Smart Garbage and Street Light Monitoring System for Smart City

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Due to an upsurge in population, every year about 60 million tons of trash is generated. The improper organization of city Municipal Corporation and lack of awareness programs to the citizen has led the monitoring of garbage become a national issue. Mahatma Gandhi's vision of Clean India has led to the initiation of Indian central government's ambitious project to make India a clean country "Swachh Bharat Abhiyan" aims to teach citizens to reduce waste generation, eliminate open defecation and improve solid waste management. To maintain an ingenious living, tidiness is necessary and cleanliness begins with proper monitoring of waste trash, hence this work aims to optimize garbage waste management by the design of a smart garbage monitoring system for "Smart City" based on Internet of Things (IoT). The system will help to minimize the garbage disposal problem by automatically monitoring the garbage bins and informing the municipal corporation about the level of garbage collected. Street lights are a major requirement in today's life for safety purposes. In today's busy life, no one bothers to switch off the lights when not required. The street lighting is one of the largest energy expenses for a city. This work aims to design an automatic street light control system using simple timing information that will minimize power consumption and manpower.

Keywords: Internet of Things, Smart City, Raspberry Pi.

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1 Introduction

In our city, we come across the overflowing garbage bins placed at public places and one of the outcomes of overflowing garbage is air pollution through foul odors caused by decomposing and liquid waste items. This unhygienic condition causes various respiratory diseases and several other health related issues. The amount of garbage being produced varies as per the population in different localities and these garbage bins are not monitored properly. To avoid this problem we need an Intelligent Garbage Monitoring System. The street lights consume larger energy and results in high costs. An Intelligent street light control system can cut municipal street lighting costs to a greater extent. It is based on the design of an automatic street light control system which uses dusk and dawn time as the parameters for switching ON and OFF of the street lights. This work based on Raspberry Pi will help in collection of the garbage from public garbage bins before they reach the threshold level and start overflowing. It also helps in effective monitoring of street light thereby minimizing the power consumption and manpower.

2 Literature and Field Survey

a. Literature Survey

In the Smart City waste collection plays a vital role for environment and this can be better understood by definition in [1], "A Smart City is a city well performing in a forward-looking way in the following fundamental components (i.e., Smart Economy, Smart Mobility, Smart Environment, Smart People, Smart Living, and Smart Governance), built on the 'smart' combination of endowments and activities of self decisive, independent and awareness to the citizens". The crucial component "Smart Environment" is constantly in connection with environmental pollution. The important counter measure to the pollution of environment in view of a Smart City is the IoT-driven waste collection. The definition of IoT described next is used in paper [2] "The Internet of Things allows people and things to be connected Anytime, Anyplace, with anything and Anyone, ideally using Any path/network and Any service". IoT technology gives a pathway to newer services and reshapes the present ones in Smart Cities [3]. For example static waste collection can be modified to dynamic waste collection that enables online dynamic scheduling and trucks routing [4]. The issues with dynamic waste collection can be divided into 2 main problems: (i) scheduling: at what time to collect garbage from garbage bins and (ii) routing: the routes the trucks should follow.

These days monitoring of garbage in every part of the city has to be done efficiently. Different methods of monitoring were proposed but only few of them were brought into action but even these are not completely perfect. Therefore, a survey was carried out among these proposed smart garbage monitoring methods in the cities by making use of IoT.

IoT enabled service in smart cities for garbage monitoring and maintenance [5] consists of ultrasonic sensors which determine the amount of garbage collected in the dustbins and communicates the information to the control room with the help of GSM system.

An advanced Decision Support System (DSS) [6] adopts a model for sharing of the data on the real time basis in between the truck drivers for collection of waste and dynamic route optimization by using surveillance cameras.

One more method is when the garbage attains the threshold level ultrasonic sensor triggers the GSM modem which in turn keeps on alerting the required authority unless the garbage in the dustbin is

cleared [7].

In [8], the aspects regarding automated lighting system along with digital visitor counters is described. The PIR Sensors consists of IR transmitter and receiver which are placed at the entrance of the room in order to sense the person entering /exiting the room. Likewise counter is incremented or decremented and depending on this the switching takes place.

