IoT-Based Smart Waste Management System

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Abstract

In today's world, the growth of population is increasing rapidly. As population increases the new problems are also generated. Advanced technology can solve these problems. Waste management is a big concern of today's world. Traditional methods are failing now. Therefore, the problem of waste management also can be solved with the help of new technologies. This waste management can be done smartly with the help of a technology IoT. The main objective of this system is to create a solution for smart waste management which is smart dustbin. As waste is collected by municipal employees from the dustbins, but tracking the waste level manually in dustbin is very difficult and costly. In this case, when bin is filled, waste comes out from the bin and becomes the reason of serious health hazard to the surrounding environment. Smart dustbin provides the facility to track the status of bin waste. It is connected to the Internet; therefore, real-time information of dustbin can be received.

Keywords

Android • Internet of things • Smart waste • Ultrasonic sensors • Node MCU • Smart dustbin

1 Introduction

Waste management is the important concerns of modern world. As nations of the world are developing, their problems and responsibilities for a health sector and sustainable environment are also increasing. While developed countries like USA, China, UK, etc., are inventing smart solutions for waste management, this makes huge positive impacts. But in other developing countries like India and Bangladesh, the condition of waste management is too harsh. According to a report capital of Bangladesh, Dhaka is the most polluted city in the world. The reason is that there are many issues with the management of municipal waste. Waste management is the most essential requirement of today's world. This system presents a solution of waste management using IoT technology (Medvedev and Fedchenkov 2012). A smart dustbin is the main product of this system. This dustbin is interfaced with Arduino, ultrasonic sensors and node MCU. The ultrasonic sensor will detect the level of the garbage available in dustbin. Then the data will be sent to Arduino. The same signal is encoded by Arduino, and it is shown on the LED screen and application screen.

The key issue of waste management is that the dustbin which is placed at public places gets overflowed (the bin is full) before the initiation of the next cleaning step. Hence, there is a need to design and implement a system that at least minimizes this problem to some extent. Today's world is filled with advancement of technology. The smart dustbin gives the potential solution for solving the problems of waste management. The waste management system will inform the status of waste level in dustbin to authorized person through mobile application using Wi-Fi and also provide the information about the status of garbage level of dustbin on LED screen attached with dustbin. This level of garbage in the dustbins is detected using the ultrasonic sensor which is placed in the upper part of dustbin called lid. When there is a garbage in hands and needs to trash that in dustbin, the lid of the dustbin will automatically open and close automatically after some defined particular time. The hardware which is required for this system is some electronic components such as an Arduino, Node MCU, 4 ultrasonic sensors, LED and an SG90 Tower Pro Servo Motor and the main dustbin.

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2 Related Work

The waste management in our cities has to be done effectively. There are many proposals for this, and some of them are already implemented. But every proposal cannot be considered as the best one. In this world, everything required improvements. The discussion about the idea of smart dustbin for main object smart waste management is present for quite a long period. In this discussion, the role of new technology which is IoT has important place. There are multiple ideas, and they appear similar to each other but these are slightly different. By using IoT technology, designing a smart dustbin which is able to make some impact on waste management in our society is the main purpose of the proposed work. This system provides the facility of better decision making by the authorized person.

It is observed during survey of maximum solutions, at hardware side, there is smart dustbin with Arduino (microcontroller) and Wi-Fi module (Node MCU). Therefore, a survey was done among different proposals and here it presents a survey which is done among different methods or solutions for smart waste management.

Smith and Waterman (1981) proposed a smart waste management using IoT that provided a solution given as a system that has multiple dustbins. These dustbins are fully accomplished with new technology devices. The level of garbage can be detected by attaching ultrasonic sensors to these dustbins. In this system, a communication is established between this system of dustbin and authorized control room with the help of GSM system. A mobile application which runs on android is also developed which monitors the data collected from smart dustbins from different locations. This will help to manage the waste efficiently. IR sensors are used to detect the level of the dustbins. For this detection, four IR sensors are used in each dustbin. These four sensors indicate the level of dustbin. When the dustbin is full, the output of fourth IR sensor becomes low. This data is sent to Arduino and microcontroller, and it encodes that data to send the message to the control room via GSM module. Control room is that place where all information is received, and after analyzing that information, right decision has taken. This whole system assures that the dustbins are cleaned as soon as possible when the garbage reaches at maximum level of dustbin.

