Smart bins for garbage monitoring in smart cities using IoT system

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Abstract. It is predicted that by 2025 more than 75 billion IoT devices will be linked with internet. Due to technological development and increase in population, industrializationand urbanization, the entire countries should need to formulate ecological development schemes.In connection with this, many countries are endowing large amount of money towards building smart cities. In the proposed work an IoT integrated smart bin for Smarter Waste Disposal Systemis devised. The proposed system will consist of waste bin that are equipped with ultrasonic sensor to detect garbage fullness, Load sensor to measure weight of the garbage, GPS sensor to locate bin location and Gas sensor to measure hazardous gas emission from bin. These sensors are interfaced with ESP 8266 NodeMCU module which a microcontroller is having cost effective Wi-Fi microchip with complete TCP or IP stack. The ESP 8266 can communicate with Wi-Fi modems present in the smart city which are in turn connected with cloud using internet. The proposed system can send alert message to municipal authorities whenever the height of garbage in the bin is greater than threshold value and also stores the data in cloud for future action.

Keywords: IoT, Smart bin, Gas sensor, microchip

1. Introduction

Modern lifestyles of the people, population outbursts and growing heights of urbanisation have resulted in numerous problems [1] in which one of the key problems is generation of huge amount of waste. Generation of huge waste has developed severethreatens to municipal authorities. The current waste disposal schemes are not effective enough to dispose the huge amount of waste that is being generated from cities. Because of the overcrowded garbage and inefficient waste disposing schemes, disease causing bacteria, viruses, germs and insects developed on this garbage and can cause spreading of various infectious diseases. In the existing waste disposal schemes, cleaners have to empty the waste bins every day periodically [2]. Because of the existing waste disposal schemes, most of the time garbage has flooded in the surrounding area and thereby increasing the possibility of spreading virus and bacteria endured diseases [3].

Several alternative waste disposal strategies are proposed by several researchers [4], [5], [6], [7] and [8]. In the proposed work an alternative efficient and economical waste disposal strategy is developed. A newer waste bin is designed in the proposed work and is attached with four sensors for effective real-time monitoring of the smart bin conditions. Whenever the garbage level in the smart bin reaches a programmed threshold level, an alert message is sent to the cleaning authority to empty the smart bin. Thus, the proposed waste disposalscheme using smart bin can effectively assist as a benchmark for waste disposal scheme used in smart cities.

The rest of the paper is organized as follows. Section 2 discuss about overall design of smart bin. The detailed method of measuring garbage fullness, measurement of garbage weight, and identification of smart bin location are discussed in Section 3. The detailed working principle of the proposed smart bin is then presented in Section 4. Finally, conclusions are discussed in Section 5.

2. Construction of smart dust bin

The detailed block diagram of construction of smart bin is shown in Fig. 1. In the proposed system, smart bin is connected with ultrasonic sensor, MQ-136 gas sensor, GPS sensor and load sensor. Garbage fullness is measured with the help of ultrasonic sensor. The weight of garbage in the smart bin is measured with the help of load sensor. The smart bin location is identified with the help of GPS sensor. MQ-136 Gas sensor is used to Hydrogen sulphide which produced through the bacterial breakdown of organic matter present in the smart bin garbage. All the sensors are interfaced with ESP-12E module in which core is ESP8266EX, which consist of 32-bit based RISC microprocessor which operates around 80 MHz to 160 MHz adjustable clock frequency and supports Real Time Operating System. This module is having cost effective Wi-Fi SoC with complete TCP or IP stack. This ESP 8266 can communicate with Wi-Fi modems in the Smart City.

The proposed system can send alert message whenever the height of garbage in the bin is greater than threshold value. In this work, Temboo is used which is having web-based services related to IoT applications such as data logging, instant notifications and control purposes. In this work, Temboo is used with ESP8266 based online IoT project which is then linked with other online platform like Google for sending Email (using Gmail choreos) and data logging (using Spreadsheets choreos). Using Temboo alert Email message is send to the municipal authority person in order to collect the garbage from the smart bin. The alert message includes smart bin location, date, time, weight of the garbage and foul smell status. The municipal authority in tern send message to nearby driver to collect the garbage. The proposed system will also store the various data such as date, time, location of smart bin, fullness status of garbage, weight of garbage, hazardous gas emission status, alert message sent, and action taken by municipal authorities in cloud for further analysis purpose.