In [9] Sensor Technology is used with an objective of saving energy. Here passive infrared technology (PIR) is used, occupancy detection and voltage switching are combined in a single package by using sensors. The lights in a room are switched OFF automatically when the room remains vacant for the duration of 5 to 10 minutes.

b. Field survey

Before starting this project, we have done field survey in Vijayapura city of Karnataka state, so as to see the loop holes and the practical problems in the existing system. As discussed earlier, the system of controlling street lights is manual and most of the time the lights will not be ON even after 8am. Sometimes we observed street lights ON even during afternoon. Figure 1 shows images taken during field survey at 8.15am; it can be observed that, lights were ON even at that time.

Fig. 1. Street lights ON during day time captured in KHB colony, Vijayapura

When we approached the KEB to get the details, they told us that a person in-charge will often take care but sometimes will miss it or delay in switching the lights ON or OFF. Approximately, we calculated the wastage of electric power in the city of Vijayapura, the details of the same is given below.

In the city there are four different sections to control the street lights. Approximately, on an average one street light consumes 300 units of power per month and there are around 800 street lights in the city as per the data collected from HESCOM, Vijayapura. Unit consumed by one street light per hour = 0.83, Cost of 1 unit = Rs. 6.30/-. On an average if street lights are ON for an extra 1 hour per day during daylight (as per our survey): Wastage of electricity per day = 0.83 x 800 = 664 units. Wastage of electricity per month = 664 x 30 = 19,920 units. Total money wasted = 19,920 x 6.30 = Rs. 1,25,496/-. Consider approximately 12 talukas in Vijayapura, the total wastage of money in one month = 12 x 1,25,496 = Rs. 15,05,952/-. This is a huge loss of capital which can be saved by implementing our smart system for street light control.

Fig. 2. Overflowing of Garbage bin, captured near Shivaji circle, Vijayapura

At the same time when we looked into garbage collection in the city, most of the garbage bins were over flowing and dogs and other animals were seen around them in search of food. This often creates ugly scenario in the city and gives bad smell everywhere. Figure 2 shows image of such scenario taken during field survey.

3 Problem Statement and Objectives

Due to the population growth, improper organization of the city corporation, lack of awareness among people and limited funds for programs; monitoring of garbage bins has become a major problem. There are many garbage bins in the city that overflow most of the time which spread foul smell and many diseases if left untreated. Another problem is wastage of electric energy due to unnecessary ON of street lights during day time. This is because of the negligence of the person who is in-charge of controlling the street lights.

With this context the objectives of the work are:

- To monitor the garbage bins level and send the live status of these bins to cloud for the access of concerned staff.
- To send a message once the garbage bin reaches certain threshold limit.
- For automatic turning ON and OFF of the street lights, based on the dusk and dawn timing set in advance.

4 System Design and Implementation

The block diagram of the system is shown in figure 3. It consists of a central control unit responsible for monitoring and controlling of the garbage level and street lights respectively.

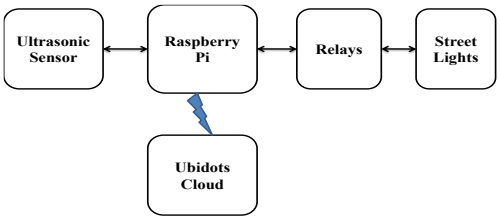

Fig. 3. System block diagram

Raspberry pi 3 is used as a controller module that continuously monitors the garbage level in dustbin and transmits it to cloud. It also monitors the time and takes the appropriate action such as switching the street lights ON or OFF. The street lights can be controlled by making use of electromechanical relays that can easily be interfaced to the controller unit of the system. Raspberry Pi 3 architecture has the built-in Wi-Fi, Bluetooth and consists of 4 USB ports. It features a Broadcom BCM2837 quad-core 64-bit ARM cortex A53 running at 1.2GHZ, a new CPU. It needs internet connection to send the garbage bin level and the status of street lights to the cloud. Our work is for a smart city which has Wi-Fi connectivity in the city.

We have used three garbage bins and three electric bulbs. In the garbage bins to find the distance between collected garbage level and the top of the garbage bin, the Ultrasonic Sensor HC-SR04 shown in figure 4 is used. It can measure the distance from 2cm to 400cm with greater accuracy.

Fig. 4. Ultrasonic sensor

It has four pins VCC, GND, Trig and Echo Distance at which the object detected can be measured by taking the product of time taken to hit the object and return, and the speed at which the wave travels as given by the equation:

$$\boldsymbol{Distance} = (\boldsymbol{T} * \boldsymbol{S})/\boldsymbol{2}$$

where, T is the time taken to transmit and receive ultrasonic wave, S is the speed of ultrasonic wave.