Mahajan (2014) implemented model based on GIS Information System in the city of Asansol in India. This is a GIS transportation model for solid waste collection, its storage and disposal (Li et al. 2008). This model is proposed for the Eastern Finland to enhance the routing of vehicles which collect garbage from dustbins and scheduling waste collection. The main aim of the research was to develop an optimal schedule for waste carrier trucks on known routes. This data is received by DSS from the dustbins, and it is sent to organizers of waste collection in the particular place and to the road police who manage the traffic on roads. The benefit of this system is that now the truck driver does not waste time for waiting because he/she is able to go to the next point, and the route is dynamically recounted (Ghose et al. 2006).

Al-Maaded et al. (2012) is presented a review that was done on waste collection in developing countries like Bangladesh, India and Pakistan from 2005 to 2011, and this survey considers the challenges for developing countries in waste management system. This research focuses on finding the stakeholder's behavior and also evaluates different influential factors which define the roles of stakeholder in waste management processes. In this survey, the methods were tested on real data and considering system approaches for solid waste management in developing countries (Guerrero et al. 2013).

Prakash (2016) proposed a model of waste management using IoT for smart cities in organizing the waste collection system of commercial areas of the cities. This proposed system is similar to other systems as the level of the garbage in dustbin has been detected with the help of ultrasonic sensors, and a communication is established between the system and the authorized control room through GSM module. GSM module is used for tracking the location of dustbin. Microcontroller which is Arduino is used to interface the sensor system with GSM system (Singh et al. 2016). An application having GUI is also developed to supervise the required information related to the garbage present in dustbins for different already known locations. The main difference between the proposed system from other existing systems is the use of MATLAB-based GUI. This system is based on master and slave phenomenon. In this system, slave unit consists of smart dustbins and master unit consists of control room where all information of dustbins is present. Dustbins which come under slave unit consists of Arduino Uno board which has Atmega328 IC, ultrasonic sensor and GSM module for providing locations.

The survey is motivated to introduce and formulate a problem statement to find the solution for waste management using modern technology which can help in collecting the garbage from the dustbin on right time before overflowing the wastes. In other words, try to make a system which is helpful in tracking the level of dustbin and work smartly by open or close the door of dustbin automatically. The facility of opening the lid of dustbin automatically when our hand which having garbage reaches to near the dustbin, make easy for human's daily activities (Navghane et al. 2016).

3 System Design

3.1 Basic Modules and Structure

In this system, work can be divided into small units. These small work units are called modules. Some modules are independent to other modules but some are dependent to each other. Basically, these six modules are.

1. Attaching different components to the dustbin for example sensors, LED screen, Arduino, Node MCU, etc.
2. Connections of sensors to Arduino, the microcontroller with the help of jumper wires.
3. Connection of Node MCU and LED screen to the Arduino.
4. Load the Arduino to the laptop and develop a program for sensors working.
5. Write a program for connectivity of mobile application to the dustbin through Wi-Fi which is inbuilt in Node MCU.
6. Install the android application in the mobile from the play store and login to connect with the system

Abovementioned six basic modules are the main phases of the work process. After implementing each individual module, the process of collaboration between modules takes place. This integration process provides a working system as output of the work. The conceptual modules in a system are defined as shown in Figs. 1 and 2.

3.2 Procedure Design

The block diagram of the system that describes the details of how the components of the system are connected to each other is shown in Fig. 3. Use case diagrams are used for the visualization of functional requirements of the system. It makes it easy for choosing design options and development priorities. These diagrams describe the set of actions between system and one or more external user called Actors. Actors are referred to users who use the system or who will collaborate with the system. Figure 4 depicts the use case diagram User, Authorized Person and System are the actors.