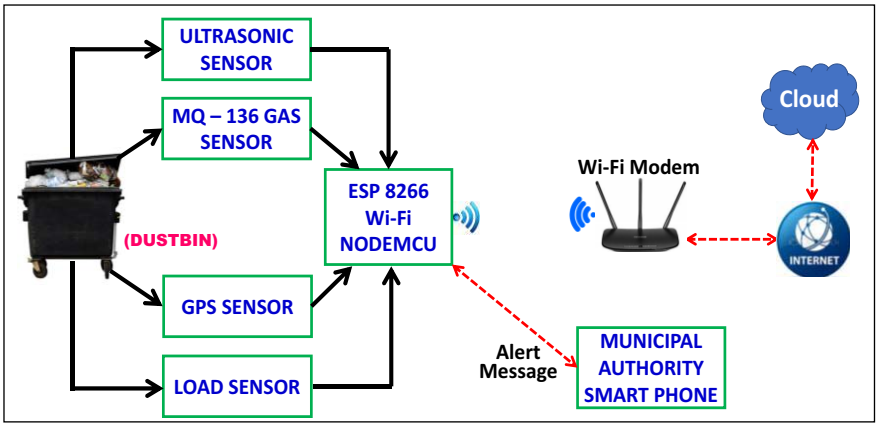

Figure 1. Block diagram of Smart Bin structure

3. Measurements in smart bin

Measurement of garbage fullness, measurement of garbage weight, measurement smart bin location and measurement of hazardous gas in smart bin are discussed in this section.

3.1 Measurement of garbage fullness

The HCSR04 is a non-contact type Ultrasonic distance sensor. It includes ultrasonic transmitter, receiver and control circuit which can measure distance range from 2cm to 400cm. The Ultrasonic distance sensor is used to measure fullness of garbage in smart bin. The ultrasonic distance sensor will be placed on the inner side of the smart bin lid. Both the transmitter and receiver of Ultrasonic distance sensor face the garbage in the smart bin. As garbage increases, the distance between the ultrasonic distance sensor and the garbage decreases.

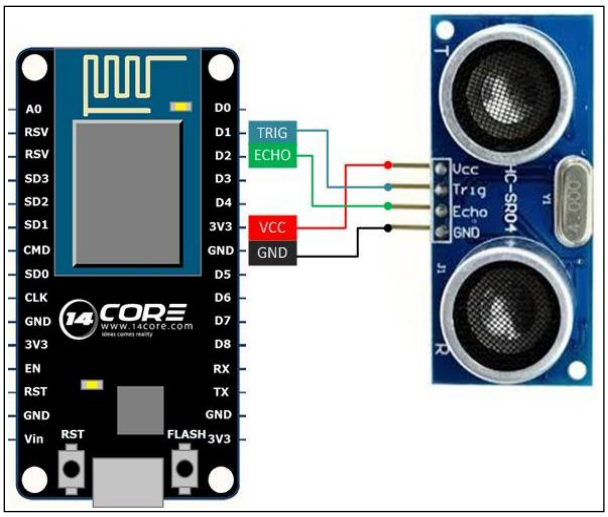

Figure 2. Interfacing diagram of Ultrasonic distance sensor with ESP8266 12E NodeMCU

The Interfacing diagram of Ultrasonic distance sensor with ESP8266 12E NodeMCU is shown in Fig. 2. The Ultrasonic distance sensor's TRIGGER pin is connected to D1 pin, and the ECHO pin is connected to D2 pin in ESP8266 12E NodeMCU Board. Similarly the Ultrasonic distance sensor's Vcc pin is connected to 3v3 supply pin, and the GND is connected to GND (ground) pin in ESP8266 12E NodeMCU Board. Arduino IDE is used in this paper to program the NodeMCU ESP8266 12E Development board. This live distance data collected by Ultrasonic distance sensor will be sent to ESP8266 12E NodeMCU board.

In this paper the threshold value for garbage fullness is 80% of the full capacity. This value can be programmatically changed. Whenever the Ultrasonic distance sensor senses 80 % garbage fullness, ESP8266 12E NodeMCU Board send the alert message to municipal authority using Temboo.

3.2 Measurement of garbage weight

The garbage weight is measured by strain gauge type load cell [9]. In this work, 10 kg Load cell is used which is having sturdy aluminium alloy body constructed with 4 strain gauges pre-attached with strain relieved wires is used. Load sensor has four wires with two excitation wires (Red wire – Excitation+ or VCC and Black wire – Excitation- or GND) and two signal wires (White wire – Amplifier+ or Signal+ or Output+ and Green wire – Amplifier- or Signal- or Output-). The load cell is shown in Fig. 3.

