# LOCATION BASED GARBAGE MANAGEMENT SYSTEM WITH IOT FOR SMART CITY

Gangodawilage Shehan Brendon Dabarera

IT14005572

Bachelor of Science Special Honors Degree in Information Technology
(Specialized in Computer System & Networking Engineering)

Department of Information Systems Engineering

Sri Lanka Institute of Information Technology
Sri Lanka

October 2017

# LOCATION BASED GARBAGE MANAGEMENT SYSTEM WITH IOT FOR SMART CITY

Gangodawilage Shehan Brendon Dabarera

IT14005572

(Dissertation submitted in partial fulfilment of the requirement for the Degree of Bachelor of Science Special (honors) In Information Technology)

Department of Information Systems Engineering

Sri Lanka Institute of Information Technology
Sri Lanka

October 2017

# DECLARATION

I declare that this is my own work and this dissertation1 does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to Sri Lanka Institute of Information Technology the non-exclusive right to reproduce and distribute my dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Name: G.S.B.Dabarera

Signature: Date:

The above candidate has carried out research for the B.Sc. Special (Hons) degree Dissertation under my supervision.

Name: Ms.Shashika Lokuliyana

Signature of the supervisor: Date:

# ABSTRACT

Smart cities integrate multiple ICT and IOT solutions to build a comfortable human habitation. One of these solutions is to provide an environmentally friendly, efficient and effective garbage management system.

The current garbage collection system includes routine garbage trucks doing rounds daily or weekly. Without knowing whether the bins are full or not lots of resources wasting on the cleaning process. Citizens are motivated to use the smartbins by integrating more functionality to the bins which will push the bin towards more user friendliness and attractiveness.

This study focuses on implemented as a network of smartbins which can measure garbage levels and use cloud based techniques to notify the cleaning staff about current garbage levels of the bins in their zones of the city. Using Statistical fault detection will help increase the effective and efficient garbage management system.

**Keywords** – IOT; Smart City; Statistical Fault Detection; Network of Smartbins

# ACKNOWLEDGEMENT

I would like to express my special thanks of gratitude to our project supervisor, Ms.Shashika Lokuliyana for her patient guidance, and useful critique of our research work. Her willingness to give her time, so generously has been very much appreciated. Especially mentioning the moral support and the continuous guidance by providing important feedback enabled us to complete our work successfully. I would also like to thank our lecturer-in-charge, Mr. Jayantha Amararachchi for constantly providing us with the guidance and assistance to carry out the research successfully. Also, I would like to thank my research group members as well as all the other friends who supported me and encouraged me throughout this project.

Finally, I would like to express my special thanks to my parents for their support and encouragement throughout my studies.

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF ABBREVIATIONS

| Term | Description |
|---|---|
| IOT | Internet of Things |
| Wifi | Technology for wireless local area networking with devices based on IEEE 802.11 standards |
| Raspberry pi zero | Tiny and affordable computer that use to implement garbage functionalities |
| Python | High level language programming language that can be used to build the code of the system |
| User | People who using the garbage bin |
| Workforce | Cleaning Staff |
| Garbage Level | Trash can filled measurement |
| GUI | Graphical User Interface |
| SSH | Secure Shell |
| CLI | Command Line Interface |
| GPIO | General Purpose Input Output |
| GSM | Global System for Mobile |
| GPS | Global Positioning System |
| IR | Infrared |
| Debian | Unix-like computer operating system that is composed entirely of free software |

# 1.0 INTRODUCTION

## 1.1 Background Context

Proper waste management is a basic requirement in any kind of an environment. city Usually cleaning is done in two or three times per day in urban. As an urban city like Colombo usually there are about 1,200,000 to 1,500,000 [1][2] employees heading for their workstations every morning. For all those people there are just not enough garbage bins available. On the streets of urban cities hundreds of people are passing the same location in short time period. most people are carrying food covers, polythene bags and plastic bottles. If they dispose all them at once, the bins will be filled in several minutes. When they fill up people just litter their trash around the garbage bins because there is nowhere else to put them. Also considering fill level of garbage bin, all garbage bins are not filled equal time period. Some garbage bin will be filled quickly and some garbage bins will be filled slowly. While collecting garbage by trucks are covered that all type of garbage bin. The obvious solution to this is for the cleaning staff to stay near garbage bins everyday till they fill up to clean them or garbage collecting trucks should go around in the city regularly. These are not effective and efficient solution. It takes way more cleaning staff and costs a lot of money. it is not practical. The same scenario is happening in workstations. For instance, a bank or a government office cafeteria usually has about five to six garbage bins to serve hundreds of employees. This is simply not enough.

There are some notable negative effects when considering the garbage bins always being full. One of the main effects is the surrounding area starting to smell and be very unpleasant. When the garbage bins are full people put their trash on sides of the garbage bins. When this is done for some time, first it starts to smell bad. So, others who come later tend not to go close and throw their trash in the direction of the garbage bins. If there are any leftover food items, throwing it causes them to spill. This attracts animals like cats, dogs and flies. And these animals spill them even more. Another negative effect is the diseases that spread. It’s not just the garbage that spread them, but the animals also can be a source.

## 1.2 Literature Survey

### 1.2.1 Cruisers: A Public Automotive Sensing Platform for Smart Cities (2016) [3]

This research introduces Cruisers, an automotive sensing platform for smart cities, which is developed based on the following ideas.

