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Smart Bin for Solid Waste Management in Cities

Lakshmi Nandakumar
Department of Electronics and Instrumentation Engineering
Federal Institute of Science and Technology
Angamaly, Kerala, India
nanda.lakshmi@fisat.ac.in

Alan Eldhose
Department of Electronics and Instrumentation Engineering
Federal Institute of Science and Technology
Angamaly, Kerala, India
alaneldhose700@gmail.com

Chandana Anil
Department of Electronics and Instrumentation Engineering
Federal Institute of Science and Technology
Angamaly, Kerala, India
chandanaanil2001@gmail.com

George Thomas
Department of Electronics and Instrumentation Engineering
Federal Institute of Science and Technology
Angamaly, Kerala, India
gtgeorgethomas2001@gmail.com

Nived P Kumar
Department of Electronics and Instrumentation Engineering
Federal Institute of Science and Technology
Angamaly, Kerala, India
nivedpkumar07@gmail.com

Pooja C P
Department of Electronics and Instrumentation Engineering
Federal Institute of Science and Technology
Angamaly, Kerala, India
poojacp2000@gmail.com

***Abstract*—With the increase in population, the amount of waste generated has increased significantly worldwide and proper waste management has become inevitable. In majority of the cities, trash cans are over flowing due to untimely management of waste. An effective system is required to collect the waste from trash cans and prevent overflow. For cleaner environment and implementation of smart cities, it is essential to reduce overflowing litter cans by a monitoring system. The proposed system keeps track on trash cans and detects the level in it and updates it in a web page. The same could be viewed on a mobile app of the garbage collector and determine the shortest path by linking various routes of the almost full bins. Alerts are produced as in app-notifications for the user. The IoT based garbage monitoring system will enable to maintain a cleaner community.**

Keywords*—IOT, Node MCU, Arduino, Ultrasonic sensor, Level detection

I. INTRODUCTION

Maintaining clean environment is a huge challenge in populated cities. Over the past decade, the population has increased manifold, but waste management has become an onerous and demanding task. According to the statistics provided by the world bank, solid waste generated in all over the world in metropolitan areas alone sums up to a whopping 2.016 billion tonnes. This was in 2016 and by 2050 it is estimated to increase by around 50% [1]. If we consider the scenario in India, 60 million tonnes of municipal solid waste are generated per year, out of which only 40 million tonnes are collected on time for processing [2]. If waste management is not given sufficient importance, it could even lead to pandemic break out in populated areas. Thus, waste management should be of primary concern especially in smart cities.

The goal of smart cities is to integrate IoT to its infrastructure to provide quality services and improved resources. A wide range of sensors, protocols, cloud and processing capabilities and employed to provide clean, safe and sustainable environment. The usage of all the above will make an ordinary city "smart". Garbage bins can be made smart by deploying a variety of sensors and making them nodes of an IoT network. The level of trash can be relayed to a mobile app and webpage through cloud. The shortest route for collecting the bins which are about to be full are mapped and given to user, thereby providing timely service and reducing the cost and time spend for the process. We must acknowledge that the existing waste collection bins and methods do not cater to needs of the growing population.

II. DISCUSSION ON EXISTING SYSTEMS

This section summarizes on the discussion of various existing methods as contemplated by various authors. In [3-5] the authors propose a smart bin that automatically monitors the level of the bin and opens the lid with a light during night time. This does not integrate a shortest route feature which make the bins to overflow. In [5] the authors propose designing a bin using 3D printer which can incorporate all sensors for making the system automatic. In [6], the authors propose a system with volume and weight of waste. Unwanted sensors and connections make the systems bulky and also expenditure increases. In [7] the authors propose a bin with an auxiliary bin for housing the IoT circuits along with each bin. Not only this increases the cost, it could also lead to occupying more space by the bin. It is important to have elegant and cost-effective designs in the modern world rather than bulky systems. [8-9] also lacks an application and user interface which could be used easily by layman.