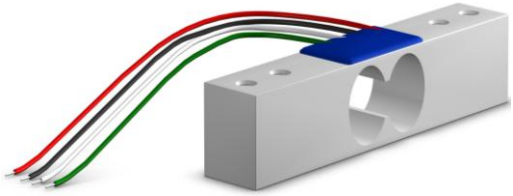

Figure 3. Strain Gauge type Load Cell

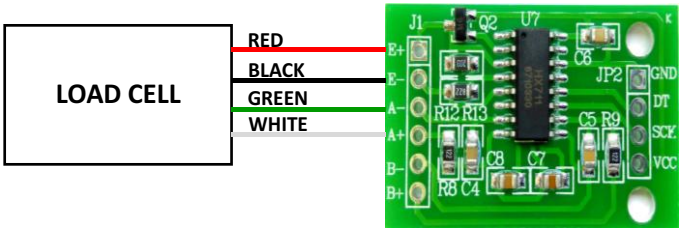

Figure 4. Interfacing Load cell with HX711 board

The HX711 board is having a high precision 24-bit ADC designed specifically for load cell. This board allows to easily interfacing with load cell to measure weight. This board comprises of two numbers of differential input ADC channels. It has on-chip Programmable Gain Amplifier with selectable gain of 32, 64 and 128 with active low noise. In this work gain of 128 is used, Theanalog power supply connected to this board is used for ADC and the on-chip voltage regulator output is connected to load cell. No programming is required to transmit the digital data from ADC to Arduino board. The interfacing diagram of Load cell with HX711 board is shown in Fig. 4. The connection details of load cell with HX711 board are described below:

Red wire of the load cell is connected to Excitation+ (E+) pin, black wire of load cell is connected to Excitation- (E-) pin, white wire of load cell is connected to Amplifier+ (A+) pin and green wire of load cell is connected to Amplifier- (A-) pin of HX711board.

The connection details of HX711 board with ESP8266 12E NodeMCU Board are described below:

Vcc pin of HX711 board is connected to 3v3 supply pin of ESP8266 12E NodeMCU Board and GND pin of HX711 board is connected to GND (ground) pin of ESP8266 12E NodeMCU Board. The DT pin of HX711 board is connected to D3 pin of ESP8266 12E NodeMCU Board and SCK pin of HX711 board is connected to D4 pin of ESP8266 12E NodeMCU Board.

The Load cell is attachedwith bottom side of the smart bin. The dead weight can be eliminated by using software calibration technique. The accuracy grade of the load cell is 0.02%. Since load cell is IP65 rated, it is guaranteed protection from water and dust.

3.3 Measurement of smart bin location

U-blox NEO-6M GPS module is a commercially popular, economical, high-efficient GPS module. It is having ceramic patch antenna, backup battery and on-board memory chip. This GPS module can be easily connected with ESP8266 12E NodeMCU Board. The U-blox Neo 6m GPS module is shown in Fig. 5.

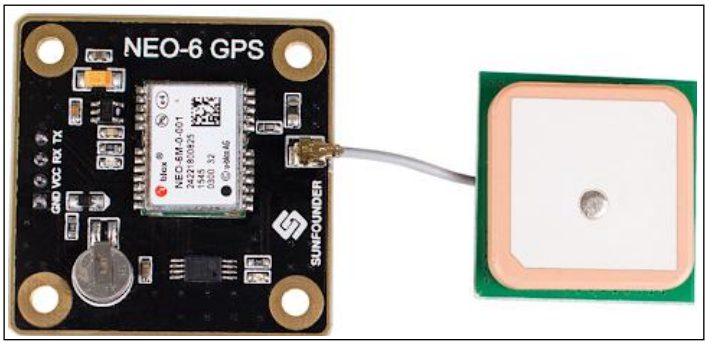

Figure 5. U-blox neo 6M GPS module

This GPS module is compatible with TTL signals and its technical specifications are given in Table 1.