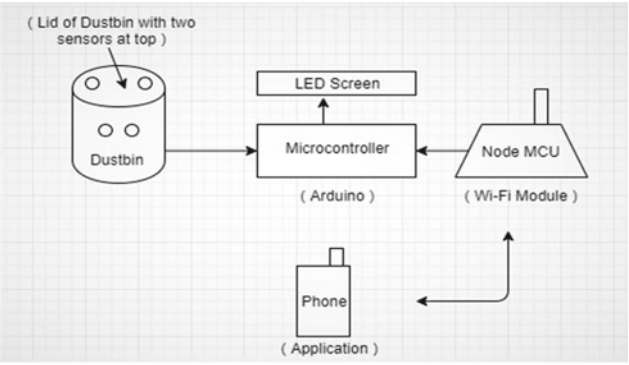

Fig. 1 Conceptual modules

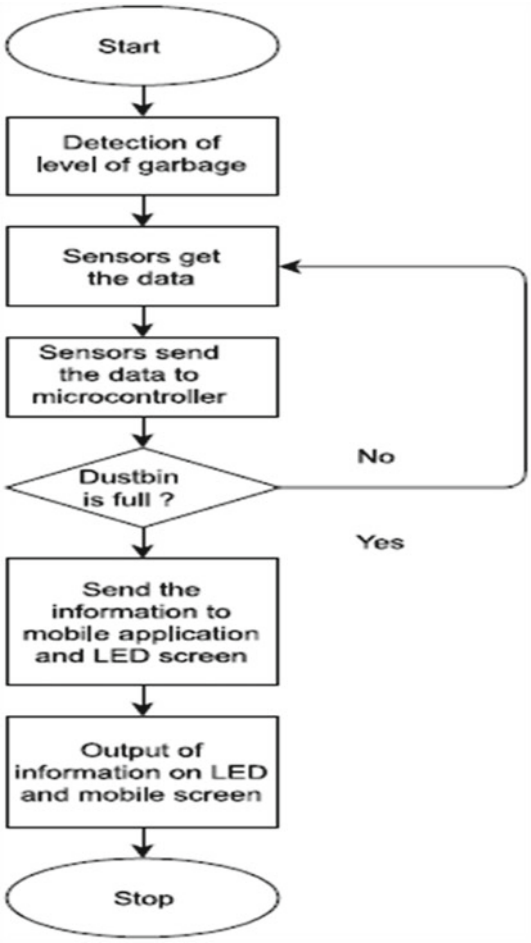

Fig. 2 Data flow diagram

The data flow diagram for the system is shown in Fig. 2.

Figure 5 presents a sequence diagram that provides the information about the interaction between different objects in sequence order. The order is in which interaction between objects takes place. These are used to model the system work. It helps in visualizing the logic or idea behind the sophisticated functions, operations or procedures.

3.3 Test Case Design

The strategies for testing are designed as test cases. These test cases describe the different functions and also provide the information about functions that what will be they provide the outcome. Here, a design of test cases is built in the form of table which consists of the details of required input,

