Design and Development of IoT based Garbage Monitoring and Management System

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Abstract. Daily garbage production causes increasing in garbage management and cleansing cost which required an approach for better monitoring and management system to be applied. Currently, demand of IoT keep increasing as a part of Industrial Revolution 4.0 (IR4.0). Eventually, this IoT based Garbage Monitoring and Management System has been developed. For hygiene, self-opening dustbin lid is applied and IoT technology is used to integrate better garbage monitoring and management into an innovative and effective system. The development of this smart bin uses a pair of infrared sensors and an ultrasonic, push notifications were developed in Blynk application, and user-friendly infographic data is designed on webpage for monitoring and garbage management purposes. The smart dustbin notifies the user when the garbage level exceeds 80%. The dustbin sends a push notification to the user's phone to alert the user to take actions needed before the bin exceed the limit.

1. Introduction

According to SWCorp (Malaysia Solid Waste Management and Public Cleansing Corporation) in BH online (Malaysia newspaper) dated Jan 2, 2020, daily garbage production among the people in the country recorded an increase of 100.75 percent to 38,142 tonnes in 2018, compared to 19,000 tonnes in 2005, which can be interpreted to a citizen is estimated to produce 1.17 kilograms (kg) of waste per day in 2018, compared to 0.8kg (2005). This phenomenon causes increasing in garbage management and cleansing cost which required an approach for better monitoring and management system to be applied [1]. This system is powered by IoT application, where the IoT is referred to the Internet of Things – a system of interrelated, internet-connected system that are able to collect and transfer data over a wireless network without human intervention or less intervention.

Traditional dustbins nowadays are inconvenient to be used, both for the user and garbage collector. For the user wise, they have to deal with the problem where the lid of the dustbin has to be opened manually either by hand or by pressing foot against the lever of the dustbin, which is inconvenient and insanitary, especially during the era of COVID-19 pandemic is spread around us over the world. According to research, bins contain more than 400 bacteria per square inches, and this indicates the need to make improvements to the existing bins. For the waste management company or garbage collector, tremendous amount of time and cost has to be spent in order to empty the full dustbin and collect the garbage from it one by one. Especially for the one that deal with large number of dustbins over a very large area.

This smart dustbin – a garbage monitoring and management system with IoT application as proposed in this paper, will automatically open its lid for 3 seconds and wait for users to throw garbage and closed.
The open-close of the lid is moved by a servo motor. This smart dustbin will automatically measure the level of garbage inside it every time user throw garbage using an ultrasonic sensor. The level measured will be recorded and a notification message will be sent to phone via network to notify the waste management authority that the dustbin is full and need garbage to be collected. An application called “BLYNK” is used in this development. A webpage showing smart dustbin location and its real-time garbage level also had been developed. In additional, this system will be equipped with data analysis where the level of garbage against time and the frequency of dustbin being used against the time is being updated online in real-time.

2. Literature Study
Recently, the development of intelligent dustbins and smart dustbins as well as studies on solid waste management have attracted the interest of many researchers. M. Sahil, et. al. proposed an IoT enables dustbin where RFID tags was used to track the waste condition (fullness of the dustbin) and linked to the municipal server. It also notifies dustbin’s location and the shorter route to the dustbin for collection [2]. D. Sonali, et. al. worked on combine IoT and KNN machine learning technique for household waste management system. This machine learning is used to generate an alert message for various of sensors value like level of bio and non-biodegradable waste and concentration of poisonous gasses [3].

Tariq A, et. al. proposed IoT based (ATMega) device performs the controlling and monitoring of the electric bins. The devices are wirelessly connected with the central hub to transmit the information about the bins filling level with the existing location. The significant advantage of the system is to collect waste material on time in order to avoid the overflow of bins that would help in saving the environment from pollution [4].