Table 1. Specifications of U-blox neo 6M GPS module

Capture time	Cool start : 27s , Hot start :1s
Communication protocol	NMEA
Serial communication	9600bps , 8 data bits , 1 stop bit, no parity and no flow control
Operating current	45mA

This GPS module is directly connected to ESP8266 12E NodeMCU Board. The GND pin of U-blox NEO-6M is connected to GND pin of ESP8266 12E NodeMCU Board and VCC pin of U-blox

NEO-6M is connected to 3v3 supply pin of ESP8266 12E NodeMCU Board. The RXD pin of U-blox NEO-6M is connected to D5 pin of ESP8266 12E NodeMCU Board and TXD pin of U-blox NEO-6M is connected to D6 pin of ESP8266 12E NodeMCU Board. The U-blox NEO-6M GPS board will give real time position data of smart bin continuously. This data will be transmitted at 9600 baud rate in NMEA format. NMEA format contain several strings.

When we use this GPS module for tracking smart bin location, we need coordinates of smart bin. We can get coordinates of smart bin in $GPGGA string. The $GPGGA string is a Global Positioning System Fix Data String. The meaning of following example $GPGGA string is described below:

$GPGGA,141848.00,2932.63200,N,08125.76516,E,1,02,2.96,1.8,M,-51.3,K,,*64

The above string describes Latitude 2932.63200,N [29(degree) 32(minutes) 63200(sec) North] and Longitude 08125.76516,E [081(degree) 25(minutes) 76516(sec) East] as an coordination about the Smart bin location. In this work we have used U-blox NEO-6M GPS Library in the Arduino IDE that provides few functions to calculate latitude and longitude information about Smart bin.

3.4 Measurement of hazardous gas in smart bin

The hazardous gas produced from garbage in smart bin is measured by MQ-136 gas sensor. The MQ-136 gas sensor is shown in fig.6. The MQ-136 gas sensor has 4 pins with two pins for excitation (Vcc and GND) and two pins for output (digital output – DOUT and analog output – AOUT).

Figure 6.MQ-136 gas sensor

The connection details of MQ-136 gas sensor with ESP8266 12E NodeMCU Board are described below:

The Vcc pin of MQ-136 gas sensor is connected to 3v3 supply pin of ESP8266 12E NodeMCU Board, GND pin of MQ-136 gas sensor is connected to GND pin of ESP8266 12E NodeMCU Board and AOUT pin of MQ-136 gas sensor is connected to A0 pin of ESP8266 12E NodeMCU Board.

4. Implementation and working principle of smart bin

The flowchart shown in Fig.7 explains the working operation of smart bin. First load sensor, Gas sensor, HX711 board, GPS sensor and Ultra sonic sensor are interfaced with ESP8266 12E NodeMCU Board. Then the sensors and boards are fixed in the inner side of the smart bin cover. 5V rechargeable long life battery is fixed with sensors, HX711 board and ESP8266 12E NodeMCU Board. Then, the required program is deployed into ESP8266 12E NodeMCU Board. In the program, first load sensor is initialized to eliminate dead weight. Then the threshold value for garbage fullness is initialized. The threshold value is taken as 80% (this threshold value can be changed in the program) in this work. The calibration algorithm for load cell will eliminate dead weight present in the smart bin. Then the smart bin location is identified using GPS library available in the Arduino IDE. The Latitude and Longitude coordinates are calculated and stored in the memory.

The garbage weight is measured by load cell and its measured value is stored in a memory. The MQ-136 gas sensor is used to measure hydrogen sulphide gas which produced through the bacterial breakdown of organic matter present in the smart bin garbage. The output of the sensor is 0 -5V which corresponds to 0 – 200 ppm. The measured gas ppm value is stored in a memory. Then ultrasonic distance sensor is getting activated. Ultrasonic distance sensor sends out sound wave. After hitting the garbage the sound wave will be reflected back to it. It contains the information regarding the garbage

filled level in a smart bin. The percentage of garbage fullness is calculated and it is stored in the memory. Then the percentage of garbage fullness is compared with threshold value. If the measured percentage of garbage fullness is less than the threshold value it will repeatedly measure percentage of garbage fullness after some delay period and the process will be repeated continuously. If the measured percentage of garbage fullness is greater than threshold value, an alert message is sent to municipal authority. The municipal authority in turn send message to nearby driver to collect the garbage. Then the complete information such as date, time, location of smart bin, fullness of garbage, weight of garbage, hazardous gas emission status, alert message sent, and action taken by municipal authorities in cloud for further analysis purpose. From cloud data, municipal authority can get much information such as density of population of a particular region, duration in which a smart bin gets filled up, particular area bins density etc.