The interfacing of ultrasonic sensor with raspberry pi 3 is shown in the figure 5.

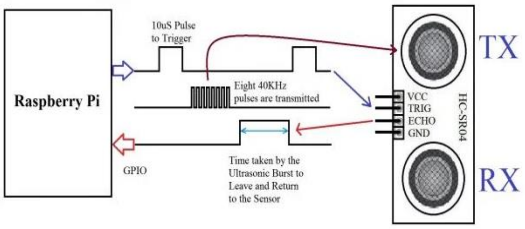

Fig. 5. Interfacing ultrasonic sensor with Raspberry Pi

Raspberry Pi 3 provides trigger signal to TRIG input which requires a HIGH signal of at least 10µS duration. This allows the module to transmit eight 40 KHz ultrasonic burst. In case of any obstacles coming in the path of the module, it reflects ultrasonic waves. If the signal returns, the ECHO output will be HIGH for the amount of time it has taken for transmitting and receiving of ultrasonic signals. Depending upon the distance of the obstacle the pulse width varies between 150uS to 25ms and in case of no obstacle it will be about 38ms.

Next for the ON/OFF controlling of the street lights we have used the electromechanical relays that contain a sensing unit and an electric coil which is powered by AC or DC current. The circuit diagram of electromechanical relay is shown in the figure 6. If the applied voltage or current to the relay crosses the threshold value, the coil starts the armature, which runs either to close the opened contacts or to open the closed contacts. When a coil is supplied with power, there is generation of magnetic force which actuates the switch mechanism.

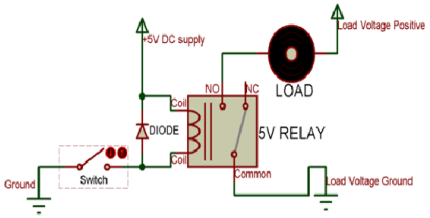

Fig. 6. Electromechanical Relay

Here +5V DC supply is used to one end of coil and ground at the other end with the help of switch. Across the coil of the relay diode is being connected, in order to protect the switch from high voltage spikes produced by relay coil. One end of the load is in connection with the Common pin and the other end to NO or NC. The load remains disconnected before triggering when connected to NO and the load remains connected before triggering when in connected to NC.

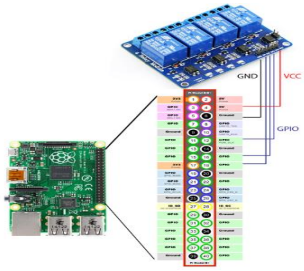

Fig. 7. Interfacing relay module to Raspberry Pi3

The interfacing circuit of relay module to raspberry pi is shown in figure 7. The relay module that we have used has four relays, out of which three relays have been used to control three electric bulbs. These three relays need three GPIOs of raspberry pi 3 to control them automatically. The relay module used in this work is with 5V of power supply and that supply has been taken from the VCC and GND pins of raspberry pi 3. The pins used in connecting the relay module to raspberry pi3 are physical pin number 33, 35 and 37; these three pins will control three relays in the module. A high on these pins will make the relay ON and a low on these pins will make the relay OFF.

Implementation of the system is done by using of raspberry pi 3, ultrasonic sensors, electromechanical relays and ubidots cloud. The level of garbage in the garbage bins will be sensed by Ultrasonic sensor and send this information to the cloud through Raspberry Pi 3.

a. Level Detection using Ultrasonic Sensor

The flow chart of the program used to monitor the level of garbage bins is shown in figure 8.

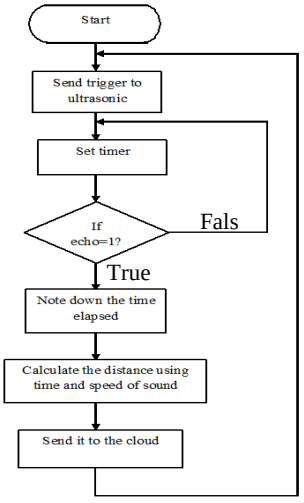

Figure 8. Flow chart of the program to monitor the level of garbage bins

At the beginning a trigger pulse is sent to the ultrasonic sensor and the time is noted. The raspberry pi 3 waits for the echo signal from the ultrasonic sensor. As soon as a trigger is sent to the sensor, it emits the ultrasonic pulse. If there are any objects in the path then the echo signal will come back to the sensor and the sensor will make its echo pin high. This is sensed by the raspberry pi 3 and it will calculate the time taken and there by the distance between the object and the sensor is calculated. Later this distance is sent to the cloud and the process monitors the dustbin's level continuously.