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Based on above survey conducted we decided that IoT is inevitable for timely collection of garbage. A sensor cloud-based architecture provides the correct fit for the application. Moreover, a system is required that gives alert to the concerned people. We combined the ideas of both [3,9] in which the lid would automatically open and close on detecting human presence with the help of sensors. Also, an LED would be on indicating the level of trash in the garbage if it exceeds a preset value. Based on discussions of various motors for trash bins in [10], we decided on server motor that can open and close the bin. The application should also have a simple interface that could be used by a non-technical person.

III. SYSTEM DESCRIPTION

The system could be mainly divided into four subsystems based on the functionality. They are mainly the sub systems for detecting human presence, transferring data to cloud, bin automation and mobile display. Figure 1 is the basic block diagram, figure 2 is the circuit diagram for bin automation which we designed. The circuit consist of mainly an Ultrasonic Sensor, Servo motor and Arduino nano. Figure 4 and Figure 5 are the flowcharts depicting the working of the system.

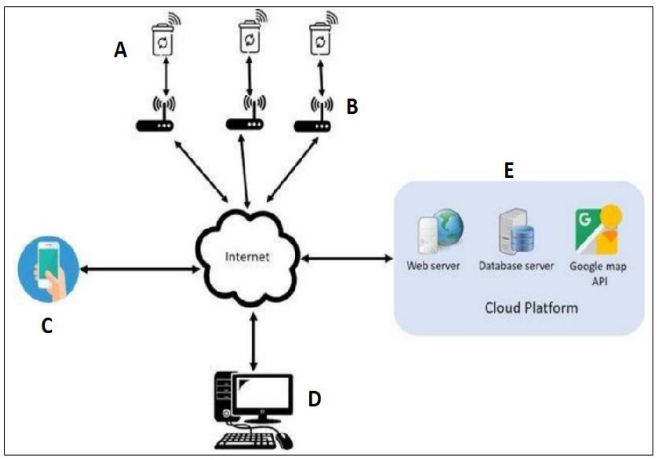

Fig. 1. Block diagram of the system A-smart bins, B- gateways, C- Mobile app, D- Web server, E- Cloud

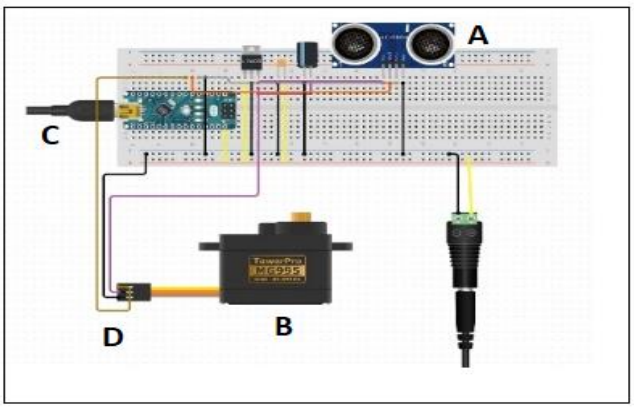

Fig. 2. Circuit diagram for bin automation A-Ultrasonic sensor, B- server motor, C- Arduino nano, D- dc dc buck converter

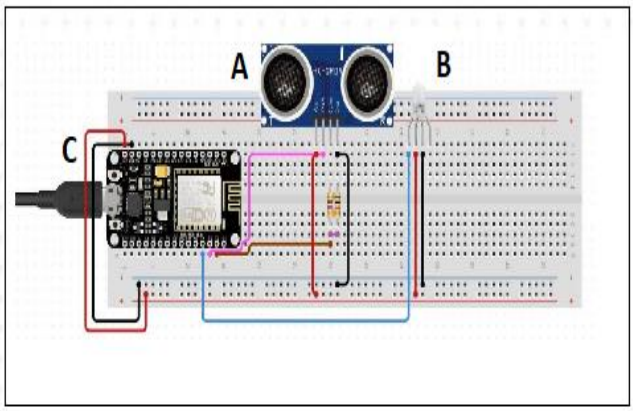

Fig. 3. Circuit diagram for detecting waste level A-Ultrasonic sensor, B-LED, C- Arduino nano

