustbin or can clear all the points if required.

The amount of waste present in these dustbins is transferred to the receiver circuitry present in the garbage collecting truck. This is done by wirelessly transmitting the data using the XBee module. Here the latest version 6.3 of XCTU has been used to configure the S2C XBee modules [17]. The XBee modules connected with the public use dustbins form a mesh network through which they can exchange data and transmit the data to the receiver XBee which acts as a coordinator. Fig. 5 (a) shows the flowchart of public use dustbin whereas Fig 5 (b) shows the flowchart of smart dustbin application.

C. Central Station

The XBee module present at the Central Station is configured as a coordinator using the XCTU software. It receives readings of waste level from all the public use dustbins via the XBee mesh network. These readings are transferred from the microcontroller to the mobile phone of the operator of the garbage collecting van through a Bluetooth module and are displayed on the Data Analysis application designed using the MIT App Inventor. Using this application, the operator can decide which places or dustbins need to be visited and emptied on a particular day.

The locations are used to generate an optimized route for the garbage collector van in Python using Google-OR software suite [18]. Brute force algorithm is used to narrow down the search set, to find an optimal solution [19].

After the optimized route is generated, it is displayed on the mobile phone of the operator using Google Maps [20]. Google Maps can be used to perform searches, get directions and navigation, and display map views and panoramic images. An URL is created for the route which can be used in any platform either Android/iOS application or a browser to display the route with directions and the distance and time required by the van.

V. RESULTS AND DISCUSSION

When a user opens the BLYNK application and gets connected with the home use dustbin via the Wi-Fi module, the amount of waste present in the dustbin is indicated on the mobile application in terms of percentage. If the dustbin exceeds the 80% level a notification alert is sent to the user in the form of an SMS or an email. Fig. 6 (a) shows the waste level of a user's dustbin using the gauge feature of the BLYNK application. Since the reading is above 80% an email alert is sent to the user which is depicted in Fig. 6 (b).

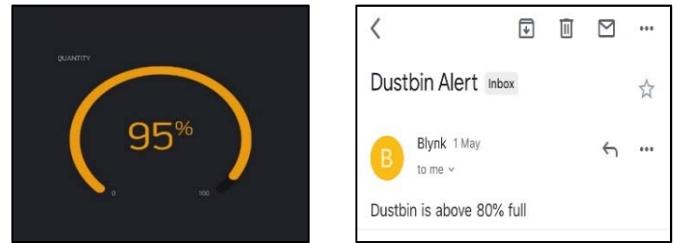


Fig. 6. (a) Quantity of Waste (b) Notification through Email (Using BLYNK Application)

The user can check or update their collected points using the smart dustbin mobile application. The application provides the provision to update the points after using the dustbin based on the amount of waste thrown. The collected points can be cleared if the user requires doing so. The points are updated by the user by pressing the update point button in the mobile application. Fig. 7 (a) shows the points collected by a user along with buttons to update or clear the points.

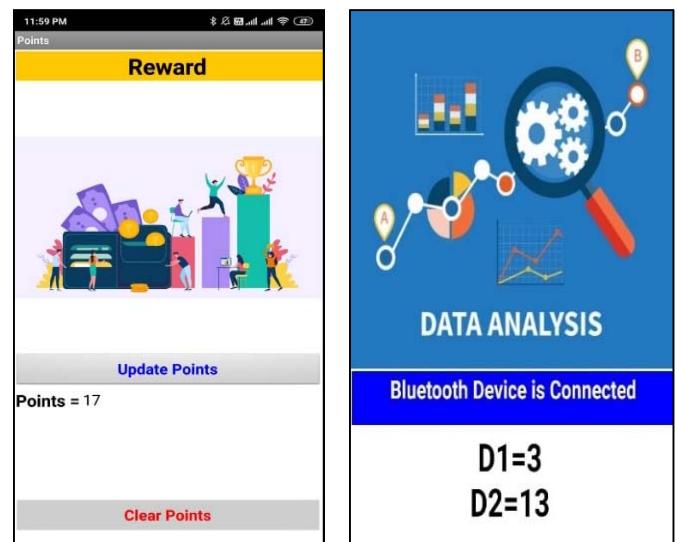


Fig. 7. (a) Total Points Earned (Using Smart Dustbin Application)
(b) Waste level in Two Dustbins (Using Data Analysis Application)

The person operating the garbage collecting van can use the data analysis mobile application to monitor the waste levels of different dustbins present in the mesh network.

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0: My Home
1: Kargil
2: Mangaldeep
3: Jalaram
4: Vertis
5: IO office
6: Water Tank
7: HCG
8: Apollo
9: Saral Heights

Number of locations to be visited today: 5
Enter the location: 0
Enter the location: 5
Enter the location: 8
Enter the location: 9
Enter the location: 3
Route:
0 -> 3 -> 2 -> 4 -> 1 -> 0
  
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Fig. 8. Details of Shortest Path Generated

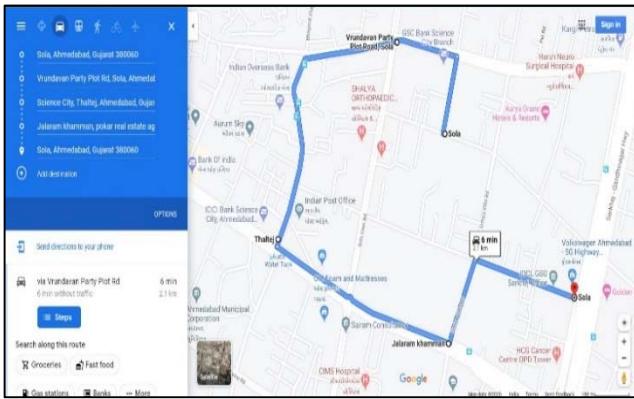


Fig. 9. The Output of Shortest Route in Google Maps

The amount of garbage present along with the dustbin's identification is displayed on the screen when the application is active. Fig 7 (b) depicts the data collected by the application. Readings are received from dustbin 1 and 2 about the waste level present. Fig. 8 shows an optimized path generated by the Python script after specifying the locations to be covered, which is used to form a URL of Google Maps.

When the user clicks on the URL the determined route is displayed on the Google Maps along with the directions and the time required. The output for the above five locations on Google Maps platform is depicted in Fig 9.

VI. CONCLUSION

A system that helps in effective waste management at public and private places is designed, developed and tested. The system identifies waste level in the dustbin, triggers SMS and mail alerts when the dustbin is full, identifies areas which have full dustbins and finds an optimal route for collecting the garbage from the dustbins. The cost of the system is 4000 INR and can be easily fitted in existing private and public dustbins. The experimental results reveal that the system is easy to use, accurate, power-efficient and cost-effective.

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