- Garbage collecting trucks are used as host automobiles to accommodate sensors
- 3G cellular communication network is used to wirelessly deliver sensed data directly to servers
- Proxy servers are adopted to convert the format of sensed data to required ones.

The technology consists of a collection of sensor nodes installed into the same number of garbage collecting trucks, one proxy server and one data server. Java program is developed to control the sensor nodes. An iOS application is also developed to demonstrate the sensing process and the covered area.

### 1.2.2 Smart Bin Implementation for Smart Cities (2015) [4]

This research is focused on creating optimal changes in the conventional methodology of waste collection. This is done by creating a smart bin that will upload the fill levels via SMS. SMS received from the GSM modules of the dustbin is taken in the form of text files. The text file is connected to the excel sheets. The updated values of the dustbin level are taken to form a real time smart bin status. 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. The data collected is then analyzed to gain insights.

These are the hardware components they used demonstrated on table 1.2.2.1.

Table 1.2.2.1: Hardware Components for Smart bins

| Hardware Components and Specifications | |
|---|---|
| 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 |
| Resistor | 10kohm |
| Capacitor | 100uf,22pf |
| Oscillator | Crystal Oscillator |

### 1.2.3 IOT Based Smart Garbage alert system using Arduino UNO (2016) [5]

This paper proposes a smart alert system for garbage clearance by giving an alert signal to the municipal web server for instant cleaning of dustbin with proper verification based on level of garbage filling. The development board used is an Arduino UNO. The process involved is ultrasonic sensors checking garbage bin levels and sending it to the municipal council. After cleaning the dustbin, the driver confirms that the task is complete using a RFID Tag. After the cleaning is verified, the information is sent to the server.

An Android application is developed and linked to a web server to send the alerts and remote monitor worker progress. The notifications are sent to the Android application using Wi-Fi module.

The e-monitoring system has two parts:

• Embedded system: It comprises of an RFID reader, a microcontroller, a Liquid Crystal Display (LCD) and a GPRS segment.

• Web based software system Interface: It comprises of a GPRS module, a Central Server, a Database Server and a Web server. The Figure reveals the block diagram of the web centered software system.

### 1.2.4 IoT Based Solid Waste Management System A conceptual approach with an architectural solution as a smart city application (2016) [6]

This paper aims at providing an IoT based solution to solve the problems faced by the present solid waste management system. By building an IoT based system, solid waste can be tracked, collected, and managed easily by automating and monitoring. Sensor data collected from the garbage bins can be sent to a gateway using LoRa technology. Data from various garbage bins are collected by the gateway and sent to the cloud over the Internet using the MQTT (Message Queue Telemetry Transport) protocol. The main advantage of this system is the use of LoRa technology for data communication which enables long distance data transmission along with low power consumption.

Four garbage bins were taken to implement the prototype. Each bin was fitted with the sensors, microcontroller and the communication module. Atmel's ATmega328p microcontroller was chosen as the development board.

### 1.2.5 Solid Waste Management Architecture using Wireless Sensor Network Technology (2012) [7]

This paper is focused on the on-site handling and storage processes and on the transfer process, with the main topic at developing a smart solid waste management system capable to ensure the public health with costs reduction and quality improvement. In order to enhance the efficiency of solid wastes on-site collection and transfer, an innovative solution for the monitoring and management system has been proposed. A Wireless Sensor Network (WSN) has been developed to improve the garbage bins monitoring process.

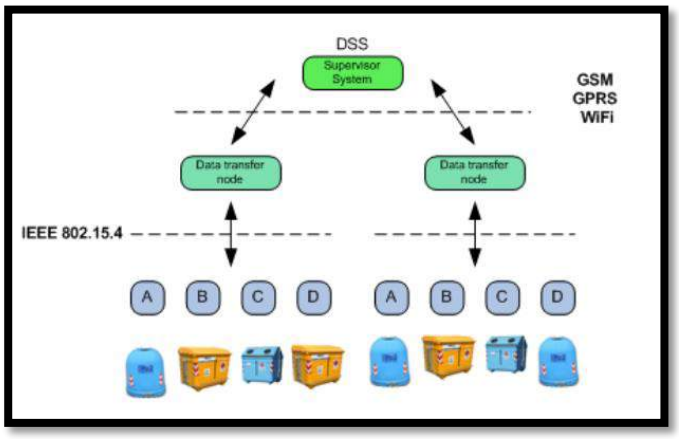



Figure 1.2.5.1: SEA project system architecture

The main components of the developed architecture on the SEA project (Figure 1.2.5.1) are decomposed into three layers. Starting from the bottom, the garbage bins reside at the first one, the DTNs at the second one and the supervisor system at the third one.

- The first layer is composed by sensor nodes, which need for the filling monitoring and provide short-range transmissions through RF technology.
- The second layer is composed by communication modules, which provide long-range transmission through GSM/GPRS.
- The third layer is composed by servers, which provide data storage and supervisor modules.