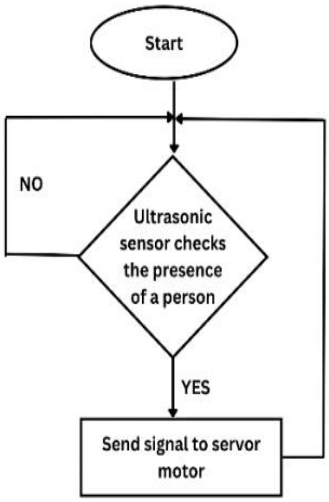

Fig. 4. Flow chart of bin automation

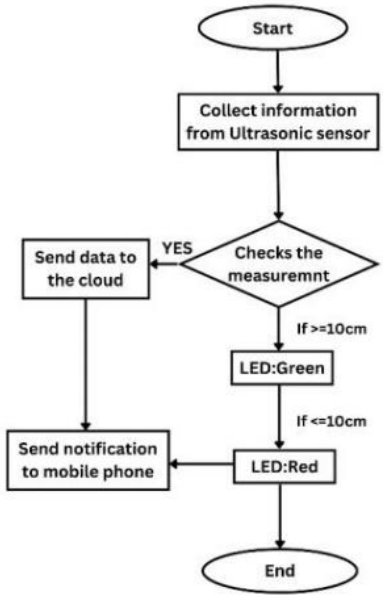

Fig. 5. Flow Chart for detecting waste level in the bin

A. Sensors

It consists of the ultrasonic sensor for detecting human presence near its vicinity. If a human is present, then further processing is done to open the bin using servo motor. The figure 3 shows the flow chart and table 1 shows the specification of the sensor used.

TABLE I. SPECIFICATION OF ULTRASONIC SYSTEM

Parameter	***Ideal range***
Measuring Range	0 – 20 m
Accuracy	0.5% - 1.0 %
Process Pressure	<= 0.3 MPa
Signal Output	(4 -20) mA

B. Data Transmission

Wireless protocols suit best for IoT based system. It also aids in reducing the space occupied by the system. ESP8266 NodeMCU has been chosen to transmit data since it's a cost-effective platform that could transmit data wirelessly. The real time data gathered from the sensors could be transferred seamlessly to the database.

C. Automatic Bin Open and Close

An Arduino Nano microcontroller board is a employed due to its small size and economical. This board is connected to the server motor which will detect the presence of human near the vicinity and will open and close the lid automatically. As long as the presence of the person is detected within close proximity, the lid will remain open, else it will close within a short time. The specifications of the servo motor which is used for the application is shown in table II.

TABLE II. SPECIFICATION OF SERVO MOTOR

Parameter	***Ideal range***
Weight	55g
Operatig speed (no load)	20 sec/ 60 deg
Torque	10kg/cm
Operating angle	Upto 120 degree
Operating voltage	4.8 -7.2 V

A DC–DC buck converter was employed to amplify the voltage provided by Arduino nano. It was a readily available circuit which had a capacity to produce output up to 35V.

D. Display

Real-time data regarding the bin's status can be accessed through a server. Additionally, a mobile application has been developed to provide information on the bin's status, and it is designed to display the data at a pre-determined location. If the bin reaches an almost full state, a notification is sent to the truck driver responsible for collecting the waste. Moreover, the mobile application also includes a map feature that showcases the location of the bin, aiding in easy identification and navigation.

IV. DEVELOPMENT OF SOFTWARE

A. Arduino Code

There are two main sections in the Arduino Sketch. One section within the sketch is for getting sensor measurements. The functionality of the second part of the code is to automate the bin using the Arduino platform. Sec cloud is used to store the sensor data. When a new data is acquired from the sensor, it is updated in the Sec cloud.