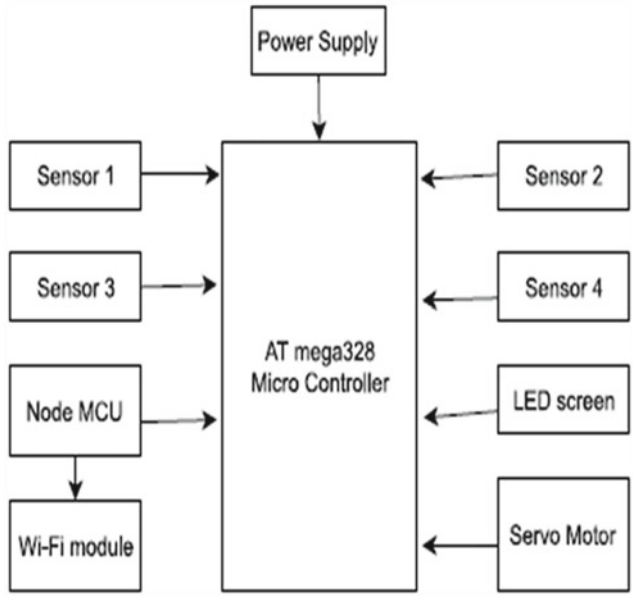

Fig. 3 Block diagram

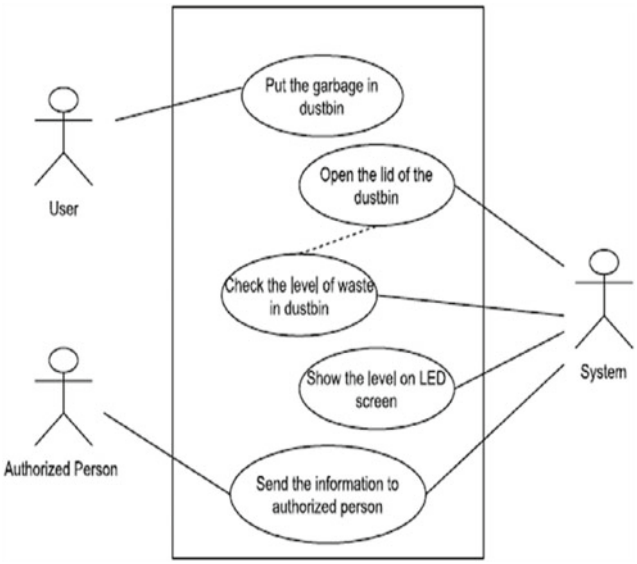

Fig. 4 Use case diagram

actions, expected outcomes, conditions, etc. The different test case scenarios are as follows in Table 1.

4 Implementation

Implementation is the process of converting the designed system into working system. Implementation process is the very crucial phase for any system. Here, implementation work can be divided into two ways. First one is implementation of hardware part and another software part. In this system, maximum implementation is the work of attaching hardware components to the dustbin and making connections between them with the help of jumper wires. This work follows the system designing work and takes the help of different type of diagrams such as data flow diagram (DFD), block diagram of system, use cases diagram and sequence diagram, etc. These diagrams will help in implementation of hardware part.

According to the planning, the sensors are connected to a medium-sized dustbin. For this, a thin plyboard is used and cut it in a circle in the size of open-top area of the dustbin. This plyboard is cut into equal two parts and stick them to each other with the help of the tape and make two holes in the center of that board. These two holes are used for fitting two sensors. These two sensors will detect the level of garbage present in the dustbin. Now, this board has to be attached with dustbin on the top with small screws. This will be the lid of the dustbin.

Other two sensors are attached to the vertical surface of the dustbin. These sensors are used for detecting the object. When user puts the garbage in dustbin via hands, these two sensors will detect the hands and send a signal to microcontroller. Microcontroller will open the lid of dustbin with the help of servomotor. This lid will close after some fixed amount of time. A servomotor is also attached to the dustbin in the bottom of the lid in the center, where the lid is cut in two parts. This servomotor is used for opening the lid of dustbin automatically when front two sensors detect any object. Now, another plyboard is cut in the shape of rectangle. This plyboard is used for attaching other components such as Arduino, Node MCU and LED screen. This also attached to the dustbin with the help of screws. LED display shows the real-time status of the garbage in the dustbin. All components are connected with the help of jumper wires. All components such as sensors, node MCU, servomotor and LED display are connected to microcontroller and Arduino.