### 1.2.6 An Error Detection Model for Ultrasonic Sensor Evaluation on Autonomous Mobile Systems [8]

This paper represents a safe navigation approach autonomous mobile systems with partially known or unknown dynamic environments. In this context, defective, inadequate and otherwise affected sensors must be recognized (error detection) and sufficient troubleshooting should be taken in general, to monitor the status environmental sensors, "error detection model", which consists of sub models of laser data and ultrasound sensors. With the models created, the different types of you can use redundancy and consistency and plausibility the controls can be carried out. Fault detection serial model for environment-based fault detection modeling and assumptions for the expected sensor readings.

## 1.3 Research Gap

Most research papers have implemented garbage bins, but they are just a bin.

IOT Based Smart Garbage alert system using Arduino UNO has used an arduino board, this poses problems because arduino does not support multi-threaded programming [5]. To avoid this situation implemented solution use a Raspberry pie zero development board, which is about the same price as the Arduino Uno and supports multithreaded programming.

Most of the papers have used only one level measuring sensor in their bins. This poses a problem because garbage levels can be at different levels at different areas of the bin. To avoid this, we are implementing two sensors which will take three distance values over a 0.3 seconds get the average distance and calculate the level is much more accurate at reading the actual level of the garbage level.

Different research papers have used different methods to transfer data from the bin.

- Smart Bin Implementation for Smart Cities has used GSM technology [4].
- Cruisers: A Public Automotive Sensing Platform for Smart Cities has used GSM technology [3].
- IoT Based Solid Waste Management System A conceptual approach with an architectural solution as a smart city application has used LORA technology [6].
- IOT Based Smart Garbage alert system using Arduino UNO has used wifi
- Solid Waste Management Architecture using Wireless Sensor Network technology has used RF and GSM technology

Most of these papers have used GSM technology. When using GSM there is the hassle of through registering to a subscriber and has to pay for the services. For the propose system wifi was chosen due to the fact that in a smart city everything would be connected through wifi. So this system can easily integrate with the existing communication system.

Without being an ordinary trash bin like earlier mentioned papers implemented trash bin is have more functions compare to other bins.

- A hand gesture system to open and close the bin door - With a simple hand gesture users can open the garbage lid and put their garbage into the bin

- An option to disable all sensor activities - Sensors safeness when people and cleaning staff using the garbage bins.

All the mentioned papers are doesn't check for the sensor faults in the garbage level detection. An Error Detection Model for Ultrasonic Sensor Evaluation on Autonomous Mobile Systems [8] paper proposed an error detection system for ultrasonic sensors when there are many ultrasonic sensors fixed in a small circular path and the specific echoing signal can be captured by wrong ultrasonic sensor. The paper shows how to identify the intersection situation and omit it. With collected garbage levels over a five weeks a statistical fault detection process is undertaken for each garbage bin. Which is using only two ultrasonic sensors and there is no cross paths between echoes as the above mentioned paper.

## 1.4 Research Problem

At present, solid waste management in Sri Lanka is not at an adequate level. Municipal councils of urban cities only collect a small portion of the total waste generated. Referring to the National Solid Waste Management Report for 2007 of the Japan International Cooperation Agency [9], the total amount of garbage collected in 311 local authorities was 2838 metric tons per day [9], which amounts to an annual garbage collection of 1.04 million metric tons per year. This is only 23% [10] of the total garbage generated Colombo District. This means that nearly ¾ of the garbage generated leads to surface and groundwater pollution.

With this much waste generated and no way of collecting them, garbage bins fill up instantly. This leads to people turning to open waste dumping. Open waste dumping is the main source of all of the below mentioned problems.

- Increase of acidic levels of ground water, which is water pollution.
- Buildup of greenhouse gases such as methane and carbon dioxide, leading to air pollution and climate change.
- Loss of wetland habitats
- Spread of diseases such as Dengue fever, malaria, etc.
- Attraction of wild animals

In spite of the statistics mentioned above, Sri Lankan government spends a substantial amount of money on solid waste management. An estimation made in 2004 revealed that solid waste management expenditure ranges from a high Rs. 2000 per metric ton in a Municipal Council to a low Rs. 1,200 per metric ton in an Urban Council. So, it could be estimated that Sri Lankan government spends an amount between 1.2 to 2 billion rupees [10] on daily collection and disposal of garbage.

## 1.5 Research Objective

### 1.5.1 Main Objective

- Build a cost effective garbage management system for the municipal council that will help them keep the city a cleaner place.

### 1.5.2 Specific Objective

- Build a more user friendly, user attractive trash can which can be used to motivate the citizens to use it more often.
- Give Alerts and warning when there is an error without using human inspections which will increase the efficiency and effectiveness of the system

# 2.0 METHODOLOGY

## 2.1 Methodology

Hardware layer of the system will be discussing in this section. Without being a basic garbage container the implemented system integrates the garbage bin with three specific functions.

1. Setting up the Garbage Bin

- Hand gesture system :

  With a simple hand gesture users can open the garbage lid and put their garbage into the bin

- Garbage level measurement system :

  Bin will be always locked and there will be no bad odors moving around the bin. Garbage level will frequently measure by the sensors and send it to the workforce server via Wifi.

- Safety system:

  Sensors safeness when people and cleaning staff using the garbage bins.

These three main functions contain sub functions for support the main function to achieve its goal. Garbage level measurement system contains how the measured garbage level data pass to the server.

