Smart Bin Implementation for Smart Cities

Narayan Sharma, Nirman Singha, Tanmoy Dutta

Abstract— In past few decades there is a rapid growth in the rate of urbanization and thus there is a need of sustainable urban development plans. Now using new age technology and strategic approach, the concept of smart cities is coming up all around the world. A smart city is incomplete without a smart waste management system. This paper describes the application of our model of "Smart Bin" in managing the waste collection system of an entire city. The network of sensors enabled smart bins connected through the cellular network generates a large amount of data, which is further analyzed and visualized at real time to gain insights about the status of waste around the city. This paper also aims at encouraging further research in the topic of waste management.

Index Terms— Smart City, Smart Bin, Urbanization, Waste Management, Machine Learning, Real Time Analytics.

1 Introduction

As the world is in a stage of up gradation, there is one stinking problem [1] we have to deal with. Garbage! In our daily life, we see the pictures of garbage bins being overfull and all the garbage spills out. This leads to the number of diseases as large number of insects and mosquitoes breed on it. A big challenge in the urban cities is solid waste management not only in India but for most of the countries in the world. Hence, such a system has to be build which can eradicate this problem or at least reduce it to the minimum level. The project gives us one of the most efficient ways to keep our environment clean and green.

The smart city [2] concept is still new in India, although it has received a lot of attention in few years when our present prime minister gave the idea of building 100 smart cities throughout India. Now, with the upcoming large number of smart cities, large numbers of responsibilities are also required to be fulfilled. The prime need of a smart lifestyle begins with cleanliness and cleanliness begins with dustbin. A society will get its waste dispatched properly only if the dustbins are placed well and collected well. The main problem in the current waste management system in most of the Indian cities is the unhealthy status of dustbins. In this paper we have tried to upgrade the trivial but vital component of the urban waste management system, i.e. dustbin.

Now with the rise of technology it is high time that we should use technology for waste management systems [2]. As we have seen that technology with analytics has made the world a better place to live by its application in the field of genetics, insurance, marketing, engineering, banking etc in past many years. So, in this paper we have integrated analytics and electronics in order to create optimal changes in the conventional methodology of waste collection with the large amount of data that is being produced by the smart bin networks.

The movement of waste across the whole city can be tracked and thus can be monitored by a single system efficiently and concretely. This system can prove to be a revolution for the whole urban waste management system of upcoming smart cities.

2 Hardware

2.1 Components

TABLE 1
List of Hardware Components

Hardware components and specification	
Components	Specifications
Microcontroller	PIC-16F73
Ultrasonic Sensor	HC-SR04
GSM Module	SIM-900A, IMEI-865904022247974
Motor	60 rpm DC Motor
LCD	16X2 (JHD162A)
Motor Driving IC	L293D
Voltage Regulator	7805
Register	10kohm
Capacitor	100uf and 22pf (2)
Oscillator	Crystal Oscillator

2.2 Circuit Diagram

The hardware consists of PIC16F73 microcontroller, HC-SR04 ultrasonic sensor, SIM900A GSM module, IC7805 voltage regulator, resister, capacitor and a crystal oscillator. PIC16F73 is a CMOS-FLASH based 8 bit microcontroller. It has got two 8 bit and one 16 bit timer/counter. We have used timer 1 for connecting the ultrasonic sensor HC-SR04 with the microcontroller. This microcontroller is also equipped with Tx and Rx pin for serial communication. These pins are connected to the GSM module through the inbuilt MAX 232IC present at the module. MAX 232IC serves to convert the logic from TTL to RS232 logic, as the GSM module operates at RS232 while PIC16F73 microcontroller at TTL logic. The circuit diagram is shown below in the diagram.