Here are some figures which show the work of hardware implementation. In Fig. 6, two sensors are attached in vertical surface of the dustbin. These sensors will detect the object when user tries to put garbage in dustbin. As objects appear, sensors send the message to microcontroller and microcontroller opens the lid of dustbin with the help of servomotor. Figure 7 shows the connections of microcontroller, sensors, Node MCU and LED display. These all components are attached to the rectangle shape board. Node MCU is used because it provides inbuilt Wi-Fi module. It will help in making connection of system with mobile application. After completion of hardware implementation, coding part takes place.

Arduino software is used to load microcontroller with the help of USB cable. A port is given in the Arduino microcontroller for connecting USB cable. Arduino software is an

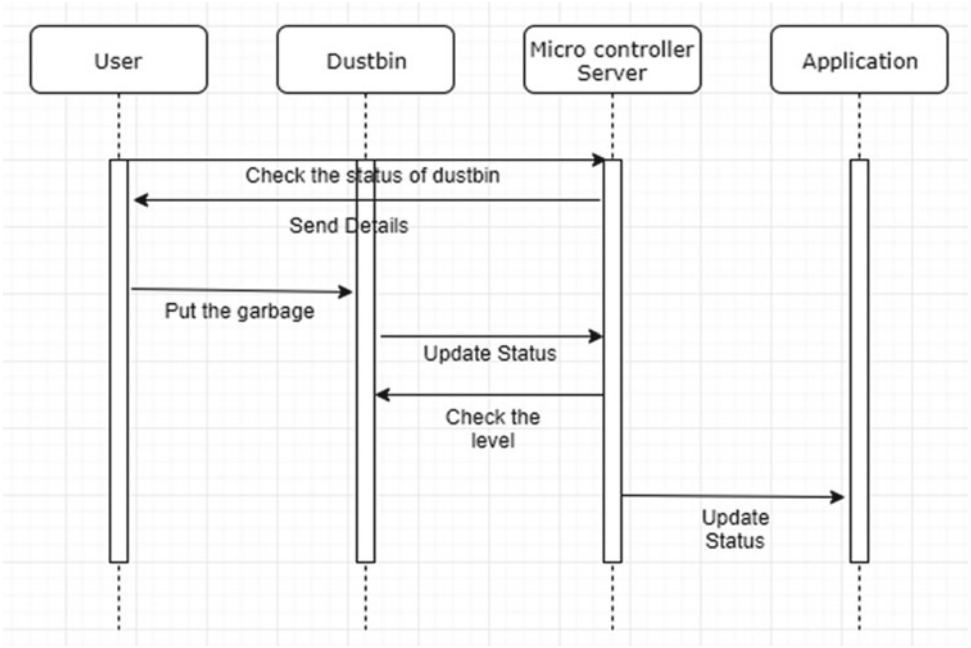

Fig. 5 Sequence diagram

Table 1 Test case scenarios

Sr. No.	Test case description	Input	Requirements	Test case status
T1	All the components work properly in synchronous manner	Power supply	All connections should be ok	Pass
T2	Connect mobile application to the system with the help of Wi-Fi by turning on the hotspot of mobile in which application is installed	Null	Wi-Fi module of Node MCU should be work properly	Pass
T3	Show the status of 'empty' dustbin on mobile application and also on LED display	Null	Dustbin should be empty	Pass
T4	Show the status of 'partial filled' dustbin with garbage on mobile application and also on LED display	Garbage filling	Dustbin should be filled partial	Pass
T5	Show the status of 'completely filled' dustbin with garbage on mobile application and also on LED display	Filled	Dustbin should be completely filled	Pass