Zainal H, et. al. presents an Internet of Things (IoT) based Smart Waste Collection Monitoring and Alert System to monitor the waste material at the selected site of garbage collection area. The system is implemented using an ultrasonic sensor which is connected to Arduino UNO as to monitor waste bin garbage level. In this system, waste bin depth level will be sent via Arduino Ethernet Shield with an Internet connection to the Ubidots IoT Cloud [5]. While Raaju V.A, et. al present a smart garbage collection management solution using an IoT with the help of ZigBee, with sensors and modules. It can read, collect, and transmit huge amount of data over the adhoc network and data can be used to dynamically supervise waste garbage collection mechanism [6]. Sohag M.U and Podder A.K presented a smart IoT based integrated system consists of an identification system, an automated lid system, a display system, and a communication system. Arduino Uno is used as a micro-controller to synchronize all of the four systems. Sensors are used for identification and measuring the garbage level. The system provides the facility of continuous monitoring of the status of waste inside the garbage bin and shows the percentage filled up on liquid crystal display (LCD). The communication system uses a global system for mobile communications (GSM) module that will inform the corresponding authority to collect the waste when the garbage bin is filled up [7].

This paper presents IoT based Garbage Monitoring and Management System via combination of mobile and webpage application.

3. Methodology
In this project, ESP-32 had been used as the single-board microcontroller to receives input signals, process signals and control the output devices. Other electrical components that been used in this smart dustbin development. A servo motor is used to open the lid of the dustbin. The servo motor that chosen for this project is Servo Motor SG90. To make sure the lid is closed properly an infrared sensor is used. The infrared sensor is placed near to the lid to determine if the lid close properly. To open the dustbin lid for throwing garbage, users are required to wave their hand above the dustbin lid as the dustbin takes the presence of hand as a signal from user to open the lid. To sense the presence of user’s hand, another infrared sensor module is used. Infrared sensor is chosen for this application because it is small is size and relatively had fast response. For measuring the level of garbage inside the dustbin, an ultrasonic sensor is used. The sensor is fixed at the inner face of the lid and is able to measure the distance from
the lid to the garbage. The distance is converted to percentages by the ESP-32 for easy visualization in mobile apps and web pages. Figure 1 shows overall block diagram for inputs (sensors) and outputs (actuator) of the developed system.

![System Block diagram](image1.png)

**Figure 1.** System Block diagram

The infrared sensor will emit infrared lights and if an obstacle presence, it will reflect the light and the reflected light will be picked up by the receiver. The operating principle is shown in the figure 2.

![Infrared Sensor Operating Principle](image2.png)

**Figure 2.** Infrared Sensor Operating Principle

In infrared spectroscopy are normally used to denote different types of light. The frequency, wavelength and wavenumber are related to each other via the following equation,

\[ c = v\lambda \quad \text{[cm/sec]} \]  \hspace{1cm} (1)

\[ W = \frac{1}{\lambda} \quad \text{[cm/sec]} \]  \hspace{1cm} (2)

where, \( v \) is frequency in Hertz and \( \lambda \) is wavelength of infrared spectroscopy.

Ultrasonic sensor transmits sound pulse towards the garbage and the sound pulse reflected back once hit the object. By calculating the time needed to receive the reflected pulse, the distance between the
sensor and the garbage can be calculated. The operating principle of the ultrasonic sensor is shown in the figure 3.

![Ultrasonic sensor operating principle](image)

**Figure 3. Ultrasonic sensor operating principle**

The calculation for the conversion of distance to percentage filled up is given below,

$$\text{Distance}, D = \left[ \frac{(V \times t)}{2} \right]$$

$$\text{Percentage filled up} = \left[ 100 - \left( \frac{100}{H} \right) \times D \right]$$

where $t$ is the ping time from the sensor, $V$ is velocity of the sound, $H$ is the height of the dustbin and $D$ is the converted distance.

In this system development, single-board microcontroller had been programmed using an open sources software named Arduino IDE *(Integrated Development Environment)*. ESP-32 can be programmed in C++ language, compile and upload the code to the single-board microcontroller. For the webpage hosted by ESP-32 single-chip microcontroller, another programming languages is needed prior to the C++ programming language. The languages are HTML5, CSS and JavaScript.