2. Statistical Fault Detection

Measured Garbage level is the most important information of the system. Garbage level is measured using two ultrasonic sensors. Faults of this sensors will cause a whole system breakdown. Identifying errors of the sensors is described in this section.

### 2.1.1 Setting up the Garbage bin

Embedded hardware devices are being use for assemble a garbage bin. With the help of the embedded devices bins can perform the earlier mention functions. For the implemented bin following hardware devices will be used.

- Development Board
- Distance level measure sensors
- Motion sensors and motors

Development Board

A microcontroller is use for connect all the other sensor modules. There are many development boards available in the market, and the basic requirements for the system have to be fulfilled by the microcontroller.

The basic requirements:

• Microchip type and the size

• Memory size (RAM)

• Number of I/O pins

• Parallel process availability

• Inbuilt features (Wifi, Bluetooth)

• Price of the board

With the unavailability of the parallel processing in Arduino boards Raspberry boards are the clear choice.

Raspberry pi 3 has more memory and inbuilt features than the raspberry pi zero W (Figure 2.1.1.1). But the price comparison in Table 2.1.1.1 revealed that is a 1:16 price ratio difference between pi zero and 3. There are pros and cons in both boards according to the comparison in Table 2.1.1.1. For this project the raspberry pi zero W will be the most suitable development board to select.

Figure 2.1.1.1: Raspberry pi zero [11]

Table 2.1.1.1: Development Board Comparison [11][12][13]

| **Requirement** | **Arduino UNO** | **Raspberry pi 3** | **Raspberry pi zero W** |
|---|---|---|---|
| **Microchip type and the size** | ATmega328 | A 1.2GHz 64-bit quad-core ARMv8 CPU | 1GHz ARM11 core |
| **Memory size (RAM)** | 32 KB (ATmega328P) | 1GB RAM | 512MB of LPDDR2 SDRAM |
| **Number of I/O pins** | 26(analog and digital) | 40 GPIO pins | 40 GPIO pins |
| **Parallel process availability** | no | yes | yes |
| **Inbuilt features ( Wifi, Bluetooth )** | no | WIFI and Bluetooth both | WIFI and Bluetooth both |
| **Ethernet Protocol** | _ | 802.11n Wireless LAN | If there is wifi inbuilt it will support 802.11n Wireless LAN |
| **Price of the board** | $50 | $80 | $5 |

Distance level measure sensors

Ultrasonic sensors (Figure 2.1.1.2) use high-frequency sound pulse to identify the objects by the reflected sound pulse.

Figure 2.1.1.2: Ultrasonic Sensor

Ultrasonic Sensors:

- Working voltage: DC 3V-12V
- Static power consumption: <0.1mA
- Delay time: 2 seconds
- The blocking time: 2 seconds
- Trigger: Can be repeated
- Working temperature: -20 - + 60 degree
- This module detects the distance 2 ~ 30cm
- detection angle 35 °  [14]

Motion Sensors and Motors

One waterproof ultrasonic sensors (Figure 2.1.1.4) and a servo motor (Figure 2.1.1.3) will be used for the motion detection of the hand.

Figure 2.1.1.3: Servo Motor

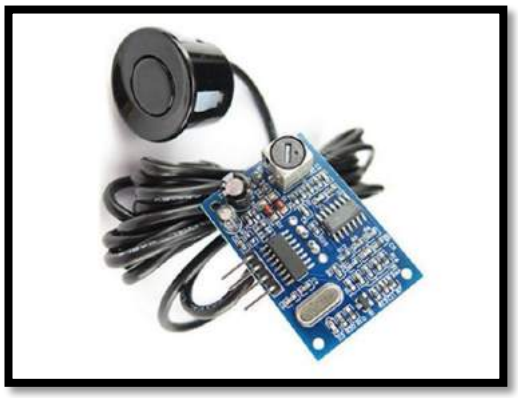


Figure 2.1.1.4: Waterproof Ultrasonic Sensor [15]

### 2.1.1.1 Hand Gesture System

When the lid of the bin covered with dirt people are lacking to use that lid to open the garbage bin. Instead of putting the garbage into the bin users are try to open dump the garbage near the bins. The Implemented System it will improve the user attraction to use the bins frequently by opening the bins' lid by a simple hand gesture.

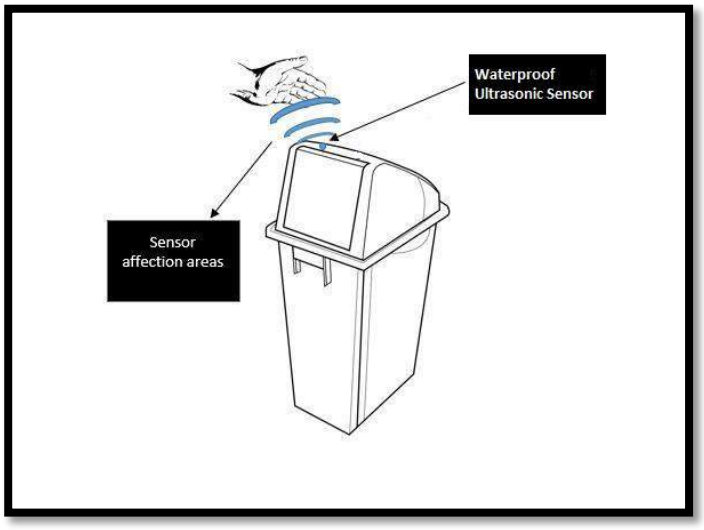



Figure 2.1.1.1.1: Front view of the bin

As shown in Figure 2.1.1.1.1 a simple hand gesture user can open the bin and after putting the garbage into the bin user can close the bin with the same hand gesture. If user forgets to close the bin after opening bin will automatically close the bin 30 second later after the opening time.