The output of ultrasonic sensor (ECHO), at the start will be low (0V) until it is triggered and now the resulting output will be 5V (with voltage divider it will be 3.3V). So there is need to set one GPIO pin as an output and one GPIO pin as an input, for triggering the sensor and to detect the ECHO voltage change.

We have used C program for the coding and wiring Pi package to access the raspberry pi GPIOs. First we have set the pin modes either as input or as output as per the requirements as shown below:

pinMode(TRIG1, OUTPUT);

pinMode(ECHO1, INPUT);

Then, trigger pin is made low and some delay is given to settle down.

digitalWrite(TRIG1, LOW);

delay(50);

In order to trigger the module the ultrasonic sensor requires a short pulse of 10uS, which causes the sensor to begin the ranging program (8 ultrasound bursts at 40 kHz) to obtain an echo response. Therefore, in order to create trigger pulse, trigger pin is set high for 10uS later it is again set to low.

digitalWrite(TRIG1, HIGH);

delayMicroseconds(10);

digitalWrite(TRIG1, LOW);

Now the pulse signal is sent, we need to listen to input pin connected to ECHO1. Now the sensor sets ECHO1 to high for the duration of time the pulse takes to go and come back and now code measures the duration of time that the ECHO pin remains high. The "while" loop is used to make sure that each and every signal timestamp has been recorded in the right order.

Once signal reception is done, change of value takes place that is low (0) to high (1), and during the presence of echo pulse the signal remains high. Therefore, we require last high timestamp for ECHO. Hence the difference between the two recorded timestamps and the duration of pulse (*travelTime*) can be calculated.

while(digitalRead(ECHO1) == LOW);

longstartTime = micros();

while(digitalRead(ECHO1) == HIGH);

long travelTime = micros() - startTime;

We can calculate the distance for the signal that has travelled to an object and reflected back again by using the following formula given below:

$$Speed = \frac{Distance}{Time}$$

In ubidots cloud, we have set the limit for the distance; if it reaches more than the critical point which is just below the overflow level then cloud will send a message to the person in-charge to collect the garbage. Every time the cloud receives the distance, it updates the same so that anyone can access the information and can visualize the levels of all the garbage bins.

b. Automatic Street Light Control

The flowchart describing the operation of automatic street light control is shown in figure 9. In this work we are making use of relays interfaced with raspberry pi 3 to control the street light from remote place. Initially raspberry pi 3 will send logic zero to the output pins to which relays have been interfaced; relays will be in OFF mode. Usually during day time street lights should be OFF. The timer has been set to 6.00pm and exactly at 6.00pm raspberry pi 3 will send high signal i.e., logic 1 to the output pins to which relays are connected. Thus relays get activated and switch ON the street lights and will be ON till 6.00am. At 6am in the morning the timer will make the controller to send logic zero to the relay which will turn OFF the street light.

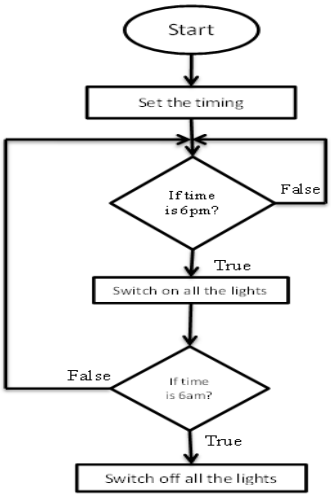

Fig. 9. Flowchart of the program for automatic street light control

5 Result

Both the ideas of smart garbage bins and smart street light control have been tested and the results are discussed as follows:

The ubidots cloud will show the live status of smart garbage bin whenever somebody puts garbage in it. At any time, the garbage levels can be monitored by concerned person who has got the access to the cloud. Figure 10 show the model of smart garbage bin and smart street lighting system. There are three smart bins and three street lights in the model that we have implemented. We can observe that, at the top of garbage bins, there is a middle section which has got the ultrasonic sensor below it. Every smart bin is below one street light.