The ultrasonic sensor used here has two pins: Trigger and Echo, which are used for calculating the distance of the object by generating sound waves and thus calculating the time du-

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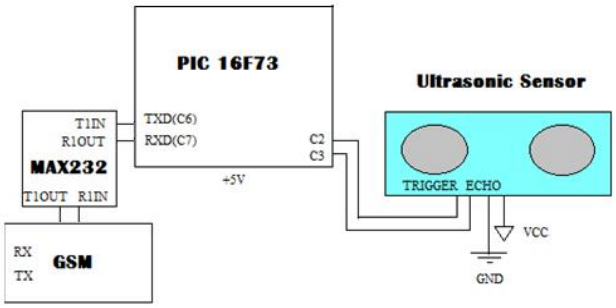
ration of the echo that is generated. A high to low signal by the microcontroller at the trigger pin of the sensor sends eight 40 kHz sound waves, after which the ECHO pin is turned high

Fig. 1. Circuit Diagram of the Hardware



until when the echo of the sound waves echoed back to the sensor. The ECHO pin which is being connected to the C3 pin of the PIC16F73 microcontroller is continuously monitored to detect its status. The timer1 of the microcontroller is used for the purpose of calculating the time period for the sound wave to travel back to the sensor. Then, the calculated time can be computed through the following equation into the distance (cm) unit.

$$D = \{(t*v)/2\}*100 \quad (1)$$

In (1), we have 'D' as the distance in cm measured by the ultrasonic sensor, 't' is the time taken by the sound wave to echo back to the receiver in seconds, 'v' is the velocity of sound wave. Thus, this equation is computed by the microcontroller and we can get the distance of any solid waste material present in the bin. The GSM module connected to microcontroller sends this garbage level in the form of text message to the central waste office. The GSM module has got a unique SIM card and a unique number, which acts as a unique ID for the respective smart bin.

As we know, the large bins are present in each locality and serve as the centre point of garbage of that particular locality. The garbage collection team collects the garbage from these central bins in their trucks. Our model of hardware is going to be applied in these central bins and thus making them smart bins. For this we have divided the dustbin into three different levels according to the level of garbage filled. Accordingly, the text messages indicating the levels are being sent to the central office, which acts as a data warehouse for all the level data being sent by the different bins. The central office of waste management department now will be able to track the level of every dustbin getting filled up just by sitting in their office at real time. This information will now guide them efficiently to take up the action of sending the trucks to empty the dustbin whose levels are significant. The hardware has used some very basic electronic components to make out the complete system at the best possible cost. The built hardware can be implemented at any dustbin irrespective of its size and height and thus is portable with any bins.

3 Software and Analysis

Every smart bin is equipped with ultrasonic sensors which measure the level of dustbin being filled up. The container is divided into three levels of garbage being collected in it. With its continuous use the levels get filled up gradually with time. Every time the garbage crosses a level the sensors receives the data of the filled level. This data is further send to the garbage analyzer as instant message using GSM module. Every message which is received at the garbage analyzer end is being saved as data which is further used for the process of analysis and predictive modelling. The data received at real time is used by the application interface for better viewing of the filled level.

The data received is saved in the database keeping all its attributes intact as time and date. A history of data collected in months is used by the department of data analysis for prediction and report making. The application interface shows the real time level to the garbage analyzer and using that it directs its team of garbage collector to collect the garbage to avoid overflow. The prediction model is designed to predict the time in which the every level of container will be filled in future. This will help the waste management department to optimize the route for the collection of waste every time garbage collector moves around the city for garbage collection. This helps in saving time, resources of the waste department and work is then performed in more efficient manner.

3.1 Real Time Interface

The real time view of the filled level of every container is developed in Microsoft Excel [4]. The dynamic reporting technique in Excel helped us develop this interface. Every level the dustbin gets filled up is received at the interface end using message service. This message received is taken in the form of text files which is connected to the excel sheet showing the filled level of every container.

SMS received from the GSM modules of our dustbin is taken in the form of text files. The text file in connected to the excel sheets. The updated values of the dustbin level are taken to form the real time report. The updated values from the excel sheet is taken using various excel function like IFERROR, LARGE, INDEX, IF, COUNTIF and ROW. The widget is developed using charts in excel. The Doughnut chart is the indicator of all three levels. The pie chart is used to make the pointer that moves accordingly as levels the dustbin gets filled in real time. The color coding of the levels is done as: Yellow for level 1, Green for level 2 and Red for level 3.

The excel application designed creates a real time dashboard along with a time series graph which shows the current trend as well as the historical trend of waste level in that particular smart bin.