Opening and closing of the lid is done by the servo motor. When the sensor detects the servo motor rotates 90º (opening the lid). When the right sensor detects servo motor rotates back the 90º to 0º (closing the lid).

Without using a normal ultrasonic sensor bin is integrated with a waterproof ultrasonic sensor to work in any environment and climate.

### 2.1.1.2 Garbage Level Measurement System

Garbage level detection is done by two ultrasonic sensors. These sensors are fix to bin shown as figure 2.1.1.2.1.

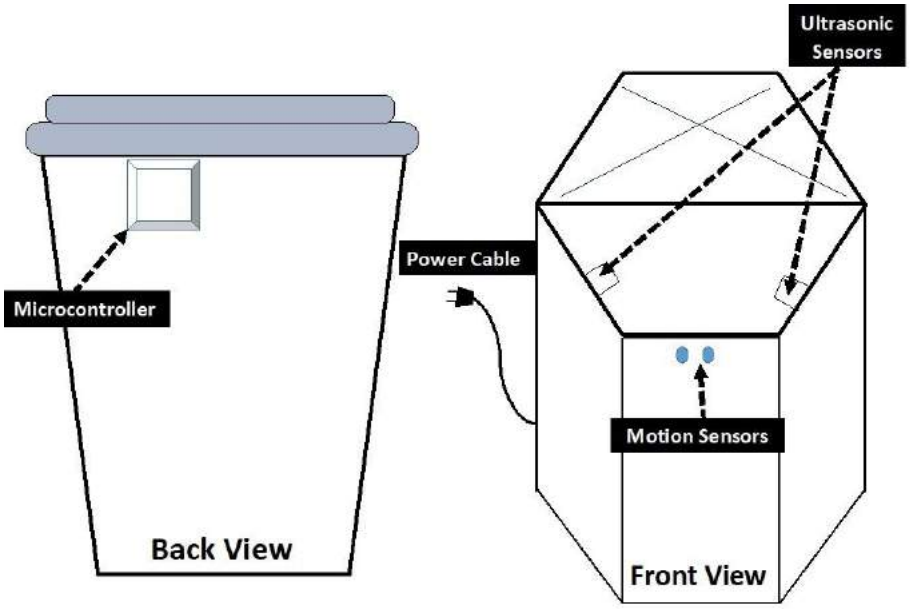



Figure 2.1.1.2.1: Bin Architecture

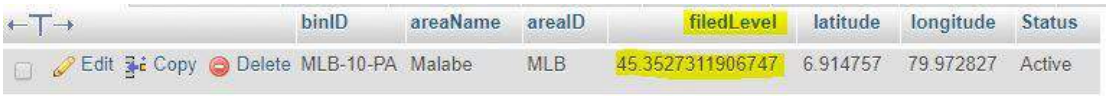
Each sensor is calculating the distance to garbage from the sensor mounted location. This distance have to subtract by the height of the garbage bin, divide it by height of the garbage bin and multiply by 100 for percentage value of the current garbage level.

$$\boldsymbol{Garbage\ level} = \frac{height\ of\ the\ garbage\ bin - \ Sensor\ measured\ distance}{height\ of\ the\ garbage\ bin} \times 100$$

This calculation is doing before sending the garbage level to the hosted server database. Garbage level is determine for each time when the lid of the bin is opened and closed. With the hand gesture system it will closed the lid each time even the user forget to close the lid. Performing calculations on specific times will help to utilize the processing power of the development board.

After calculating the garbage level it will send the calculated value specific field in the table that is included in the database where the cloud server hosted. Uploading the data to the server will be done by the inbuilt wifi adapter on the raspberry pi zero W and each bin have to connect to internet using this adapter. Data is uploaded to the server only when a client uses a bin. This will reduce the data traffic and reducing the

database's public network connectivity. Database should grant privileges for incoming database connection request from the raspberry pi zero w. For each bin there is only one field to represent the garbage level even there are two sensors because these two sensors calculated garbage level to their own measured values, get the average of the two calculated values and upload that averaged garbage level to the database as shown in figure 2.1.1.2.2.



| | binID | areaName | arealD | filedLevel | latitude | longitude | Status |
|---|---|---|---|---|---|---|---|
| Edit Copy Delete | MLB-10-PA | Malabe | MLB | 45.35273119067 47 | 6.914757 | 79.972827 | Active |

Figure 2.1.1.2.2: Uploaded garbage level

### 2.1.1.3 Safety System

When workforce staff come to clean the bins there should be an option to disable the sensors in the bin until the cleaning process is over.

For this, a solution has developed using the workforce application. Workforce application is the main interface where the workforce staff always interact. As show in figure 2.1.1.3.1 a toggle switch button was developed to disable the all the sensors in the smart trash can.