Internet of Things (IoT) application requires a system had been connected to the network through Wi-Fi successfully. By connecting to an online time server, the ESP-32 single board microcontroller updates the clock in real time and send the required data to the client on the webpage. The webpage visualizes a map, a real-time dustbin levels, and graphs. An infrared sensor is used to detect if the user's hand is on the lid. If a hand is present, the servomotor will open the lid by rotating the servomotor counterclockwise for 2 seconds to open the dustbin lid (number of pulse 1 pulse = 1.3ms). On the other hand, if the user's hand is on the lid, the movement will stop immediately to prevent an accident. After the lid opens normally, it holds for 3 seconds for user to throw garbage. After a delay of 3 seconds, the lid will return to initial position. The 2nd infrared sensor is used to determine if the lid is closed properly. If the user's hand is on the lid when the lid is closed, it will stop immediately and wait for the user to release it. After it is completely closed, the ultrasonic sensor activates to measure the distance from the lid to the object in the dustbin. The distance obtained is converted to a percentage data and transferred to the user's phone application named BLYNK and displayed in infographic format. When the dustbin percentage exceeds 80%, a push notification will be sent to the user's phone to notify the garbage collector to empty the dustbin. The pie chart infographic, line chart, and histogram dustbin data locations and levels are then updated on the website, the system runs the entire loop again, and the user is ready to dispose of the garbage again. Figure 4 below shows the details flowchart of the system operation.
Figure 4. Flowchart of system operation
4. Results
As shown in Figure 5(b), the smart dustbin notifies the user when the garbage level exceeds 80%. The dustbin sends a push notification to the user’s phone to alert the user to take actions needed before the bin exceed the limit.

Figure 5. Smart dustbin with BLYNK application.

On the BLYNK application Figure 5(c) the bin space is highlighted in the form of levels and percentages. In field of work, things need to be considered from the aspect of the location of the garbage bin placement and the method of monitoring. Therefore, in webpage development the main thing is access to the location of the bins and a short monitoring time is taken into account. Figure 5(d) a real-time bin monitoring feature has been developed capable of reducing the time employees manage garbage collection along with the management cost can be minimized.

Figure 6 shows additional infographic data on real-time garbage levels, dustbin frequency and time. From this data, garbage collectors can predict the time of garbage collection and place additional dustbins in high-use locations. This system suitable for implemented in office buildings and supermarkets where many people gather. The more frequent garbage collections indicate more crowd of people and from all this data, management staff can estimate the number of people and customers at any location at any given time, analyze it, and use it for other purposes such as air conditioning management systems and power saving projects.

Figure 6. Pie chart, Line chart and Histogram
5. Discussion and Conclusion

Many methods have been used to open the dustbin lid suggested by other researchers in developing smart dustbin. In public areas with too much background noise, the use of sound sensors that detect clapping and stepping foot sounds to open the lid was not appropriate. Passive IR sensors (PIRs) also had the same drawback when having a dustbin in a public place, where a passerby would respond the sensor and unintentionally open the lid automatically. In this development, infrared sensor had been selected to detect the presence of the user’s hand in range of 7cm from the dustbin.

Automatic open-close lid was confirmed function properly by a use of servo motor. Ultrasonic sensors measure the level of garbage present, it has been observed to capture sensor data in real-time. While garbage level is sensed by ultrasonic sensor and notified the collector when its full. The system was able to count lid opening event and estimate crowd size where the dustbin is located and record most dustbin utilisation’s time.

The overall performance of the system has been tested above 80%, the smart dustbin has notified the system operator based on the result. The system has archived the target to measured and monitored the level of garbage based on real-time data. The data from the BLYNK application helped the garbage collectors can predict the time of garbage collection and place additional dustbins in high-use locations. These data were analysed and updated in webpage for better garbage monitoring and management system. The system helped management staff can estimate the number of people and customers at any location at any given time, analyze it, and use it for other purposes such as air conditioning management systems and power saving projects.

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