Initially when the setup is given the power supply, raspberry pi will send the trigger pulses to all the ultrasonic sensors to start finding the distance of object and this is used to calculate the status of the

garbage bins and the result is sent to the cloud. The communication between cloud and the raspberry pi 3 is through internet and the python coding is done to achieve it.

We can observe in figure that, all three garbage bins are showing some levels; this is because, there was some garbage collected within them. The level indication along with the percentage of filled status can be seen in the figure 10.

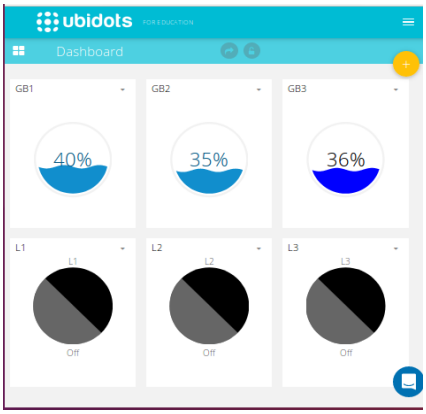

Fig. 10. Status of smart bins and street light model during day time

Lights L1, L2 and L3 are three street lights which are in OFF state as shown in figure 10. OFF status has been indicated by black colour. This screen shot has been taken during day time. The street lights will be OFF up to 6pm in the evening.

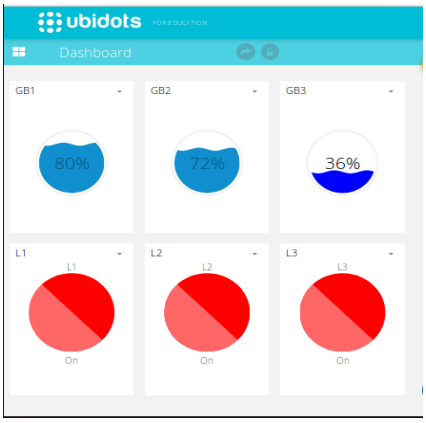

Fig. 11. Status of smart bins and street light model during evening time (after 6.30pm)

The screen shot which has been taken after 6pm is shown in figure 11. Referring to this figure, street lights L1, L2 and L3 are ON, which has been indicated by red colour. We can also observe the change in levels of garbage bins GB1 and GB2 where as GB3 is as it is. Whenever the level of any bin increases

more than 80%, an alert message will be sent to the concerned person so that, he/she can take appropriate action to collect it.

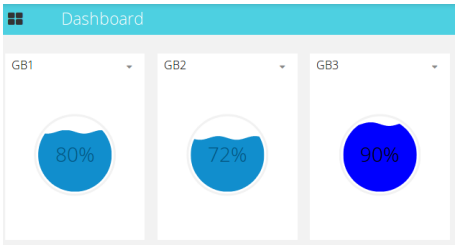

Fig. 12. Status of garbage bins showing during the message alert

The garbage bin GB3 has filled more than 80% and message will be sent to the concerned person, from the ubidots cloud and this is shown in figure 12. Here we are sending the telegram message which can be observed in figure 13.

Fig. 13. Telegram alert messages received by the smart phone

6 Conclusion

The main aim is to build smart city by using a smart system that reduces the human resources and efforts. We always come across garbage overflowing from the dustbins on the roads and this is the problem which requires immediate solution. The quote "Cleanliness is next to god and clean city is next to heaven" has boosted to think conceptually and frame this work. Smart dustbins play a key role to reduce the pollution.

This work gives solution for unhygienic environmental conditions in the city. This smart system assures to send a notification message and status on dashboard of cloud whenever the garbage level reaches its maximum. Concerned staff can attend to the clean-up procedure depending on the number of bins filled in a particular street or area. Therefore, the smart garbage management system makes the garbage collection more efficient helping to keep the society clean.

In the automatic street light controlling mechanism, the control has been done using the timing information. This will help to control the street lights properly and even over comes the problem of using IR sensors; as IR sensors need proper light intensity and any kind of dust will give the reduced intensity there by leading to wrong controlling of street lights. The control based on timing is the best method and gives advantages compared to any other methods. Thus, this smart monitoring system can be used for any of the smart cities around the world to manage and control garbage bins, and the street lights.

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