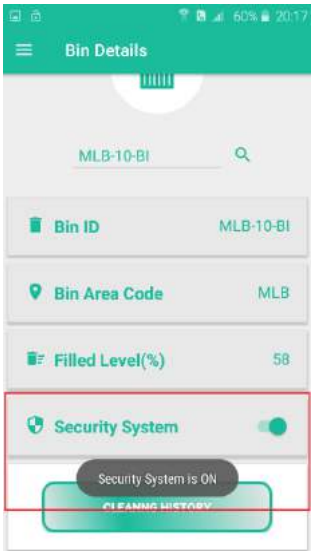


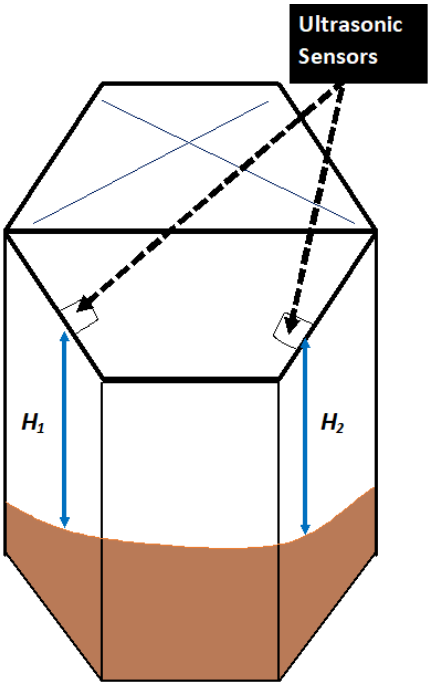

Figure 2.1.1.3.1: Safety button on Workforce Application

Enabling this toggle button will disable the all the running processes which includes hand gesture system and the garbage level measurement processes. When a workforce employee has to clean a bin he/she have toggle this button to mode ON and start their cleaning process. After cleaning is done he/she has to disable the safety system to make the trash can operational.

If there is an error found with a trash can operational status can be disable from any this option until the trash can fixed.

### 2.1.2 Statistical Fault Detection

Calculated garbage level is the most important information in whole system. If there is an error in the calculated garbage level it will breakdown the whole system. Garbage level is calculated by the ultrasonic distance measurements. There are no mechanical way to check these measurements are true. Because of that creating a statistical fault detection model is the best approach to overcome this problem.




*$H_1$ - Ultrasonic sensor1 ($S_1$) measured distance*

*$H_2$ - Ultrasonic sensor2 ($S_2$) measured distance*

$time\ (t) = t_i$

$G_i \rightarrow Calculated\ garbage\ level$

Figure 2.1.2.1: An operational bin

At $t = t_1$,

$$|H_1 - H_2| \leq \alpha$$

$\alpha \rightarrow Confidence\ Factor$

*Confidence Factor is a hypothetical value where the hypothesis is $S_1$ and $S_2$ operates without any errors. Confidence factor is determined by testing the trash can under various conditions and observing the visible garbage level and the measured garbage level.*

If at $t = t_2$,

$$|H_1 - H_2| > \alpha$$

Check the garbage levels of the previous 5 weeks at the, $time = t_2$;

$Garbage\ level\ on\ 1^{st}\ week \rightarrow G_1$

$Garbage\ level\ on\ 2^{nd}\ week \rightarrow G_2$

$Garbage\ level\ on\ 3^{rd}\ week \rightarrow G_3$

$Garbage\ level\ on\ 4^{th}\ week \rightarrow G_4$

$Garbage\ level\ on\ 5^{th}\ week \rightarrow G_5$

$G_i \pm \beta\ ;\ \{i = 1,2,3,4,5\}$

$\beta \rightarrow Range\ Factor$

*Range factor is determined by taking a large sample size of $S_1$ and $S_2$ measured distances and taking the average difference.*

If $G_i \pm \beta \rightarrow is\ in\ the\ range\ three, four\ or\ five\ previous\ weeks$

- Ignore the $S_1$ and $S_2$ deviation. Both sensors are working properly.

If $G_i \pm \beta \rightarrow is\ not\ in\ the\ range\ three, four\ or\ five\ previous\ weeks$

- Anomaly detected. Notify administrator about the sensor fault through the monitoring dashboard.

## 2.2 Testing and Implementation

### 2.2.1 Testing

Each and every sub components in smart trash can system is tested before the integration into a one programme. Garbage level measure system, Hand gesture system and Safety system are tested individually and then integrated as a one programme to run independently. Uploaded garbage level can be checked within the mysql database and compared to the calculated garbage level by giving a simple print command.

#### 2.2.1.1 Assumptions

One of the main assumption is smart city is consisted with Wifi and solar power. Without being connected to a wifi network trash can can't upload the calculated garbage level to the server. Trash can needs a 5v power input via the power grid or the solar panels in the smart city.

Another assumption is user should use their hand gesture system to open and close the bin. At least need a one single motion to open the bin lid and if user forget close the lid with another hand gesture bin will automatically close its lid.