Fig. 2. Real Time Indicator

Fig. 3. Smart Bin Real-time Monitor System

The map of the city will be used in the application interface and these widgets marking the level of dustbin filled will be put in the location in map exactly the way dustbins are placed throughout the city. This will help the garbage analyzer to keep a track of dustbin filled in exact location. Thus our application will help the garbage analyzer to keep a check on every dustbin throughout city at real time. It will help him taking accurate decision and avoid the overflow of dustbins and use the resources more efficiently. These multiple smart bin model can be applied to any of the smart cities around the world. A waste collecting team which is deployed for collection of garbage from the city can be guided in a well manner for collection. The application will serve as a central application for the person responsible for monitoring the waste status across the city. The model interface in excel is made as shown below, it is completely dynamic in nature and is well connected with the respective dataset generated by the bins.

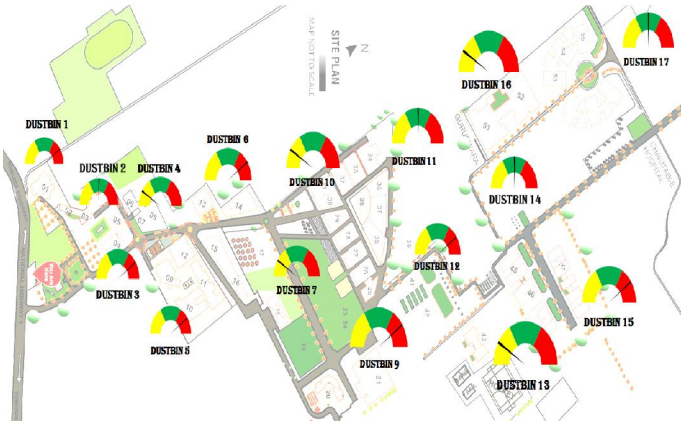


Fig. 4. Application Interface for Sample City

4 Data Analytics

The smart-bin designed will be sending data about the levels of garbage collected in different parts of the city/town. The dataset created can be analyzed [5] to gain lots of insights. The collected data set over a period of time will create a historical data set. This data set will contain many variables such as shown below in the table.

TABLE 2
METADATA OF HISTORICAL DATA

Variables of Historical Dataset	
Variables	Description
ID	Unique ID of each smart-bin
Sector	Sectors are divided as A to G based on driving routes
Date	Date stamp
Time	Time stamp
Day	Day stamp
Level	Level sent by the smart-bin (1,2,3)
QuantityID	Total quantity of garbage in Levels for a particular ID
QuantitySector	Total quantity of garbage in Levels for a particular Sector
DayTimeNum	Day and Time in numerical (0 to 7)
TimeNum	Time in numerical (0 to 1)
Full	Full or not, i.e. Level 3 (1=Full, 0=Not Full)
Almost	Almost full, i.e. Level 2 or 3 (1=Almost Full, 0=Not almost full)

The dataset contains different variables of which "ID", is the unique ID of a bin, and is the primary key. Our smart-bin sends us the message which contains the updated level of garbage along with the Date and Time stamp. The other factors like Location of the smart-bin and Full or not status is included using SQL joints and Excel spreadsheet functions. The main aim of our smart-bin's data analysis is to create a prediction model which can predict the time a particular smart-bin will be getting filled up. We can use the concept of Machine Learning in order to train our prediction model with the available

historical dataset generated in the given time period. In order to check the predictive model, we can divide the dataset into training and testing data set. The goal will be to predict "Full" and "Almost" status, i.e. Level 3 and Level 2 or 3 respectively. With large amount of dataset produced, a larger accuracy can be obtained and thus a trend in the waste generation can be known effectively based on factors like locality, time, day of the week etc. Moreover, with the historical dataset, we will be able to figure out the average time it takes a smart-bin to get filled up totally and the average time it takes to gain a single level. Now, this analysis can be used in building up the algorithm for route planning by predicting the fill due date of each bin based on their last updated level. We will be using the following variables for the algorithm:

TABLE 3
ROUTE OPTIMIZATION ALGORITHM

i ,k = 1,2 ... n , ID of n number of smart-bins
L_i = Current Level of the i^{th} smart-bin.
t_i = Time for which the i^{th} bin is filled up totally.
a_{k1} = Average time for k^{th} smart-bin to get filled 1 level up. It is computed through analysis of a month's data for each Bin.
a_{k3} = Average time for k^{th} smart bin to get filled up completely. It is computed through analysis of a month's data for each Bin.
$T_k[L_k , t_k]$ = Array which consist the last updated level and time of every smart-bin in the network.