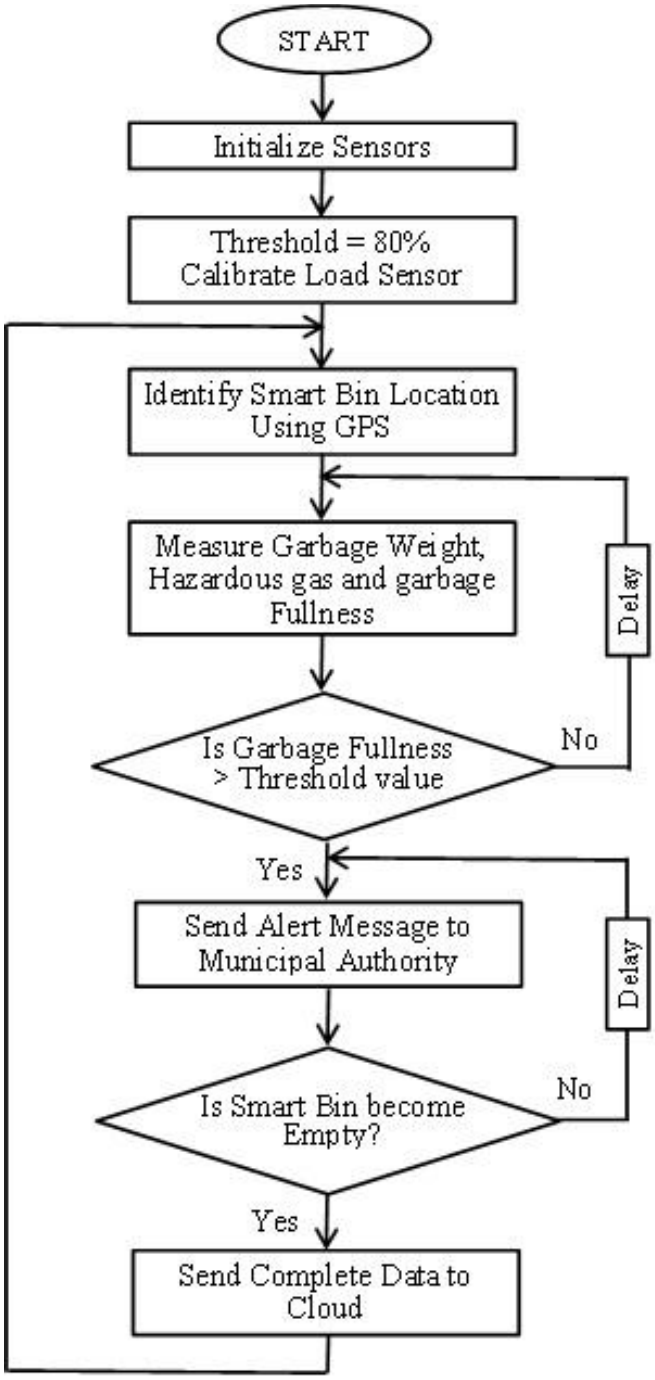

Figure 7. Work flow diagram of smart bin

The complete specifications of smart bin are listed in Table 2.

Table 2 Specifications of Smart Bin

Specification	Value
Nominal Volume	125 Litres
Dimension of the bin : Length	40 cm

Width	40 cm
Height	120 cm
Net weight	9 kg
Maximum Load	50 kg
Battery specification	- Lithium-ion battery - 3.3 V, 10 Ah - battery lasts upto 5 years
Wireless communication	Wi-Fi

5. Conclusion

The population outbursts, modern lifestyles of the people and growing heights of urbanisation have caused generation of huge amount of waste. Generation of huge amount of waste has developed severe challenges to government authorities. The current waste disposal systems are not sufficient to dispose the huge amount of waste that is being generated from cities. The present waste disposal systems are not at all in line with the waste disposal schemes suitable for smart city. It is right time to apply various technologies such as sensors, embedded systems, IoT etc., to the present waste disposal schemes to make it highly suitable for smart city and efficient enough to handle generation of huge amount of waste. In this work an alternative waste disposal strategy is proposed by utilizing various newer technologies efficiently to develop a smarter waste disposal scheme suitable for smart cities.

A prototype of smart bin comprising various cutting edge technologies such as sensors, embedded systems, IoT etc., has been developed and it has been tested successfully. The proposed newer technology would assist as an inspiration to other researchers to further explore the waste management systems. The proposed concept can be easily installed as an add-on module in a conventional waste management infrastructure exists in the present cities. The proposed smart waste disposal schemewill make the cities cleaner and provide hygienicenvironment to live.

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