#### 2.2.1.2 Test Cases

Table 2.2.1.2.1: Test case 01

| | |
|---|---|
| Test ID | 01 |
| Description | User should be able to open the trash can's lid |
| Pre-condition | Trash can should be powered on and connected to a wifi network. |
| Actors | Citizens, Workforce staff |
| Main Flow Events | 1. Get near to the smartbin<br><br>2. Perform a simple hand gesture. |
| Expected Output | Bin lid will open after the hand gesture |
| Actual Output | As expected bin lid is opened |

Table 2.2.1.2.2: Test case 02

| | |
|---|---|
| Test ID | 02 |
| Description | User should be able to close the trash can's lid |
| Pre-condition | Trash can lid should be opened. |
| Actors | Citizens, Workforce staff |
| Main Flow Events | 1. Get near to the smartbin<br><br>2. Perform a simple hand gesture. |
| Expected Output | Bin lid will close after the hand gesture |
| Actual Output | As expected bin lid is closed |

Table 2.2.1.2.3: Test case 03

| | |
|---|---|
| Test ID | 03 |
| Description | User forget to close the trash can's lid |
| Pre-condition | Trash can lid should be opened.<br>bin lid's opened time should exceeded 30seconds |
| Actors | System |
| Main Flow Events | 1. Check whether the bin lid is open<br><br>2. Execute the closing lid function |
| Expected Output | Bin lid will be automatically closed. |
| Actual Output | As expected bin lid is closed |

Table 2.2.1.2.4: Test case 04

| | |
|---|---|
| Test ID | 04 |
| Description | Garbage level measuring |
| Pre-condition | Execute after the trash can lid closed. |
| Actors | System |

| | |
|---|---|
| Main Flow Events | 1. Get the ultrasonic sensors readings<br><br>2. Calculate the garbage filed level |
| Expected Output | Calculating the average garbage filed level |
| Actual Output | As expected calculated the average garbage filed level |

Table 2.2.1.2.5: Test case 05

| | |
|---|---|
| Test ID | 05 |
| Description | Garbage level uploading to server |
| Pre-condition | Garbage level should be calculated. |
| Actors | System |
| Main Flow Events | 1. Establish the database connection with the server<br><br>2. Update the filed level of the specific garbage bin |
| Expected Output | Garbage level will be update in the database. |
| Actual Output | As expected garbage level will be update in the database. |

Table 2.2.1.2.6: Test case 06

| | |
|---|---|
| Test ID | 06 |
| Description | Disable sensors via workforce application. |
| Pre-condition | Established database connection |
| Actors | System |
| Main Flow Events | 1. From workforce application switch the toggle button to enable the safety measures<br><br>2. Trash can identified the bin set into inactive state<br><br>3. Execute the sensor disabling function |

| | |
|---|---|
| Expected Output | Trash can's sensors will be disable. |
| Actual Output | As expected trash can's sensors are disabled. |

### 2.2.2 Implementation

Smart bin is programmed run their functions at the startup. Whenever the smart bin plugged into the power bin will automatically execute the Garbage level measure system, Hand gesture system and Safety system programme which make the bin as a plug n play device.

Bin will automatically connect to a wifi network where the network credentials are preconfigured on the wifi adapter. Concerning physical safety of the bin, it is supposed mount permanently on a fixed location and bin is implemented as a waterproof device to protect the electronic devices.

## 2.3 Research Findings

At the very early stages of the research, something that was noted was that there were some studies conducted in the field of the 'Location Based Garbage Management System with IOT for Smart City'. There were research papers even related to the individual research components of the group members. But the main notable point was that this research was unique, in the sense that there were no researches which integrated all of the research components that was integrated into this system. So more in-depth research studies were conducted, some professors were consulted and based on some good research components from different studies, the research components of this project was finalized.

Then it was time for the components. Initially an Arduino board was selected as the development board, but then switched to Raspberry Pie Zero due to the lack of parallel processing in the Arduino board.

An Infrared sensor was considered to measure distance, but some incompatibilities arose due to the fact that the Raspberry Pie Zero board did not contain any analog pins, and the Infrared sensor operated on analog signals. An analog signal contains infinite

number of levels, the digital signal contains only two levels, so when an analog to digital converter was used a base voltage has to be given; the IR signal is checked against this base voltage to see if the signal is higher or lower. The problem arises when different types of garbage is used, the base value has to be changed when the garbage type changes. This cannot be done. So the switch to an ultrasonic sensor was made, since they were digital. A Waterproof ultrasonic sensor was selected, since the bins had to be kept in the open.

# 3.0 RESULTS AND DISCUSSION

The research produced a usable, functional product that allows citizens to dump their trash, and without a human expert measures the filled garbage value as well as check for sensor errors. The outputs and outcomes of this research is discussed in this section as well.

In figure 3.0.1 illustrates the components for the hand gesture system. Marked ultrasonic sensor is used to open and close the lid. Servo motor will perform a 90° degree rotation for open and close the lid.

Figure 3.0.1: Motion sensor & Servo motor

Figure 3.0.2 shows where the distance measuring sensors are mounted. These two sensors are giving two independent distance measures and according to that garbage level is calculated.