The previous data are shifted and the oldest data is removed. The same could also be viewed on the mobile app. The data from the sensors are sampled every 5 seconds. The Sketch's many steps are:

1. Set up the Arduino and NodeMCU.
2. The sensors' analog input ports are set up on 2 pins of the Arduino.
3. The sensor's analog input ports are set up on NodeMCU's 1 pin.
4. Configure Wi-Fi and Sec cloud with the required security keys.
5. Data from ultrasonic sensor is sampled every 5 seconds.
6. New parameter values have been changed for the Sec cloud. Through Node MCU, the sensor's data is sent to Sec cloud
7. From step 5, the procedure is repeated.

B. Arduino Code

A Java code was created to get sensor values from the Sec Cloud. The website and application are linked together using the web view functionality of the Android Studio platform. A table that displays the amount of waste that has been collected and updated in Sec Cloud in real time has been integrated into the application user interface.

As the sensor data change, so does the real-time values which are displayed on the screen. A notification will be sent to the email address provided if the bin is 90% full. The front end of mobile app which was designed is depicted in Figure 5.

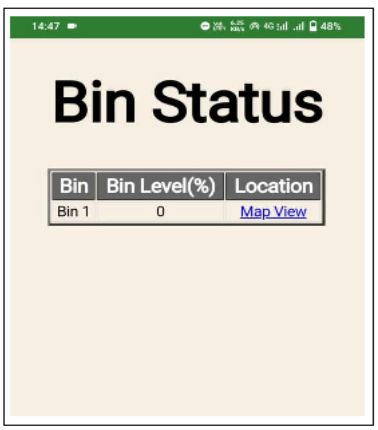

Fig. 6. Mobile app showing the bin status

C. Sec Cloud and XAMPP

The use of Sec Cloud enables us to access the data through any mobile device with the help of internet. Even if a device is lost, we can access data through the cloud. Also, XAMPP was used for running the server and testing the system in host machine. It was user friendly and allows the application to be run without much configuration.

V. RESULTS

We employed bins in 3 different regions and the system worked correctly. The status of the three bins were updated in real time based on the amount of garbage deposited into the system. Moreover, the red LED also glowed when each of bins had garbage above 70%. This provides an indication to the person coming near to the bin.

Fig. 7. The bins with automatic lids.

Till the bin reaches 70% a green LED will glow. The mobile app and server also displayed the location and status of the bin in real time. The shortest route to the location of the bin was shown using Google maps to the person using the mobile app. This helps in saving time and money and prevents overflow of the garbage at any location.

BIN 3

ID	Date $ Time	Sensor	Location	Distance	Percentage
533	2023-05-22 10:35:00	Dustbin-03	Location-03	55	0.43
532	2023-05-22 10:34:00	Dustbin-03	Location-03	55	0.43
531	2023-05-22 10:33:01	Dustbin-03	Location-03	55	0.43
530	2023-05-22 10:32:00	Dustbin-03	Location-03	55	0.43
529	2023-05-22 10:31:27	Dustbin-03	Location-03	0	0.00

Fig. 8. Sec Cloud data showing the bin status

A sample bin status when viewed through the server is shown in figure 8 and a sample map is shown in figure 9.

Fig. 9. Map showing location of bin and route

VI. CONCLUSIONS

The Arduino microcontroller is successfully used in this project to control the opening and shutting mechanism of a bin. An ultrasonic sensor detects the presence of a person and activates a servo motor, which opens the bin's lid accordingly. A node MCU ESP8266 module and an ultrasonic sensor mounted on the lid are used to monitor waste levels. To indicate the fill level, an LED positioned on the bin changes colour.

A server offers real-time data on the status of the bin, and a mobile application provides information and notifications to the appropriate people. The introduction of a map element in the app aids in efficiently locating and navigating to the bins. Overall, this project successfully integrates hardware, sensors, and software to develop an IoT based automated bin to help manage waste.

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