Fig. 6 Two sensors attached to dustbin

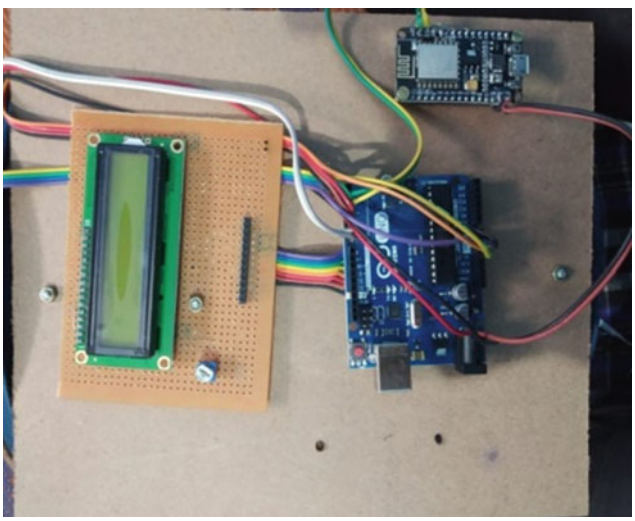

Fig. 7 Connections of different components

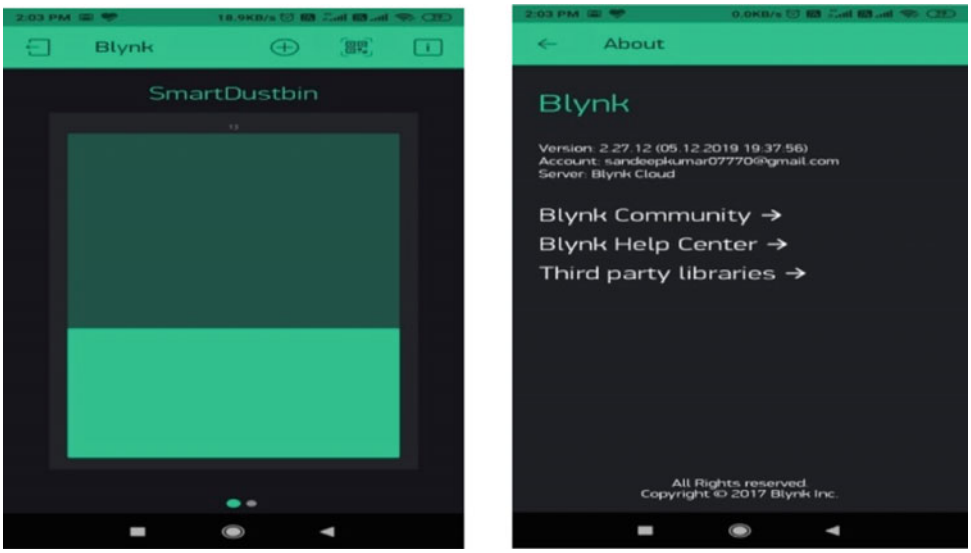

Fig. 8 Status of dustbin in mobile application 'Blynk'

Fig. 9 First message displayed on LCD

Fig. 10 When dustbin is full

integrated development environment (IDE) which provides the facility to write and upload programs to Arduino board.

First a new file is created to write the program and then by clicking on file option, a new file is generated. It contains two functions already without any inner code. These are setup() and loop(). Now, a program is written with these two functions to achieve desired outcome. After loading the microcontroller to the laptop, there are two programs need to write in C/C++ language. One of these program is written for the working of sensors, servomotor to open–close the lid of dustbin and LED screen to display the level of dustbin. Second program is written for establishing the connection of mobile application to the system. This is possible with the help of logging in to the mobile application with the help of Wi-Fi connection.

4.1 Test Reports

An Android mobile application 'Blynk' is used in this system. It is a popular Internet of things platform which provides free cloud, web dashboard and Android mobile applications. The output of the system is to show the status of dustbin in real time in mobile application as well as in LED display. This section discusses some screenshots of system's output. Figure 8 represents the outcome of the system.

Figures 9 and 10 depict the LCD display which also show the status of dustbin.

5 Conclusion

With the use of smart dustbin, the level of garbage can be checked whether the dustbin is full or partial full. The information regarding fill level of dustbins can be known from anywhere by the authorized person with the help of android mobile application, and the user can take a decision according this. This proposed system can reduce the cost which is spent on collection of garbage from dustbin. This system also helps in resource optimization.

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