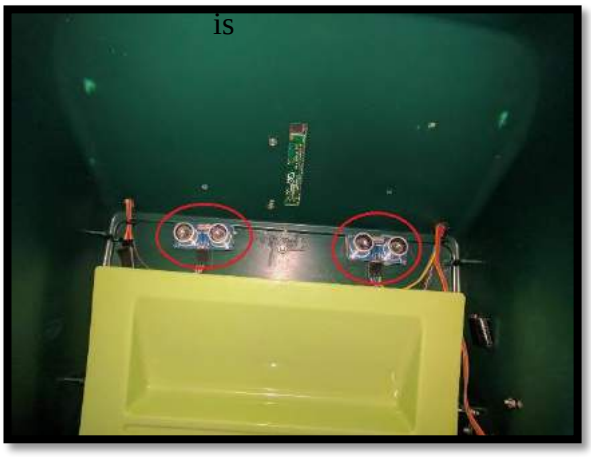


Figure 3.0.2: Mounted ultrasonic sensors

Raspberry pi zero w board is the microcontroller used to perform every logical calculations. Each and every sensor and the servo motor connected to the microcontroller. As in figure 3.0.3 wired connection paths for every component is visible.


Figure 3.0.3: Raspberry pi zero w board

# 4.0 CONCLUSION

This report incorporates IOT solutions to implement a system that provides the municipal council with a system that better equips them to handle the garbage problem in a smart city. Every party is interacting with this system that is the citizens, the workforce and the admins. Citizens can interact through the android application and the website, workforce through the app and the admins through the website. This system mainly focuses on the ease of use of the users.

# 5.0 REFERENCES

[1] "Colombo Vehicle Statistics (2015)." Indi.ca. [Online]. Available: http://indi.ca/2015/10/colombo-vehicle-statistics-2015/. [Accessed: 09-Jan-2017]

[2] "Population and Housing." Population and Housing. [Online]. Available: http://www.statistics.gov.lk/page.asp?page=Population%20and%20Housing/. [Accessed: 09-Jan-2017]

[3] Y. Chen, J. Nakazawa, T. Yonezawa, T. Kawsaki and H. Tokuda, "Cruisers: A Public Automotive Sensing Platform for Smart Cities," *2016 IEEE 36th International Conference on Distributed Computing Systems (ICDCS)*, Nara, 2016, pp. 767-768.

[4] Narayan Sharma, Nirman Singha, Tanmoy Dutta, Smart Bin Implementation for Smart Cities, International Journal of Scientific & Engineering Research, Volume 6, Issue 9, September-2015, pp. 787- 791.

[5] N. S. Kumar, B. Vuayalakshmi, R. J. Prarthana and A. Shankar, "IOT based smart garbage alert system using Arduino UNO," *2016 IEEE Region 10 Conference (TENCON)*, Singapore, 2016, pp. 1028-1034.

[6] A. S. Bharadwaj, R. Rego and A. Chowdhury, "IoT based solid waste management system: A conceptual approach with an architectural solution as a smart city application," *2016 IEEE Annual India Conference (INDICON)*, Bangalore, 2016, pp. 1-6.

[7] S. Longhi *et al*., "Solid Waste Management Architecture Using Wireless Sensor Network Technology," *2012 5th International Conference on New Technologies, Mobility and Security (NTMS)*, Istanbul, 2012, pp. 1-5.

[8] D. Bank . (2002, September 25). “An Error Detection Model for Ultrasonic Sensor Evaluation on Autonomous Mobile Systems,” 2002 EEE Berlin, Germany,pp. 288-293.

[9] "National Solid Waste Management Support Center." National Solid Waste Management Support Center « Ministry of Provincial Councils and Local

Government. [Online]. Available: http://www.lgpc.gov.lk/eng/?page_id=1118/. [Accessed: 03-Jan-2017]

[10] Management of Municipal Solid Waste in Sri Lanka: A Comparative Appraisal of the Economics of Composting. PDF. [Accessed: 04-Jan-2017]

[11] "Raspberry Pi Zero." Raspberry Pi. [Online]. Available: https://www.raspberrypi.org/products/pi-zero/. [Accessed: 25-Jan-2017]

[12] "Raspberry Pi 3." Raspberry Pi. [Online]. Available: https://www.raspberrypi.org/products/pi-3/. [Accessed: 25-Jan-2017]

[13] "Arduino - ArduinoBoardUno." Arduino - ArduinoBoardUno. [Online]. Available: https://www.arduino.cc/en/main/arduinoBoardUno/. [Accessed: 25-Jan-2017]

[14]Ultrasonic Distance Sensor. [Online]. Available: https://www.parallax.com/product/28015. [Accessed: 23-Jan-2017]

[15] Waterproof Ultrasonic Module Distance Measuring Transducer Sensor. [Online]. Available: https://www.pishop.co.za/store/dc-5v-waterproof-ultrasonic-module-distance-measuring-transducer-sensor. [Accessed: 13-June-2017]

# 6.0 APPENDICES

Raspberry pi zero specification:

Table 6.0.1: Raspberry pi zero specification

| **Type** | **Model A** | **Zero** |
|---|---|---|
| Memory (SDRAM) | 256 MB (shared with GPU) | 512 MB (shared with GPU) |
| USB 2.0 ports | 1 (direct from BCM2835 chip) | 1 Micro-USB (direct from BCM2835 chip) |
| Video input | 15-pin MIPI camera interface (CSI) connector, used with the Raspberry Pi camera or Raspberry Pi NoIR camera | None |

Python:

Raspberry Pi Python Code Library

- Adafruit_ADS1x15
- Adafruit_ADXL345
- Adafruit_BMP085
- Adafruit_CharLCD
- Adafruit_DHT_Driver