Result: Predicted percentage filled status of every smart-bin and thus estimate the optimal route based on potential filled Bins.

```
begin
    for i=1 to n do
     If L_i==3 then  // Compare L_i with 3 to check if i^th bin is full or not.
       for k=1 to n do
        if k!=i then
          q_k = T_k[1]+(3-T_k[0])a_k1  // Compute the expected time for every k^th smart-bin to get full.
          p_k = q_k - Ti  // Compute the time required more to get full by the k^th smart-bin.
          if p_k<=0 then  // Check if k^th bin is already filled.
            f(b)=k  // Store ID of k^th smart-bin in an array.
          else if p_k>0 then
            pr_k= [(a_k3-p_k)/a_k3]*100  //Compute the predicted current percentage level filled of k^th bin.
            if pr_k>65 then //The threshold percentage is considered as 65 here.
              f(b)=k // Store ID of k^th smart-bin in an array.
            end
          end
        end
```

```
for b=0 to length(f(b)) do
        | Action = create optimized route in the map from the smart-bin ID in f(b) array
       end
      end
    end
  return Action
end
```

5 ADVANTAGES

When everything around the world is shifting itself to technology, then why not the dustbin? Dustbin is an essential part of the cleanliness mission and thus need to be looked after well. The present methodology being followed for waste collection has many flaws in it so an immediate step has to be taken before it breaks down the whole system. Adding a bit of smartness to our dustbins will solve most of our problems and the smart-bin has a lot of advantages.
The product which is designed to make every dustbin smart is very handy as it can put to work just by placing the sensor and GSM integrated model in the bottom of closing lid of dustbin. The first major advantage of it is that it will stop overflowing of dustbins along roadsides and localities as smart bins are managed at real time. The filling and cleaning time of smart bin will also be reduced thus making empty and clean dustbins available to common people. Using the prediction and route algorithm it will smartly find the shortest route thus reducing the workforce, the number of trucks required to clean, the amount of fuel consumed by trucks and thus can save a large amount of tax payer's money as well. It also aims at creating a clean as well as green environment, as it will reduce the fuel consumption and in turn reducing the pollution in the air. As it is being said that the technology which goes parallel with environment is the need of an hour. Our project is a step towards such green technology.

6 CONCLUSIONS

Urbanization is at its rapid growth stage around the world, as more number of people desire to live in the city lights with more opportunities for growth and success. Cities are expanding like never before to accommodate this growth and in this process the concept of smart cities came into action. The parameters like cleanliness and hygiene are the topic of concern in these smart cities and concrete measures should be taken for that. Also, the growth should go hand in hand with the green environment and research should be further done on such technology. Our work is a small but efficient step towards cleanliness and we believe that this paper would encourage people to do good work on the similar topics. We have successfully made and tested the model of our smart bin so we believe with encouragement from the side of government we can successfully transform this model into product.

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REFERENCES

[1] Michael Alexander, John Walkenbach, "Microsoft Excel Dashboards & Reports", Wiley; Second edition, 28 June 2013. (Book style)

[2] Yann Glouche, Paul Couderc. A Smart Waste Management with Self-Describing objects. Leister, Wolfgang and Jeung, Hoyoung and Koskelainen, Petri. The Second International Conference on Smart Systems, Devices and Technologies (SMART'13), Jun 2013, Rome, Italy. 2013. (Conference proceedings)

[3] Foday Pinka Sankoh, Xiangbin Yan, Quangyen Tran on "Environmental and Health Impact of Solid Waste Disposal in Developing Cities: A CaseStudy of Granville Brook Dumpsite, Freetown, Sierra Leone," on Journal of Environmental Protection, 2013, 4, 665-670. (Journal or magazine citation)

[4] Michael Batty , Kay Axhausen, et al., "Smart Cities of the Future," UCL centre for advanced spatial analysis on working paper series, ISSN 1467-1298, Paper 188 - Oct 12.

[5] Ron Zacharski. A Programmer's Guide to Data Mining. Available: http://http://guidetodatamining.com.